Environmental Radiation Program

STATE OF WASHINGTON DEPARTMENT OF HEALTH

ANALYSIS OF ENVIRONMENTAL RADIOLOGICAL DATA RELATING TO THE 2000 WILDFIRE AT HANFORD

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Lynn Albin
Richard Jaquish

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Acronyms

DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
MDC	Minimum Detectable Concentration
NESHAP	National Emission Standards for Hazardous Air Pollutants
PAG	Protective Action Guide
PHL	Public Health Laboratory
PNNL	Pacific Northwest National Laboratory
WDOH	Washington State Department of Health

Executive Summary

This report summarizes the Washington State Department of Health (WDOH) response to the June, 2000 Hanford wildfire and evaluates associated monitoring data. The United States Department of Energy (DOE) Hanford Site is the location of the DOE's past operations for production of plutonium used in making nuclear weapons. While weapons materials are no longer made at this site and the mission has changed to one of clean up, there remains areas of high level radioactive waste storage, contaminated buildings and some areas where surface contamination is present. WDOH has conducted independent environmental monitoring of the Hanford Site and surrounding areas since 1985 and works with the DOE to coordinate responses to emergency situations.

The purpose of WDOH's involvement in responding to the Hanford fire was to assure that emergency workers and the public were safe from radiological hazards. The immediate concern was for firefighters and other emergency workers. WDOH along with local, state and federal agencies assessed risks and made determinations for immediate protective actions. Additionally, the WDOH initiated investigations to evaluate the potential for radiological hazards to the public after the fire was extinguished. Overall, the response to this fire involved hundreds of individuals including firefighters, field teams, decision makers, planners and chemists.

Environmental monitoring was an important aspect of the response to the Hanford Fire. WDOH collected 335 environmental samples from 56 locations. Department chemists subsequently conducted 772 analyses on these samples. The results were reviewed along with data provided by the DOE contract laboratories and U.S. Environmental Protection Agency (EPA) laboratories. The sample results showed that very low levels of radioactive contamination were present in environmental samples. The source of the contamination is thought to be the surface soils that were resuspended by the winds during and after the fire.

The joint decision-making team used the initial laboratory data for air particulates, soil and vegetation and field measurements to conclude that no radiological-based emergency protective actions were necessary. Continued sampling and analyses showed that the air quality at the Hanford Site and nearby communities remained within the annual criteria set by the EPA and no contamination or dose limits were exceeded.

The coordinated approach allowed for timely decision-making. It also provided an opportunity to test emergency procedures, determine criteria for adequate sampling and learn about the transport of radiological contaminants during a fire.

This report covers WDOH's response, presents and interprets environmental measurements and summarizes information on criteria for adequate air sampling that may improve future responses to radiological emergency situations. Appropriate choices in sampling equipment and analyses protocol allow for good health assessments during both emergency phases and post-incident monitoring.

ANALYSIS OF ENVIRONMENTAL RADIOLOGICAL DATA
RELATING TO THE 2000 WILDFIRE AT HANFORD

Introduction

On June 27, 2000 an automobile accident started a large wildfire that swept through a portion of the U.S. Department of Energy's (DOE) Hanford Nuclear Site. The Hanford Nuclear Site is located in the high desert plateau of southeast Washington State. The local ecology is described as a shrub/steppe environment and at that time of year, the vegetation is very dry. The fire lasted three days and burned an estimated 192,000 acres of sagebrush and grasslands including an 86,000-acre area on the Hanford Site that contained some surface contamination (see Figure 1). Also at risk of burning were waste disposal sites and buildings that contained radioactive waste. The Washington State Department of Health (WDOH) responded to this emergency and worked with local, state and federal agencies to assess risks, make determinations for immediate protective actions and initiate investigations to evaluate the potential for radiological hazards to the public in nearby communities after the fire was extinguished. Overall, the response to this fire involved hundreds of individuals including firefighters, field teams, decision makers, planners and chemists. The predominate radiological hazards considered were plutonium, uranium and aged fission products that were produced from the U.S. Department of Energy's past operations on the Hanford Site. This report covers WDOH's response, presents and interprets the environmental measurements and presents information that may improve future responses to other radiological emergency situations.

The Emergency Response

WDOH's overall responsibility is to protect public health. During the fire, staff worked with other agencies to coordinate the response efforts and assess the radiological risk imposed by the fire. WDOH also provided independent status reports, worked with the media to inform the public and evaluated its own performance in order to improve the response to future emergencies.

WDOH has written procedures and conducts training for response to radiological emergencies (WDOH, 2000). Scenarios include transportation accidents, weapon accidents and accidents at the nuclear power plant located within the state. Department staff trains throughout the year to ensure that actions to assess hazards and protect the public are appropriate, adequate and timely. Drills and exercises are coordinated with local, state and federal agencies. The Hanford fire presented a scenario not specifically covered in the emergency response procedure manual. The coordinated response team followed the process used for assessing and responding to any emergency and adapted sampling, hazard determinations and work scope as needed to appropriately respond to the Hanford fire.

Typically a response to a radiological emergency is divided into three phases, early, intermediate and late. WDOH followed this principle in assessing and evaluating the emergency response. The initial actions were to ensure firefighters and emergency workers were safe, followed by actions to assess any impact to the surrounding community. Finally the potential for future impact from this event was evaluated. A description and scope of work for each phase and a review of measurements and data interpretation follows. Figure 2 shows all the sampling locations and the media sampled.

The Initial Response (Early Phase)

The early emergency phase describes actions taken when a situation is considered unstable and there is a release or a potential for a release. When the fire began to spread towards facilities onsite, the US Department of Energy (DOE) declared an emergency alert. This official declaration initiated actions on local, state and federal levels. WDOH immediately dispatched field teams and along with federal, state and local agencies, staffed emergency operation centers on both sides of the state. WDOH's Public Health Laboratory (PHL), located near Seattle, was alerted and prepared to receive samples for analyses.

The lead agency for the initial response was DOE. Decisions and actions taken at this time were directed at safely containing the fire. There were over 100 firefighters, many of them volunteers, who worked to extinguish the fire. The immediate concern was for their and other emergency workers' safety. WDOH and DOE contractor field teams were dispatched to collect air samples, deposition samples and to make direct measurements using portable instruments to evaluate both emergency worker and public safety. Table 1 lists the samples collected by WDOH during the emergency phase of the fire.
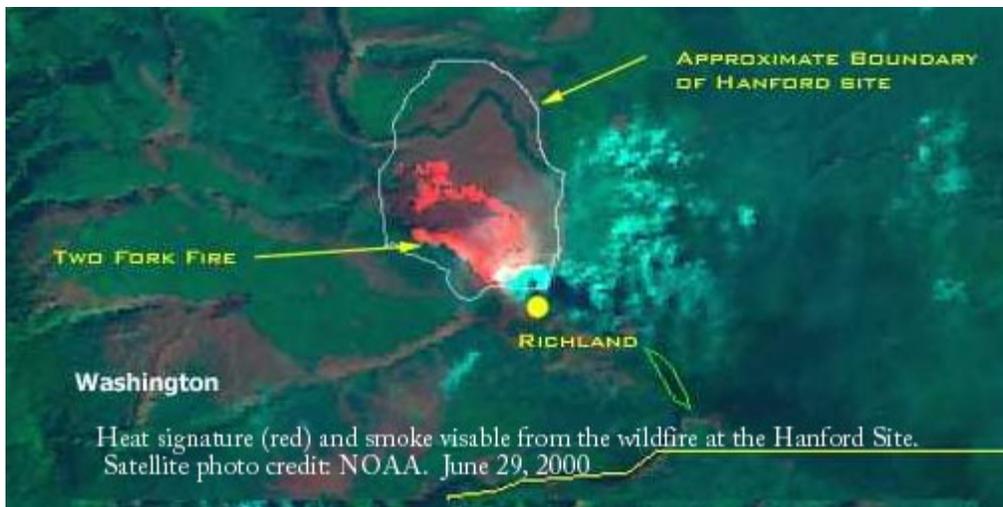
Figure 1

