HIGH EFFECIENCY PARTICULATE AIR (HEPA) FILTER GENERATION, CHARACTERIZATION, AND DISPOSAL EXPERIENCES AT THE OAK RIDGE NATIONAL LABORATORY

D. E. Coffey
Oak Ridge National Laboratory,
UT – Battelle, LLC
P. O. Box 2008, Oak Ridge, TN 37831-6023

ABSTRACT

High Efficiency Particulate Air filtration is an essential component of the containment and ventilation systems supporting the research and development activities at the Oak Ridge National Laboratory. High Efficiency Particulate Air filters range in size from 7.6cm (3 inch) by 10.2 cm (4 inch) cylindrical shape filters to filter array assemblies up to 2.1 m (7 feet) high by 1.5 m (5 feet) wide. Spent filters are grouped by contaminates trapped in the filter media and become one of the components in the respective waste stream. Waste minimization and pollution prevention efforts are applied for both radiological and non-radiological applications. Radiological applications include laboratory hoods, glove boxes, and hot cells. High Efficiency Particulate Air filters also are generated from intake or pre-filtering applications, decontamination activities, and asbestos abatement applications. The disposal avenues include sanitary/industrial waste, Resource Conservation and Recovery Act and Toxic Substance Control Act, regulated waste, solid low-level waste, contact handled transuranic, and remote handled transuranic waste. This paper discusses characterization and operational experiences associated with the disposal of the spent filters across multiple applications.

INTRODUCTION

The University of Tennessee-Battelle (UT-B) manages the research and development activities and the associated facilities at the Oak Ridge National Laboratory (ORNL) for the Department of Energy (DOE) Office of Science. The Bechtel Jacobs Company LLC (BJC) currently manages the waste disposal from the Oak Ridge Reservation (ORR), which includes two other complexes on the ORR, for the DOE Office of Environmental Management. The general roles are that UT-B is the waste generator and BJC has the waste certification authority. As such, BJC provides the main interface with the waste disposal sites concerning certification and disposal of the waste.

BJC has developed an ORR Waste Certification Program (WCP) (1) which contains the requirements and responsibilities for certification of waste for disposal. To ensure that ORR waste generators meet the Waste Acceptance Criteria (WAC) of the disposal sites, BJC has developed a series of "Master Profiles" based on the requirements found in the WAC. The profiles specify the requirements related to material description, chemical constituent limitations, radiological constituent limitations, physical parameter limitations, characterization parameters and methodology, prohibited items, packaging requirements, additional requirements, and required documentation.

To support compliance with the ORR WCP and document compliance with the BJC Master Profile System, ORNL has established the ORNL Waste Certification Program (WCP) (2). The ORNL Waste Certification Program consists of a series of program plans, guidance documents, and procedures that establish the responsibilities and requirements for the waste characterization, acceptance, and certification to BJC. To implement the requirements of the ORNL Waste Certification Program for waste characterization, ORNL has established guidance documents, training requirements, and a radiological waste characterization plan. The spent High Efficiency Particulate Air (HEPA) filters are characterized, certified, and transferred to BJC for disposed by the guidelines of these plans and programs.

The HEPA filters are in use throughout ORNL in a variety of radiological and non-radiological applications. The physical characteristics (size and shape) vary widely depending on the application of the filter. Small cylindrical filters, installed on portable HEPA Filtered Vacuum systems, are used for asbestos abatement, chemical spills and radioactive material decontamination. Larger scale applications include building ventilation systems with HEPA filtration on both the intake and exhaust sides of the airflow. The larger applications generate the greatest volume of HEPA filter waste. The following sections discuss some operation experiences associated with the disposal of the spent HEPA filters across multiple applications.

REGULATED HEPA WASTE

The Tennessee Department of Conservation and Environment (TDEC) categorizes the HEPA filters from paint booths and the manipulator boot shop at ORNL as Special Waste. The paint booths are much the same as found throughout industry, while the mission of the manipulator boot shop is unique. The boot shop fabricates a synthetic rubber like sheath or boot, which is used to maintain the primary containment barrier preventing radioactive material from coming in direct contact with the mechanical parts and components of the Master Slave Manipulators (MSM) at ORNL. The MSM are used for remote operations inside shielded hot cells containing high levels of radioactivity. The operating staff stand outside the hot cells and conduct those activities required by the ongoing process or research looking through heavily shielded windows. The slave portion of the manipulators, located inside of each hot cell, is covered by a protective boot to prevent radioactive material from coming in direct contact with the mechanical parts and components of the MSM. To meet the specific needs of several independent hot cell facilities, ORNL maintains the manipulator boot fabrication shop.