**Satellite Photo of the Hanford Site**

The heat signature and smoke visible from the Hanford Site Wildfire on June 29, 2000. In this satellite photo, the fire is referred to as the "Two Fork Fire". DOE reports use the name, "24-Command Fire".
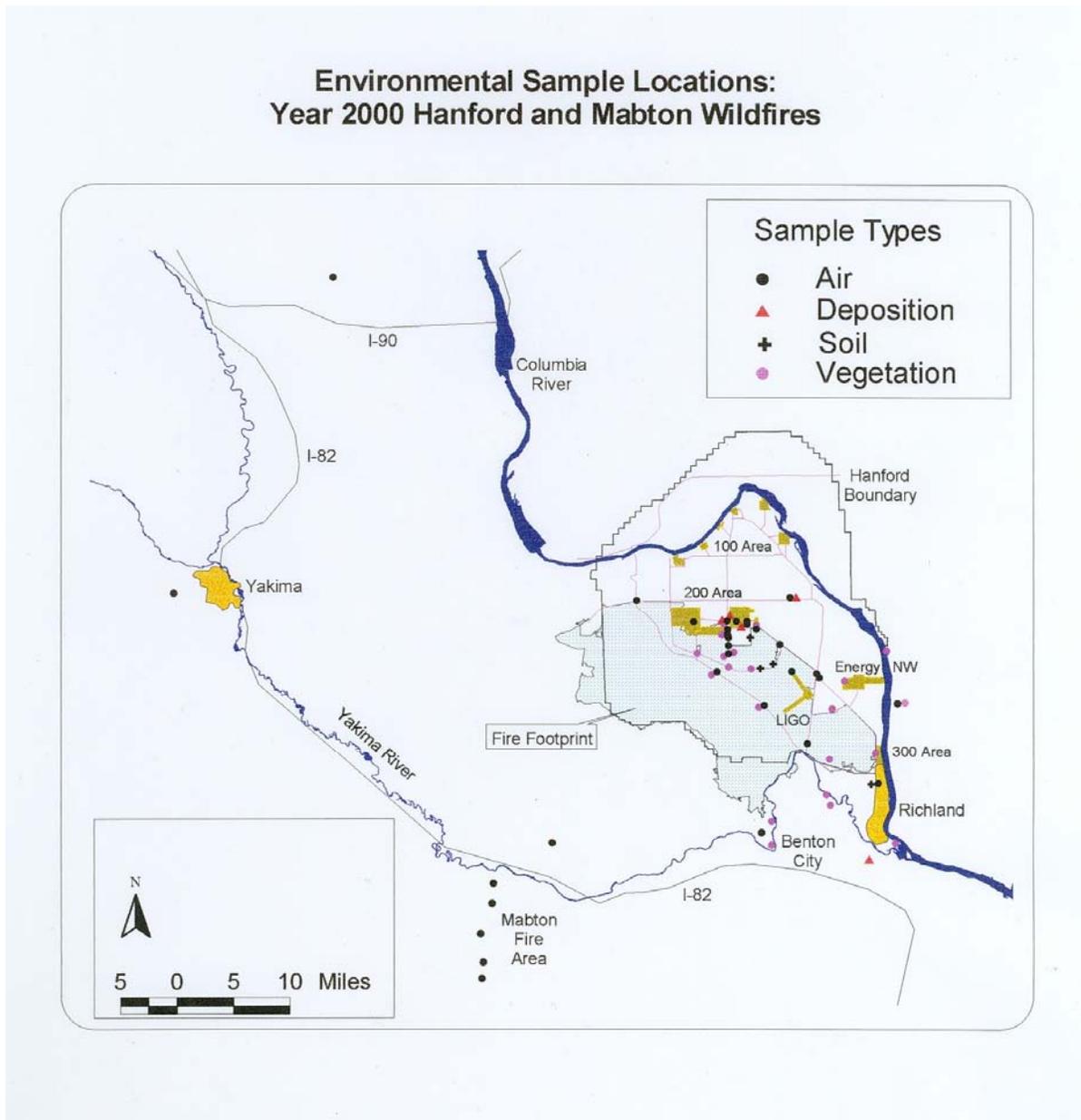
Figure 2

Initial Department of Health Sampling Locations

Initial screening of air filters was conducted in the field using portable survey instruments to obtain a rapid estimation of the gross alpha and beta activity on the filters. The next step was to get the filters to a laboratory for more sensitive analysis. Gross alpha and beta, and gamma spectrum analyses were performed at the Hanford site for DOE contractor samples and WDOH samples were transported by State Patrol to the state's P.H. Laboratory in Shoreline, Washington. Radiochemical analyses for strontium, plutonium and uranium require more time and these results were available after the fire ended.

Many of the initial samples were collected from WDOH's routine air sampling network. Samples were analyzed using emergency procedures directed at quickly providing the data needed to evaluate health significance. A description of WDOH 's laboratory instrumentation and procedures is found in Appendix A. Some adjustments in analytical protocol were required at PHL to be able to process samples that were collected using DOE contractor air samplers because the sample size differed from the standard size filters used by WDOH. Sampling results showed that levels of airborne radionuclides were below the Protection Action Guides set by the U.S. Environmental Protection Agency (EPA). No protective actions were required or taken for radiological reasons.

Vegetation samples were initially evaluated using emergency procedures that require a quick turn around of sample results for decision-making. These samples were reanalyzed using the customary environmental analysis protocol and no evidence of weapons-related radionuclides was seen. No contaminants were seen in the soil or deposition samples.

Table 1

**Department of Health Hanford Wildfire Samples
During the Initial Phase**

Initial Phase	Number of Samples (Number of Analyses)	Types of Analyses
Air Particulate Individual Samples (pCi/m^3)	13 (116)	Alpha, Beta, Gamma, Pu, Sr
Vegetation (pCi/g)	21 (125)	Gamma
Soil (pCi/g)	1 (4)	Gamma
Deposition (pCi/wipe)	4 (19)	Gamma

The Intermediate Phase (Ingestion/Relocation)

Actions during this phase focused on determining exposure to the public from deposition, resuspension and ingestion of contaminated particles. WDOH and DOE field teams continued to sample onsite air and other environmental samples

in order to evaluate public health hazards (Table 2). WDOH took the lead for offsite evaluations and requested assistance from the US Environmental Protection Agency (EPA) who subsequently set up air stations and began sampling on June 30, 2000 (see Figure 3). Their emphasis was directed at evaluating nearby communities, offsite areas with the highest probability of becoming contaminated, and agricultural areas. The National Air and Radiation Environmental Laboratory in Montgomery, Alabama analyzed the EPA samples. The EPA used air-sampling equipment not available at the Hanford Site and collected large volume air samples from a total of twenty-four locations, including the nearby communities, distant communities and tribal lands. The large volume samplers allowed the EPA to detect extremely low levels of contaminants.

Most of the 63 samples analyzed by the EPA showed that the levels of plutonium, uranium and strontium were at background levels when compared to a similar volume of air samples that are collected over an entire year as part of the EPA's nation-wide Environmental Radiation Air Monitoring network. At five locations during the fire, results of plutonium analysis were elevated as compared to national levels and to DOE reported annual average levels from nearby communities. The EPA data showed that plutonium was measurable only for a single 24-hour period during the fire and was not detected in samples collected after that day.

During the intermediate phase, WDOH collected vegetation and soil. Department field teams also used air-sampling equipment onsite to collect resuspended soil during several windstorms. The high winds caused very dusty conditions and presented a mechanism by which contaminated surface soils could be moved away from the Hanford Site and into nearby communities. See Figure 4. The remaining sample collected during this phase was a deposition sample taken offsite. It consisted of resuspended soil that had settled following a windstorm. Procedures allowing detection of environmental levels of radionuclides were used to analyze these samples. Heavy dust loading was observed on the windstorm sample filters. Three of the four composite filters contained plutonium.

Collection Date	Site	Type	Analyte	Result pCi/m^3	Error pCi/m^3
07/20/00	Hanford Windstorm #1	Composited Air Filters	Pu-239/240	0.0001	0.0001
07/20/00	Hanford Windstorm #2	Composited Air Filters	Pu-239/240	0.006	0.002
07/22/00	Hanford Windstorm #3	Composited Air Filters	Pu-239/240	0.002	0.001
07/31/00	Hanford Windstorm #4	Composited Air Filters	Pu-239/240	0.0013	0.0003

All data reported during this time period confirmed that the emergency workers and the public were not in danger due to radionuclides transported in the fire. Even though the $^{239/240}$Pu concentrations were 100 times the annual average ambient levels, the one day peak plutonium value reported by the EPA was 100

times less than the annual air quality standard. To understand the sensitivity of this measurement, the peak level recorded on one day would have to have been 100 times higher for every day of the year to exceed the EPA standard for safe air quality. The minimum plutonium concentration that could be detected varied with sample size, but was approximately 0.00002 pCi/m^3. Further discussion of WDOH and EPA air filter data follows in the section on Data Review. WDOH analyzed 19 individual air samples collected during windy conditions. Samples that were collected from the same location during the same windstorm were composited in order to create a larger volume of air and allow for lower detection limits for contaminants. Plutonium was detected in three of the four windstorm composite samples.

Vegetation samples were collected at seven locations during the intermediate phase. The vegetation sample consisting of charred, ashed sagebrush was collected in the BC Cribs area that has known surface contamination. It contained measurable plutonium, fission products (both cesium 137 and strontium 90). The remaining vegetation samples contained ^{137}Cs and ^{90}Sr within the range of activity observed in similar samples collected on and near the Hanford Site.

Soil samples were collected from three locations within the known surface contamination area that was burned by the fire. Samples contained a range of fission products, natural radionuclides and plutonium that has previously been observed in this area.

The single deposition sample was collected following a windstorm at a private residence in Richland, Washington. The sample represents resuspended sediment and was taken by wiping an outdoor tabletop with a paper towel. The paper towel and contents were analyzed for the presence of plutonium. Because it was not possible to measure the weight of the windborne soil, the plutonium content cannot be quantified in terms of the amount of radioactivity per gram of windborne soil. The sample did contain a measurable amount of plutonium.

Of all the sample results, the plutonium in air values reported by the EPA were the most surprising. It was not originally expected that the grass fire onsite would release and transport radioactivity from surface contamination. The reason for the observed levels of plutonium is not clear. While the fire did not damage any facilities that housed radioactive material, it did burn vegetation that was growing in several areas where radioactive wastes had historically been buried or disposed. Some of the plants growing on the reservation have absorbed radioactive material from the soil and this could have been released during the fire. Fire-fighting activities also stirred up potentially contaminated soil. Three possible sources are:

- The strong winds from the fire blew contaminated soils offsite
- Ash of burned, contaminated vegetation was carried in the smoke
- One or both of the above sources mixed with current levels of plutonium present because of worldwide fallout from weapons tests

Figure 3

DOH and EPA Air Sampling Locations

Table 2

**Department of Health Hanford Wildfire
Samples Taken During the Intermediate Phase**

Intermediate Phase	Number of Samples (Number of Analyses)	Types of Analyses
Vegetation (pCi/g)	7 (63)	Alpha, Beta, Gamma, Pu, U, ^{90}Sr
Air Particulates in windstorms (pCi/m^3)	Individual Samples 19 (60)	Beta, Gamma, Pu
	Composite 4 (8)	
Soil (pCi/g)	3 (37)	Gamma, Pu, U, ^{90}Sr
Deposition (pCi/wipe)	1 (2)	Pu

The Late Phase (Recovery)

The fire was contained on July 1, 2000. Field teams continued sampling in order to evaluate the potential for offsite transport of radionuclides (Table 3). The wildfire burned away the vegetation that helps prevent contaminated soil from becoming resuspended by wind and carried off the Hanford Site. Sampling efforts during this phase were directed at investigating the likelihood of offsite transport and radiological hazard related to resuspended contaminants over an extended period of time. Five new air-sampling stations were established to assess the ambient air quality downwind of the burned area. Samplers were established on site at the southeast corner of U.S. Ecology, ESE corner of the 200 Area, LIGO, Prosser Barricade and offsite in Benton City. These new air-sampling stations were equipped with continuous, low-volume samplers. Air particulate filters were collected weekly, analyzed for gross beta activity and then stored. WDOH calculated the volume of air needed to reach the very low levels of plutonium found in ambient air samples. The flow rates of the new environmental samplers were set so that over a six-month period, sufficient sample volume was collected to reach these detection levels. At the end of the six-month collection period, the weekly samples for each station were combined and analyzed for plutonium. Only the Prosser Barricade six month sample had detectable plutonium. The level was 5.0 x 10^{-6} ± 4 x 10^{-6} pCi/m^3.

Mid-Point Collection Date	Site	Volume Collected m³	Analyte	Result pCi/m³	Error pCi/m³
09/15/00	200 ESE	17899.63	Pu-239/240	0.000002	0.000007
09/15/00	Benton City	16668.7	Pu-239/240	0.000002	0.000002
09/15/00	LIGO Facility	17310.98	Pu-239/240	0.000000	0.000002
09/15/00	Prosser Barricade	15697.68	Pu-239/240	0.000005	0.000004
09/15/00	SE Corner	15995.85	Pu-239/240	0.000003	0.000003

Additionally, the Pacific Northwest National Laboratory (PNNL) and WDOH collected samples at an unrelated, but nearby fire to assess the presence of plutonium in air samples. Plutonium is a contaminant that is present worldwide because of nuclear weapons tests. It is also a contaminant produced at the Hanford Site. Samples were collected to help determine if plutonium could be expected in air samples collected at a similar, but distant fire. Portable air samplers were staged in areas directly downwind from the Mabton fire. An additional two distant, upwind locations were also sampled. None of the samples had measurable plutonium. There was evidence of some naturally occurring radionuclides.

The last type of sample that was collected in the late phase was a deposition sample. The sampling followed a similar protocol as the previous deposition sample collected from a table top in Richland following a windstorm. This follow-up sample did not have measurable plutonium.

Figure 4

Dust Storm/Air Sampling

Table 3

**Department of Health Hanford Wildfire
Samples Taken During the Late Phase**

Late Phase	Number of Samples (Number of Analyses)	Types of Analyses
Air Particulate Samples (pCi/m^3)	New Environmental Weekly Stations: 229 (229)	Beta
	At a nearby fire: 10 (38)	Gamma, Pu
Air Particulate Composite Sample (pCi/m^3)	New Environmental Stations, Quarterly: 5 (10)	Gamma
	Environmental Stations, Semiannual 9 (62)	Gamma, Pu
	At a nearby fire: 2 (4)	Pu
Deposition (pCi/wipe)	1 (2)	Pu

Data Review

Early Phase Air Monitoring Data

Initial decisions on potential health impacts from radionuclides released by the Hanford fire were based on gross alpha, gross beta, and gamma spectroscopy measurements performed by DOE contractors and WDOH. To evaluate the significance of the fire data, historical air monitoring results from the Hanford site were used as a basis of comparison. The 1999 average Hanford onsite gross alpha concentration (PNNL 2000) was 6.7×10^{-4} pCi/m^3 and the maximum was 2.9×10^{-3} pCi/m^3. WDOH does not normally report gross alpha data on air filters but does make these measurements since filters are counted on an alpha-beta proportional counter that measures both types of radiation. Because of the interest in plutonium resuspension during the fire, WDOH was asked to report gross alpha results. The initial analyses were performed as soon as the filters were received at the PHL. Results from the initial analyses were inflated as compared to results of routine air monitoring results because standard operating procedures were not followed. Normally air particulate filters are held for at least three days to allow decay of the short-lived daughter products of radon and thoron, which are part of natural radioactivity. Following this procedure allows for comparison of samples from week to week and allows for better evaluation of data trends (natural radioactivity interferences are discussed under Air Monitoring Systems below). Gross alpha results for six air filters collected on June 29, 2000 ranged from -4.2 to 3.5×10^{-1} pCi/m^3, with most of the results around 1.5×10^{-1} pCi/m^3. These measurements could not in themselves determine if there was a significant increase in alpha radioactivity. As an initial screening evaluation, it was assumed that all gross alpha activity was $^{239/240}$Pu. The values were then compared to the Protective Action Guide (PAG) and National Emission Standards for Hazardous Air Pollutants (NESHAP) levels as shown in Table 4. This showed that, even with this conservative assumption, levels were not above the PAG level of 4.3×10^{-1} pCi/m^3.