The fabrication shop uses a variety of raw materials and solvents to fabricate the boots inside a ventilated area. Before being released the ventilation air is passed through the fabrication area and exhausted through a HEPA filtration system. Both the HEPA filters and the roughing filters (which are in-line before the HEPAs) must be sampled for Resource Conservation and Recovery Act (RCRA) constituents prior to disposal. If the samples reveal RCRA regulated constituents in the filters, they are disposed of as a RCRA-regulated hazardous waste. If radiological surveys reveal the presence of radioactive material in addition to the RCRA hazardous constituents on or in the HEPA filters, the filters are categorized and disposed of as RCRA Mixed waste.

If no RCRA materials are identified in the sample analysis, the filters are categorized as non-hazardous per RCRA regulations, but are still managed as Special Waste by TDEC. Due to the Special Waste status, the disposal the non-RCRA regulated HEPA filters must be approved by TDEC before being placed in the Sanitary/Industrial Landfill.

The non-radiological HEPA filters generated from asbestos abatement also are categorized as Special Waste by TDEC because of to the presence of asbestos. ORNL has approval from TDEC to dispose of asbestos containing material (ACM) in the Sanitary/Industrial Landfill.

NON-RADIOLOGICAL HEPA WASTE

Some research and development areas at ORNL do not use or handle radioactive material as a constituent in their project or facility, but still require HEPA filtration to maintain ventilation through the laboratories. Many of the laboratories are equipped with ventilated hoods used for primary containment of material being used in the laboratory. These ventilation systems include HEPA filtration on both the intake supply and the exhaust system. The waste intake filters from ORNL are not included in the Special Waste category unless they receive intakes from another operating area. Therefore, the HEPA filtration on intake systems using outside air can be disposed in the Sanitary/Industrial Landfill.

Several of the non-radiological HEPA filters at ORNL have metal frames that surround the filter media. Prior to the DOE Scrap Metal Moratorium, the filters with metal frames were included in the recycle program for material recovery. Under the recycle program, a vendor would recover metal from the filter frames and then discard the filter media.

Radionuclides from natural occurring radioactive material (NORM) trapped in the HEPA filters are not categorized as DOE-added radioactive material. However, uranium and thorium are present in the soils and rock formations of the geological region surrounding ORNL. Radon (Rn) gas, a naturally occurring radioactive decay daughter of both uranium and thorium, percolates into the atmosphere from the deposits in the region. The intake HEPA filters capture the naturally occurring radioactive decay daughters from the radon gas. The isotopes of Rn-222, a decay daughter in the uranium series, and Rn-220, a decay daughter in the thorium series, exist in the atmosphere as gases. In contrast, their respective radioactive decay daughters are not gaseous. As the Rn-222 (radioactive half-life 3.8 days) and Rn-220 (radioactive half-life 56 seconds) isotopes undergo radioactive decay, the decay daughters that are also radioactive are trapped in the media intake HEPA filters. Once the HEPA filters are removed from service, they are stored for sixty days to allow the natural radioactivity to decay before recycle or disposal.

A series of intake HEPA filters from non-radiological areas across the laboratory were collected and staged for radon decay in two open top dump pans. Each pan had a volume of 40 cubic yards. To maximize the loading of the pans, the filters were pressed or compacted into the pan using heavy equipment. After being staged sixty days, the outside of each pan was surveyed before being transferred to the offsite recycling vendor. The standard practice by the vendor was to do radiological surveys before the final acceptance of the filters. Several of the compacted HEPA filters were found to have detectable levels of radioactivity at the vendor's site. All filters were removed from the recycle program and returned to ORNL. After further investigations, a beryllium (Be) isotope, Be-7, was identified as being the activity present on the filters. The Be-7 was imbedded deep inside the filter media, and had been undetected until the filters were compacted. Once the compaction took place, the Be-7 was moved closer to the outer surface where it was detected using standard radiological field instrumentation. The radioactive half-life for Be-7 is fifty-three days. Therefore, only one half-life cycle of the Be-7 deposited in the filter had occurred during the sixty-day staging period of the filters. The origin of the Be-7 is suspected to be from cosmic radiation interacting with gas molecules in the atmosphere. Typically, radioactive material is undetectable after 10 half-life decay cycles. As with the Rn-222, the nuclide would have been through 10 half-life decay cycles after approximately 38 days, and would not be detectable. However, the Be-7 isotope would require staging for 533 days before it would have completed the 10 half-life decay cycles. These intake HEPA filters are being re-evaluated and considered for disposal in the Sanitary/Industrial Landfill or as solid low-level waste (SLLW).