Recounts of these filters after a 3-day decay period showed the results all to be in the range of $1-4 \times 10^{-3}$ pCi/m^3 which is in the same range as the NESHAP limit of 2×10^{-3} pCi/m^3 for continuous exposure and similar to the pre-fire levels seen at Hanford. Results on air filters collected by the DOE contractor field teams on June 28 and June 29, 2000 had a maximum gross alpha result of 1.8×10^{-1} pCi/m^3. These filters were analyzed under emergency protocols that did not allow for decay of short-lived natural radioactivity. In contrast, the DOE Near Facility Monitoring Program followed standard measurement protocol allowing results to be compared to past monitoring results. Measurements at the time of the fire around facilities were similar but a little higher than the normal range with the high values averaging about 5×10^{-3} and a maximum value of 7.1×10^{-3}. Although the gross alpha measurements were not specific for plutonium and have inherent uncertainties, they were completely adequate to make initial decisions on the magnitude of potential health problems from resuspension and release of plutonium to the air.

The 1999 average Hanford onsite gross beta concentrations were 1×10^{-2} pCi/m^3 with a maximum of 4×10^{-2} pCi/m^3. Initial WDOH measurements (not decayed) on six filters on June 29, 2000 showed gross beta results in the range of $1.8-3.2 \times 10^{-1}$ pCi/m^3, approximately an order of magnitude above normal, decayed-average concentrations. The maximum DOE field teams readings were 1.5×10^{-1} pCi/m^3. Assuming the entire gross beta to be ^{90}Sr, the results

were still below the PAG of 141 pCi/m^3. Measurements made by the Near Facility Monitoring Program showed all measurements (after decay period) to be less than 3.9×10^{-2} pCi/m^3, the maximum pre-fire measured value. These decayed gross beta results were somewhat elevated but within the range of normal onsite air concentration measurements. Gross beta measurements were timely and adequate to evaluate potential impacts from resuspended ^{90}Sr.

The laboratory analysis of the early phase WDOH air filters showed all gamma-emitting radionuclides to be below the minimum detectable concentration (MDC) with the exception of ^{7}Be, which is a naturally occurring radionuclide. The volumes for these samples were small and therefore the MDCs were high (MDCs and sample volume are discussed further below). The most important gamma emitter with potential for release was ^{137}Cs. The results for ^{137}Cs on 27 WDOH samples were all less than the MDC and the estimated MDC was in the range of 0.006 –9 pCi/m^3. DOE contractor measurements on five early collected samples were also all less than the MDCs for ^{137}Cs with MDCs in the range of 3-26 pCi/m^3. The wide range of MDC values for both WDOH and DOE results were due to the wide range of air sample volumes. Evaluation of these data used the conservative assumption that the MDC values were the measured concentrations. These values were compared to the Protective Action Guides, NESHAP, and ambient background levels. These levels are shown in Table 4. Even with this conservative assumption, the rapid analyses showed air concentrations were not above PAG limits for gamma emitting radionuclides.

Table 4

Values Used to Evaluate Health Significance of Air Monitoring Results
(pCi/m^3)

Nuclide	1 Year PAG*	NESHAP Standard**	Hanford Area Average Background***
Gross Beta	--	--	6.2×10^{-4}
Gross Alpha	--	--	1.1×10^{-2}
^{90}Sr	141	1.9×10^{-2}	1.3×10^{-5}
^{137}Cs	5700	1.9×10^{-2}	1.3×10^{-5}
^{238}U	1.5	8.3×10^{-3}	2.2×10^{-5}
$^{239/240}$Pu	0.43	2.0×10^{-3}	0.9×10^{-6}

*   First year Protective Action Guide (PAG) for relocation of affected population of 2 rem in the first year. It assumes an inhalation rate of 30 m^3/d doing 4 hours of heavy work, 8 hours of light work, and 12 hours of rest. (EPA 400-R-92-001 page 4-3)

**   NESHAP limit for 40CFR61, App. B, Table 2. These continuous concentrations would result in a dose of 10 mrem/y EDE.

***   Average 1999 concentrations at Hanford distant communities from PNNL-13230

Soil and vegetation were collected by WDOH during the active phase of the fire. These were collected to determine if radionuclides from the smoke and suspended particles were deposited onto vegetation. There was only one soil sample collected. The samples were analyzed for

gamma emitters at WDOH laboratory with 10-minute count times. None of the samples showed any detectable radionuclides other than natural radioactivity. After the initial phase of the fire, all of these samples were recounted with a 1000-minute count time. No elevated levels of radionuclides were observed in these recounts. The DOH fire data are available on the web site "DOH Response to the Hanford Wildfire" at www.doh.wa.gov/ehp/rp/wildfire.htm.

U.S. EPA Samples

At the request of WDOH, the U.S. Environmental Protection Agency collected samples during the period of June 30 to July 4, 2000 at 24 locations around the Hanford Site out to a distance of 80 miles from the site. The initial analytical results for 41 of the 63 samples collected were released on July 25, 2000. These first analyses were for isotopes of plutonium and uranium. This was a very rapid turn around time for this large number of detailed radiochemical analyses. The remainder of the results came out later and the final results, with filter blank corrections, were distributed on October 30, 2000. The final report provided results for:

Gross Beta	Uranium 238
Gross Alpha	Uranium 235
Gamma Spectral Analysis	Uranium 234
Plutonium-239/240	Strontium-90
Plutonium-238	Strontium-89

All of the data are available on the U.S. EPA website www.EPA.gov/r10earth/ (follow the links to Air and Hanford Fire). The EPA sampling system used a pump with a flow rate of 25-30 CFM, which collected a volume of about 1000 m^3 for the 24-hour sampling period used. This volume provided an MDC that is far below NESHAP limits, but not down to ambient levels for some radionuclides. The MDC for the samples varied because the sample size was not exactly the same for all samples, but the typical MDCs for the major radionuclides are shown in Table 5.

Table 5

U.S. Environmental Protection Agency Detection Limits for Fire Samples

Nuclide	Approximate MDC (pCi/m^3)
Gross Alpha	2×10^{-4}
Gross Beta	1×10^{-3}
^{90}Sr	3×10^{-3}
^{137}Cs	3×10^{-3}
^{238}U	3×10^{-5}
$^{239/240}$Pu	5×10^{-5}

At the 24 locations around the Hanford Site and up the Yakima valley, air samples were collected one to three days following the fire. All but one location had more than one sample

collected and most had three samples. At seventeen of the locations, the results from all analyses were either below detection levels or at typical background levels. At seven locations there was an elevated air concentration for one day only. These results are shown in Table 6 below.

Table 6

U.S. EPA Sampling Stations with Above Normal Results

Location	Nuclides	Start Date	End Date	Concentration pCi/m^3	2 Sigma Uncertainty	Volume	MDC pCi/m^3
EPA Hanford Office	$^{239/240}$Pu	7/1/00	7/2/00	3.6 x 10^{-4}	9.6 x 10^{-5}	1000	4.5 x 10^{-5}
	$^{239/240}$Pu	7/3/00	7/4/00	*3.0 x 10^{-6}	2.3 x 10^{-5}	1000	5.6 x 10^{-5}
Richland Residence	$^{239/240}$Pu	6/30/00	7/1/00	1.4 x 10^{-4}	4.8 x 10^{-5}	1000	1.2 x 10^{-5}
	$^{239/240}$Pu	7/1/00	7/2/00	*5.0 x 10^{-6}	1.6 x 10^{-5}	1000	3.7 x 10^{-5}
Richland Residence 2	$^{239/240}$Pu	6/30/00	7/1/00	2.3 x 10^{-4}	6.4 x 10^{-5}	1000	2.8 x 10^{-5}
	$^{239/240}$Pu	7/1/00	7/2/00	*2.0 x 10^{-6}	1.0 x 10^{-5}	1000	2.9 x 10^{-5}
West Richland	$^{239/240}$Pu	7/1/00	7/2/00	1.2 x 10^{-4}	4.2 x 10^{-5}	1000	1.1 x 10^{-5}
Pasco	$^{239/240}$Pu	7/1/00	7/2/00	4.2 x 10^{-4}	9.6 x 10^{-5}	1000	4.1 x 10^{-5}
	$^{239/240}$Pu	7/2/00	7/3/00	*4.0 x 10^{-6}	1.1 x 10^{-5}	1000	2.7 x 10^{-5}
	$^{239/240}$Pu	7/3/00	7/4/00	*1.1 x 10^{-5}	2.7 x 10^{-5}	1000	5.4 x 10^{-5}
Sunnyside	$^{239/240}$Pu	7/1/00	7/2/00	*6.9 x 10^{-6}	3.0 x 10^{-5}	1000	5.1 x 10^{-5}
	$^{239/240}$Pu	7/2/00	7/3/00	6.1 x 10^{-5}	4.5 x 10^{-5}	1000	4.1 x 10^{-5}
	$^{239/240}$Pu	7/3/00	7/4/00	*-1.2 x 10^{-5}	1.5 x 10^{-5}	1000	3.5 x 10^{-5}
Yakima	^{90}Sr	7/1/00	7/2/00	*3.5 x 10^{-4}	1.9 x 10^{-3}	1000	2.7 x 10^{-3}
	^{90}Sr	7/2/00	7/3/00	6.6 x 10^{-3}	3.2 x 10^{-3}	1000	4.0 x 10^{-3}
	^{90}Sr	7/3/00	7/4/00	*-9.3 x 10^{-5}	1.5 x 10^{-3}	1000	2.2 x 10^{-3}

* Results below MDC
Complete U.S. EPA sampling data can be found at the following website:
www.epa.gov/r10earth/ (follow links to Air and to Hanford)

There were six samples that had elevated $^{239/240}$Pu concentrations. Three of the samples were in Richland (the EPA Hanford Office and two Richland residences) and one each in West Richland, Pasco, and Sunnyside. In each case, except West Richland, the concentration was below MDC on the following day. At West Richland, a sample was only collected on one day. The highest concentration was in Pasco on July 1-2, 2000 with a concentration of 4.2 x 10^{-4} pCi/m^3. At the three Richland locations and West Richland, the elevated levels were of a similar magnitude. The positive Sunnyside result was 6.1 x 10^{-5} pCi/m^3, which is about a factor of 10 below the highest level in Pasco and close to the MDC level of 4.1 x 10^{-5} pCi/m^3. The 1999 average ambient $^{239/240}$Pu concentration in communities distant from the Hanford Site was 0.9 x 10^{-6} pCi/m^3. By comparison, the measured levels for one day only were over 100 times above the ambient level. The NESHAP continuous exposure standard for $^{239/240}$Pu is 2.0 x 10^{-3} pCi/m^3. The elevated one-day concentrations, while higher than ambient, were approximately a factor of 10 below the standard.

ANALYSIS OF ENVIRONMENTAL RADIOLOGICAL DATA
RELATING TO THE 2000 WILDFIRE AT HANFORD

The only ^{90}Sr concentration above MDC was on July 2-3 in Yakima. The measured concentration was 6.6 x 10^{-3} pCi/m^3. The 2-sigma uncertainty on this sample was 3.2 x 10^{-3} pCi/m^3 and the MDC was 4.0 x 10^{-3} pCi/m^3. This measured concentration was below the NESHAP standard of 1.9 x 10^{-2} pCi/m^3. There are some reasons to question this result, these being:

a. The decayed gross beta on this sample was 3.9 x 10-3 pCi/m3, approximately one-half the ^{90}Sr result. The gross beta result should be twice the value of the ^{90}Sr result.
b. At all locations that were nearer to the Hanford Site, ^{90}Sr results were below MDC.
c. On the day before and the day following this sample, the concentrations were below the MDC.

The EPA effort provided rapid low-level analyses of ambient air in populated areas around the Hanford site. The results showed that there was increased radioactivity, particularly $^{239/240}$Pu in air particles, for one day following the fire. The elevated levels were higher than the normal ambient levels, but in all cases were less than the NESHAP standard for continuous radionuclide air concentrations. The EPA data was very useful for evaluating the health impact of the fire from radionuclides in air.

After the fire, the Pacific Northwest National Laboratory analyzed the composites of air filters routinely collected from onsite, perimeter, and distant community locations. These composite samples did not show elevated levels of radionuclides in air. Their results are available in 2000 Hanford Site Environmental Report, PNNL-13487 (www.hanford.gov/docs/annualrp00). The DOE Near Facility Monitoring Program also performed specific radionuclide analysis on 12 composites from 100 sampling stations. The analyses showed a similar pattern as other analyses with elevated levels but not exceeding NESHAP continuous exposure standards during the period of the fire.

Air Monitoring Systems

It is essential to rapidly obtain air concentration data in a situation where radioactivity can potentially be released from a site, such as the Hanford Fire. There are several constraints to obtaining data of the desired quality in a timely manner. These include:

- Natural radioactivity in air
- Availability of electrical power
- Transport of samples to a laboratory
- Collection of sufficient air volumes
- Analysis and counting times

Natural Radioactivity

The principal interference to gross alpha and beta measurement by natural radioactivity in air is from the progeny of radon and thoron. The effective half-life of these naturally occurring radionuclides are controlled by relatively short half-life radionuclides, namely 26.8 min ^{214}Pb, 19.7 min ^{214}Bi for radon and 10.6 hr ^{212}Pb for thoron. Waiting until the daughter activities are

negligible before counting eliminates this interference. This requires about three days for the long-lived thoron progeny. It is not possible to apply a correction factor to estimate the contribution of the mixture of short-lived radionuclides because the initial concentration is unknown and the mixture of the three radionuclides varies widely. This natural radioactivity does not interfere with gamma spectrum analysis of air filters if a high purity germanium detector is used.

Because of the normal variability of gross alpha and beta levels, it is difficult to detect a small increase in air concentration using these measurements. This is particularly true if $^{239/240}$Pu is the nuclide of interest. The historical gross alpha measurements around Hanford range from 2-20 x 10^{-4}pCi/m^3. The ambient levels of $^{239/240}$Pu are in the range of 0.5-1 x 10^{-6} pCi/m^3. The following example shows the impact of the gross alpha variability on the ability to detect an increased $^{239/240}$Pu increment using 1 x 10^{-6} pCi/m^3 as the ambient $^{239/240}$Pu level.

Increase in $^{239/240}$Pu Concentration	Gross Alpha Incremental Increase pCi/m^3
100 fold increase	1 x 10^{-4}
1000 fold increase	10 x 10^{-4}
10,000 fold increase	100 x 10^{-4}

A 100-fold increase in $^{239/240}$Pu could not be seen in the variability range of 2-20 x 10^{-4} pCi/m^3. A 1000-fold increase might be detectable but still could be interpreted to be within the range of normal variability. A 10,000-fold increase would definitely be detected. The variability of natural activity in air coupled with the elevated but decaying levels present in the first three days after collection makes it difficult to quantify increased concentrations of pure alpha emitting radionuclides. A similar situation exists for pure beta emitters like ^{90}Sr. Fortunately for most situations there are gamma-emitting radionuclides in the radionuclide matrix. This fire was rather unique in that $^{239/240}$Pu and ^{90}Sr were detected without the presence of other radionuclides.

Availability of Electrical Power

The availability of electrical power can limit the locations and size of samples that can be collected. It is often necessary to rely on battery-operated samplers. If a single 12V battery powers a sampler, the sampling period is short and the sample size is therefore small. WDOH procedures for emergency air sampling specify a ten cubic foot sample size. This allows for an adequate sample size to assess the immediate health impact from a reactor accident where radioiodine is a major item of concern, but it may not be adequate for detecting other radionuclides, such as plutonium, (sample size is discussed below). A 10ft^3 (0.28 m^3) sample is adequate to detect PAG levels, but cannot detect NESHAP levels for some important radionuclides (see Table 7). A 1000 ft^3 (28 m^3) sample was collected with battery-powered samplers for post-fire monitoring. This sample size is marginally adequate to detect NESHAP levels. The U.S. EPA hi-volume samples operated for 24 hours and used portable generators to collect 1000 m^3 samples.

During an incident, battery powered samplers can provide adequate air volumes for PAG determinations. Post-incident monitoring involves looking for lower concentrations and

therefore the choice of sampler and the power availability must be considered in the follow-up phase of an incident.

Transport of Samples to Analytical Laboratory

Samples collected by field teams must first be transported from the field to a location where samples are accumulated for transport to a laboratory. It can be 1-3 hours after a sample is collected in the field before it is ready for transport to a laboratory. During the fire, samples were rapidly transported to the P.H. Laboratory; however, even rapid transport from Hanford requires two to four hours. Logging in and sample preparation takes time before analyses are started. Actual sample analysis began on WDOH samples 4-8 hours after the samples were collected. This is a quick response for fixed laboratory analysis, but for real-time decision making during an emergency, this is a long time.

Sample Analysis and Counting Times

After samples are delivered to the laboratory, the first task that takes time is the receipt, logging, and sample preparation. Logging involves the transfer of data from sampling logs and tags into the laboratory analytical system. Sample preparation for gamma spectral analysis is relatively simple, is not greatly hampered by natural radioactivity in air, and counting can begin with a relatively short delay. The counting time is an important consideration in getting rapid analysis and the tradeoff must be made between counting sensitivity and the number of samples that can be analyzed in a timely manner. For example, for normal low-level environmental gamma counting, a counting time of 420 minutes (7 hours) or 1000 minute (16.6 hour) is used. In emergency response it is necessary to count large numbers of samples and get adequate results in as short a time as possible; therefore shorter counting times are used. During the fire, the early phase samples were gamma counted for 10 minutes and later recounted for 1000 minutes. As an example, a comparison of the ^{137}Cs MDC for an air filter with a 10 m^3 volume counted for ten minutes, 420 minutes, and 1000 minutes is as follows:

Count Time (Minutes)	MDC (pCi/m^3)
10	0.55
420	0.063
1000	0.040

The MDC decreases by about a factor of 10 (10 times more sensitivity) with the 420 or 1000-minute counts over the 10-minute counts. Note that the MDC decreases as approximately the square root of the counting time so that one gets a diminishing return as longer count times are used.

Radiochemical analyses like ^{90}Sr and $^{239/240}$Pu, and uranium require long chemical separation and counting times. For plutonium and uranium, if the laboratory gave the highest priority to an emergency sample, it would still take two to three days to get a result. For ^{90}Sr, because of the ingrowth period required in the analytical procedure, it takes approximately 34 days before a result is obtained.

Air Samplers and Volumes

Air sampling equipment and the air volumes collected are key components during an emergency response. The air volumes and the immediate need for results must be matched with the concentration levels that one is trying to measure. The target MDC is derived from the analytical parameters of the radiation measurements and the health protection standard being evaluated. During the Hanford fire, the three target values for evaluation of the significance of measurements were:

- The Protective Action Guide which is an EPA recommendation based on an exposure to the public of 2 rem and is used as a basis for recommending evacuation or sheltering
- The NESHAP Clean Air Act standard for exposure from the air pathway which is based on continuous exposure with a dose limit of 10 mrem per year
- Ambient Air Concentrations which are used as a basis for evaluating if there has been an increase from normal conditions

To be confident a measurement is above or below the radiation standard, the lab must be able to measure levels less than that standard. Table 2 shows the air volumes that are needed to have an MDC that can measure PAGs, NESHAP, ambient levels, and one-tenth of the PAG and NESHAP limits. These MDC concentrations for the major radionuclides of interest during the fire are based on calculations using a 5% alpha and beta error (a 5% chance of concluding that there is radioactivity present above background when there really isn't (false positive) and a 5% chance that one will conclude that there is no radioactivity above background when there really is (false negative). It also assumes the normal low-level count times, which will not always be the case as discussed above.

As can be seen in Table 7, there is a wide range in the sample volumes needed to detect the three target concentrations defined above. There is also a wide range in the volumes needed between radionuclides that is due primarily to the difference in the dose conversion factors between the radionuclides.

Several air samplers were used by WDOH during and after the fire. The WDOH emergency kit samplers were battery operated and had a flow rate of 0.5-3 cfm with a 2-inch diameter filter. Emergency monitoring procedures specify a 10-minute sampling period, which will provide a sample volume of 0.14 - 0.85 m^3. The WDOH field teams also used portable samplers that can pull 20-30 cfm with a 4-inch filter. The specific flow rate depends upon the filter and the cartridge used in the sampling train. In the mode used during the fire, these samplers had a flow rate of 20 cfm and a sampling period of 5 minutes giving a 100 ft^3 (2.8 m^3) sample. As shown in Table 4 above, the total air volumes collected by these portable samplers were adequate for evaluating air concentrations relative to the PAG; however were insufficient to measure down to NESHAP levels for the nuclides listed.

Table 7

Air Sample Volume Needed to Detect Various Concentrations

Nuclide	Basis	Concentration pCi/m^3	Sample Volume Needed-m^3
^{90}Sr	PAG	141	0.005
	0.1 PAG	14	0.05
	NESHAP	1.9×10^{-2}	35
	0.1 NESHAP	1.9×10^{-3}	350
	Ambient	1.3×10^{-5}	5.1×10^4
^{137}Cs	PAG	5700	0.0001
	0.1 PAG	570	0.001
	NESHAP	1.9×10^{-2}	33
	0.1 NESHAP	1.9×10^{-3}	330
	Ambient	1.3×10^{-5}	4.8×10^4
^{238}U	PAG	1.5	0.03
	0.1 PAG	0.15	0.25
	NESHAP	8.3×10^{-3}	4.6
	0.1 NESHAP	8.3×10^{-4}	46
	Ambient	2.2×10^{-5}	1730
$^{239/240}$Pu	PAG	0.43	0.1
	0.1 PAG	0.043	1
	NESHAP	2.0×10^{-3}	22
	0.1 NESHAP	2.0×10^{-4}	215
	Ambient	0.9×10^{-6}	4.7×10^4

Sample volume based on an MDC calculation with average laboratory parameters for low-level
analyses and with a 0.05 probability for a Type I and Type II error.
1 m^3=35.3 ft^3

After the active phase of the fire, the U.S. EPA sampled using generator-powered
samplers with a flow rate of 25-30 cfm that collected a 1000 m^3 sample in a
24-hour period. The WDOH follow-up sampling utilized three sampling
arrangements. Air samples were collected from the regular fixed station samplers
that have a 1.5 cfm flow rate. Additional stations were established that used this
same equipment but the flow rate was set at 3 cfm. These samplers were placed
at locations where there was a concern over soil resuspension where ground cover
had been burned off during the fire. The higher flow rate was used to obtain a
larger sample volume. A third sampler was a portable hi-volume sampler that had
a flow rate of 22 cfm with a 4-inch head. These samplers were used to collect a
1000 ft^3 (28.3 m^3) sample at locations where there was blowing dust during high
wind conditions. Information in Table 7 shows that this air volume will provide
an MDC that is in the range of adequate minimum air volumes needed to measure
down to the NESHAP concentration for the significant Hanford radionuclides.

Each of these samplers is useful for a given set of circumstances. The air monitoring of the fire emphasized the importance of selecting the sample volume and flow rates to provide the detection level (MDC) that will meet the objectives of the sampling. The concepts of MDC and air volume were discussed above. Tables 8 and 9 summarize the air sampling equipment and the sample volumes that would be obtained at various flow rates. Using the technique used to develop Table 7, the flow rates and sampling times can be determined to establish the volume needed for the specific sampling goals. If the purpose of sampling is to characterize short-term spikes in air concentrations, then high volume samplers must be used. If long-term composites of filters from low volume samplers are used to obtain the needed volume for a desired MDC, short-term spikes in air concentration will not be detected since the measured concentration is the average over the period of composited filters. Fixed station low-volume samplers may not be adequate to characterize short-term releases. High volume samples are not practical for routine air monitoring because of sampler costs for continuous operation, frequent filter change requirements and maintenance costs. Trade offs must be made in the selection of air samplers and no single sampler meets all needs. Portable hi-volume air samplers are probably the best for emergency response purposes.

Table 8

Air Samplers Used During and After the Hanford Fire

Sampler Type	Flow Rate CFM	Typical Sampling Time	Typical Total Volume m^3
WDOH Emergency Response Samplers			
Emergency Kit Low-Vol.	3	10 min.	0.8
Battery Operated Hi-Vol.	20	10 min	5.7
WDOH Fixed Station Samplers			
Regular Stations	1.5	90 day Comp. *	5500
Post Fire Special Stations	3	6 month Comp. *	20,000
Resuspension Hi-Vol.	20	50 min	28
EPA Hi-Vol. Sampler	25-30	24 hour	1,000

*Filters changed weekly

Table 9

Air Sample Volumes (Cubic Meters) for Various Sampling Times

Sampling Time	Fixed Station Lo-Volume Sampler 1.5 CFM	Emergency Kit Battery Operated Sampler 3 CFM	Emergency Kit Hi-Vol Sampler 20 CFM	EPA Hi-Volume Sampler 25 CFM
10 Min.	.4	0.8	5.7	7
1 Hour	2.5	5	34	42
24 Hour	61	-	-	1020
7 Day	428	-	-	7130
30 Day	1830	-	-	30,600
90 Day	5500	-	-	91,700

Evaluation of the Source of Radionuclides in Air During Fire

The air monitoring conducted during and immediately following the fire was done to determine if radioactive particles had been transported into the air. The early gross alpha and beta monitoring indicated that there could be some elevated air concentrations. The later specific radionuclide analysis from EPA and contractor samples confirmed that there had been elevated levels of $^{239/240}$Pu and ^{90}Sr in airborne particles. These radionuclides are contaminants known to be in the surface environment (soil and vegetation) and facilities of the 200 Area. Since no structures were involved in the fire and there were no known releases from facilities during or near the fire period, the source of airborne radioactive particles must have been from burning vegetation or resuspended contaminated soil. A limited number of soil and vegetation samples were collected during the fire, but these were not necessarily in areas that were subsequently burned. There is however, considerable data on radionuclide concentrations in vegetation and soil from WDOH, PNNL and the near-facility monitoring program. Vegetation data shows that the concentrations of $^{239/240}$Pu and ^{90}Sr are not elevated, except for some results in the 100-N area that showed elevated ^{90}Sr. Concentrations of $^{239/240}$Pu in vegetation are usually not elevated because plutonium does not readily transfer to plants by soil uptake. Russian thistle is known to concentrate strontium but there is no data on contaminated Russian thistle in the areas burned by the fire. Visual observation of partially burned waste sites immediately following the fire did not indicate areas with heavy Russian thistle growth in the nearby-unburned areas. Sampling of ash from sagebrush burned during the fire did not show elevated radionuclide levels in the ash. Burning vegetation does not appear to be the main source of radionuclide contamination measured on airborne particles.

A review of historical soil data from the near-facility monitoring shows that there are some elevated $^{239/240}$Pu and ^{90}Sr concentrations in the 200/600 areas. These data are summarized in Table 10 (actual data are available on web site www.hanford.gov/docs/annualrp00). The mean and maximum concentrations of $^{239/240}$Pu and ^{90}Sr are both elevated relative to the offsite Hanford perimeter 1992-1999 average concentrations. Some near-facility areas and waste disposal areas were burned in the fire.

To determine if soil contamination could reasonably account for the observed air concentrations, a mass loading model was used. The mass loading model is a technique that derives the airborne concentration of specific radionuclides by assuming the specific activity of the suspended particles (pCi/g) are the same as the specific activity of the surrounding soil. Anspaugh (Anspaugh 1974 and Anspaugh et al 1975) employed this model to predict air concentrations at a number of sites. In their studies, predicted values did not exceed measured values by more than roughly a factor of five. To use this model, data on soil concentrations or soil deposition (pCi/g or pCi/m^2), and airborne particulate mass loading (μg/m^3) are needed. Soil concentration data in Table 10 was obtained from the Hanford Near-Facility Monitoring Program and Surface Environmental Surveillance Program (PNNL-13230). Air-borne particle concentrations were obtained from the Benton County Air Pollution Control District. A summary of airborne particle concentrations for dusty conditions in the July-August 2000 period is shown in Table 11. Typical average August concentrations are about 25 μg/m^3.

Mass loading calculations were made for three air-borne particle concentrations, 50, 100, and 200 μg/m^3. These concentrations of particulates in air represent respectively the amount of suspended particulates for visibly dusty conditions, the average upper 95th percentile of air particulate concentrations during the July-August period, and the maximum concentrations observed during the Hanford fire. To estimate the amount of radionuclides one would expect in an air sample if one considers the source of the airborne radioactivity to be surface soil, concentrations of radionuclides in soil representing the maximum and mean near-facility values and the Hanford perimeter values were used. An estimated radionuclide air concentration was determined by multiplying the amount of particulate/volume of air (ug/m^3) by a representative soil concentration (pCi/g). The results of these calculations are shown in Table 12. The mass loading calculations showed good agreement with the radionuclide concentrations measured offsite and at near-field locations. For $^{239/240}$Pu, the 1999 average Hanford perimeter concentration was 0.63 x 10^{-6} pCi/m^3. The mass loading calculation for 50 μg/m^3 and the 0.02 pCi/g soil concentration was 1 x 10^{-6} pCi/m^3. The elevated air concentrations measured during the fire at offsite locations were in the range of 10^{-4} pCi/m^3 (see Table 6) and a calculated value using 0.6 pCi/g soil concentration and a 200 μg/m^3 was 1 x 10^{-4} pCi/m^3. Twelve onsite composite air samples measured for $^{239/240}$Pu for the period 6/26/2000 to 7/10/2000 ranged from 9.5 x 10^{-6} to 1.6 x 10^{-3} pCi/m^3. Most of the values were in the range of 2 x 10^{-5} to 1 x 10^{-4} pCi/m^3. The mass loading calculations using previously measured mass loading and soil values resulted in concentrations in the same range as measured concentrations.

Even though there are numerous uncertainties in these calculations (non-uniformity of soil contamination, locations of contaminated soil relative to air measurements, particle size differences for mass loading measurements, etc.), the calculations support the speculation that contaminated soil was the source of the $^{239/240}$Pu. The measured air concentrations were consistent with predicted air concentrations based on measured concentrations using the mass loading model.

For ^{90}Sr, the situation was similar. The EPA offsite air results showed only one positive ^{90}Sr result and this was discussed above as being a questionable result. The results at other locations were below the MDC and this corresponds well with the mass loading calculations that show concentrations for the condition examined to be in the range of 8 x 10^{-6} to 1 x 10^{-3} pCi/m^3.

The MDC for the EPA ^{90}Sr analyses was about 3 x 10^{-3} pCi/m^3; therefore most results would be below the MDC, which corresponds to the calculations. The twelve near-field composites measurements had ^{90}Sr concentrations in the range of 1 x 10^{-4} to 6.3 x 10^{-3} pCi/m^3. This again is in the range of calculated concentrations using high particle loading and high soil concentration values in the mass loading model.

The contaminated soil concentrations near facilities when used in a mass-loading model provide reasonable agreement with the measured air concentrations for $^{239/240}$Pu and ^{90}Sr. This supports the contention that the levels observed during and after the fire came from resuspended contaminated soil.

Table 10

Hanford 1999 Soil Concentrations pCi/g

Location	$^{239/240}$Pu		^{90}Sr	
	Mean	Max	Mean	Max
200/600 Area Near Field	0.1	0.6	1.1	5.9
Hanford Perimeter 1992-1999 Average	0.008	0.021	0.78	0.15
WDOH Post-fire Measurement in BC Crib Area	-	0.02	-	-

Table 11

Tri-Cities Airborne Particle Concentrations
July-August 2000

Measurement	PM-10 Concentration ug/m^3
Highest Measured Value	200
Average of Upper 95% Percentile	100
Visibly Dusty Conditions	50

Measurements in Kennewick, WA by the Benton County Air Pollution Control District

Table 12

**Calculated Air Concentrations of $^{239/240}$Pu and ^{90}Sr
Using a Mass Loading Resuspension Model**

Particulate Loading	$^{239/240}$Pu Soil Concentration pCi/g			^{90}Sr Concentration pCi/g		
ug/m^3	0.02	0.1	0.6	0.15	1.1	5.9
50	1 x 10^{-6}	5 x 10^{-6}	3 x 10^{-5}	8 x 10^{-6}	6 x 10^{-5}	3 x 10^{-4}
100	2 x 10^{-6}	1 x 10^{-5}	6 x 10^{-5}	2 x 10^{-5}	1 x 10^{-4}	6 x 10^{-4}
200	4 x 10^{-6}	2 x 10^{-5}	1 x 10^{-4}	3 x 10^{-5}	2 x 10^{-4}	1 x 10^{-3}

Conclusion

Environmental monitoring was an important aspect of the response to the Hanford Fire. DOE contractors, WDOH, and the U.S. Environmental Protection Agency each contributed to the monitoring effort. Based on observations during the response and the review of the monitoring data, the following can be concluded:

- Monitoring data provided during the fire was adequate in timeliness and quality for emergency managers to make decisions on health-related actions.

- Gross alpha and beta measurements, while providing rapid screening information, must be evaluated in a conservative manner because significant levels of plutonium and strontium can be hidden within the natural variability of these gross measurements.

- Selection of air sampling equipment and sample collection times must be coordinated to provide adequate sample volumes over reasonable sampling times to meet the detection levels desired.

- Monitoring results that are less than detectable must be evaluated conservatively. Interpretation and dissemination of results should emphasize that such results are less than the Minimum Detectable Concentration (MDC) and not simply that radionuclides were not detected. Not detected can be interpreted as there is nothing in the sample.

- Emergency planning should incorporate sample volumes and MDC considerations.

- Grass fires at Hanford can release radioactivity from surface contamination.

- Contaminated soil is the likely source of the elevated ^{90}Sr and $^{239/240}$Pu levels measured in air on and around the Hanford site. Mass loading calculations can be used to estimate air concentrations that might be expected to occur in a fire or windstorm.

- ▪ The EPA monitoring capability and rapid radiochemical analysis was very helpful in evaluating the impact of the fire. This capability was not readily available from other sources at Hanford.

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APPENDIX A

Laboratory Instruments and Analytical Procedures

Samples collected for the Hanford fire investigation were sent for analysis to the Washington State Public Health Laboratory in Shoreline, Washington. Equipment and procedures used for analyses performed at the PHL are described here.

While the laboratory used standard protocols for sample analysis, new techniques for sample preparation were needed. During the emergency, the laboratory received air filters that did not match the size and composition of WDOH's standard filters. New procedures for preparing these samples, along with a procedure for compositing and digesting large amounts of weekly air filters, had to be developed before analysis could proceed. The laboratory is continuing to work on methods for sequential analysis of plutonium and uranium on a single sample and on methods for analysis that would require a much smaller sample size. For more information about the laboratory, please see the following web site.

www.doh.wa.gov/ehsphl/phl/

Radiation Counting Equipment

Gamma Analysis

A Digital Equipment Corporation (DEC) model 3100 VAX Station, connected to the detectors via ethernet, controls the laboratory's primary gamma spectroscopy system. The qualitative identification of specific radionuclides as well as quantitative determination of radionuclide concentration is accomplished with ND nuclide analysis software. The system supports four High Purity Germanium coaxial detectors and one Low Energy Photon (LEPS) detector. Each detector has a resolution of less than 2 KeV of Full Width Half Maximum. Three detectors have a counting efficiency of 30 percent and one detector has a counting efficiency of 90 percent relative to a 3" x 3" sodium iodide crystal. The laboratory also has two coaxial 20 percent detectors that are used for screening samples.

Sample geometries used for gamma counting were:

> 400 ml container
> 100 ml - 4 ounce container
> 2" planchet for counting air filters

Gross Alpha and Beta Analysis

Low background gas flow proportional counting systems, two Tennelec LB5100 series and one Tennelec LB4110 with eight detectors were used for measuring gross alpha and beta radioactivity. The LB5100 systems are equipped with an automatic programmable sample changer. The LB4110 system, which uses a manual sample changer, can count eight samples simultaneously. A manually operated Tennelec system TC 535P is also available. Counting data are collected on a PC for all systems. A PC driven data reduction program is used for calculating a gross alpha and beta sample activity.

Alpha Spectroscopy Analysis

A VAX Station 3100 is used to operate seven silicon surface barrier alpha detectors installed in spectrometers. The laboratory is using alpha detectors and spectrometers manufactured by the Canberra Company. An ND-589 AMX Multiplexer is used to connect the VAX Station to all of the detectors. The laboratory also has one Canberra alpha analyst that supports 12 detectors.

Radiochemistry Procedures

The following is a brief summary of pertinent radiochemical techniques used in the preparation of samples prior to instrumental analysis.

Preparation of Soil and Vegetation for Uranium and Plutonium Analyses

Soil

Uranium analysis. A soil sample is prepared for alpha-emitting radionuclides analyses by drying and sieving. Then a portion of the sample, with proper tracer added, is fused in the presence of potassium sulfate, sulfuric acid and sodium sulfate. The fused sample is dissolved in acidified water.

Plutonium and strontium analysis. A soil sample with tracer is leached with dilute HCl (hydrochloric acid) by stirring for four hours, filtered and brought up to volume for analysis.

Vegetation

A vegetation sample is dried in an air driven oven and then ashed in a muffle furnace. The ashed sample is dissolved in dilute hydrochloric acid. Aliquots of the solution are analyzed.

Air Filter and Wipe Samples

An air filter sample or a collection of air filters (a composite sample) or wipe samples are prepared through a wet ashing method with a combination of acids to digest the filter and organic matter. The silicate residue that might be present in air particulates is treated with HF (hydrofluoric acid). After acid digestion, the sample is dissolved in dilute HCl, filtered if necessary and brought up to volume for analysis.

Uranium Analysis of Soil and Vegetation by Alpha Spectroscopy

This method determines isotopic uranium-234, uranium-235, uranium-236 and uranium-238. A uranium-232 tracer and ferric chloride carrier are added to a prepared sample solution. The solution is boiled to eliminate carbonate and bicarbonate ions and ammonium hydroxide is added to precipitate uranium along with ferric hydroxide. The precipitate is then dissolved in hydrochloric acid and the uranium further separated from other radionuclides by anion exchange chromatography. The purified uranium fraction is precipitated with cerium fluoride on a filter that is analyzed using alpha spectroscopy.

Plutonium Analyses for Soil and Vegetation by Alpha Spectroscopy

This method determines the isotopic activity of plutonium-238 and plutonium-239. Plutonium-242 tracer solutions are added to a prepared sample solution. Chemical separation requires steps to assure that the elements are in the proper oxidation state. The elements thorium through plutonium are then precipitated on barium sulfate and dissolved in aluminum nitrate. A quaternary amine is used to extract the elements thorium through plutonium from the solution. Thorium is removed from this amine solution by scrubbing with hydrochloric acid. Plutonium, protactinium, and neptunium are removed by scrubbing with a perchloric/oxalic acid solution. Each fraction is purified and then precipitated with cerium fluoride on a filter that is analyzed by alpha spectroscopy.

Strontium Analysis for Water, Food, Vegetation and Soil

Water

A nitric acid separation method is used to determine Sr-89 and Sr-90 in water samples. After strontium and calcium carrier solutions are added to a sample aliquot, strontium, calcium, barium, radium, and rare earth nuclides are precipitated as oxalates in an excess of oxalic acid. The oxalates are then converted to nitrates to allow separation of calcium from strontium by differences in solubility. Strontium is scavenged with barium, iron and rare earth carriers and then precipitated as a carbonate. Yttrium 90 is allowed to in-grow. The strontium nitrate is then dissolved and reprecipitated with fuming nitric acid, leaving Y-90 in the supernate solution. Both fractions are transferred to planchets and counted

for beta activity. The Sr-90 activity is determined as Y-90 from counting the Y-90 planchet. The Sr-89 activity is the calculated difference between the activity of total radioactive strontium and that of Sr-90. Chemical yield is determined by atomic absorption spectrometry.

Vegetation

The vegetation sample is thoroughly blended to achieve homogeneous slurry. The blended sample is dried in an oven and ashed in a muffle furnace. The ashed sample is dissolved in dilute hydrochloric acid and the solution is analyzed for strontium-89 and strontium-90 as a water sample.

Soil

A sieved and well-mixed sample is leached with diluted hydrochloric acid and the leachate filtered. Strontium carrier solution is added to the leachate and the analysis of the leachate proceeds as it is described in strontium analysis of water samples.