RADIOLOGICAL HEPA WASTE

Radiological research and development activities at ORNL include basic elemental research, process development, proof-of-process before deployment, and support for environmental remediation activities for other Department of Energy (DOE) and Department of Defense (DOD) facilities. Concentrations of radioactive constituents or activity range from trace quantities in environmental studies to several hundred tera Becquerel (TBq) (i.e., thousands of curies (Ci)) inside heavily shielded hot cells. The specific applications could occur for a single project or take place over several years of operation. The types of radiation emitted by the nuclides include alpha particles, spontaneous fission neutrons, beta particles, and gamma rays in single decay modes or combinations. The nuclide may be a single radiological constituent in a waste stream or one of thirty nuclides present in a single waste stream. The spent HEPA filters are included in the solid low-level waste (SLLW) and transuranic (TRU) waste streams depending on the nuclides present and their respective concentrations in that waste stream. The nuclide ratios or isotopic distribution from each research area or process is determined by process knowledge, sampling, or a combination of both. The radiological characterization of the spent HEPA filters is tied to the facility where the filters are in use.

The intake and exhaust HEPA filters may be located on the inside or outside the facilities. The intake filters from the radiological areas are included in the radioactive waste generated from the facility, because some surfaces in the filter media are inaccessible to the Radiological Control Technician (RCT). Both the intake and exhaust filters are characterized using the same approach.

The HEPA filters are first placed inside poly bags or wrapped in plastic sheeting to maintain containment of the radioactive material when transferred to the disposal container. The ORNL Waste Characterization Plan (3) provides guidance for several techniques to calculate the nuclide concentrations in or on radioactive waste, once the isotopic distribution or the mode of radioactive decay is determined (see Table I). If gamma-emitting nuclides are on the spent HEPA filter, Method # 4 provides a stepwise approach for calculating the quantity of the gamma-emitting nuclide(s) on the filter. The gamma emitters are then used to calculate the non-gamma emitters present in the filter. The spent HEPA filter would be characterized as a single item, placed in the poly bag, and transferred to the disposal container. Once the container is filled with radioactive waste, the nuclide quantities from the individual items inside the container are combined to determine the total nuclide quantities loaded inside that container.

Method # 4 of the ORNL Waste Characterization Plan is based on a MicroShield®, version 5.01 model constructed assuming the radionuclides are uniformly distributed throughout the matrix. A scaled-up MicroShield® model is constructed for the radiological characterization of larger items or containers, such as a 208-liter (55-gallon) drum or 2.7 cubic meter (96 cubic feet) disposal box loaded with radioactive waste. The fraction of the gamma emitting nuclides presented in the isotopic distribution is applied to the total source strength of 37 GBq (1Ci). The MicroShield® model calculates the total gamma dose rate emitted from the container based on 37 GBq (1Ci) of total gamma activity inside the container. The total gamma activity from the model is divided by the calculated dose rate to determine the Bq (Ci) to sievert (Sv) per hour (mrem/hr) conversion coefficient to be used to calculate the gamma emitting nuclides present in the loaded container. The non-gamma emitting nuclides are calculated based on the ratios or scaling factors to the gamma emitters present in the total isotopic distribution.

Approximately one hundred and twenty intake HEPA filters and low activity, < 1 micro sievert per hour (Sv/hr) (< 0.1 mrem/hr), exhaust HEPA filters had be staged in Building 4501 for an extended period of time. The dry active waste (DAW) originating from the operations inside Building 4501 has been categorized as SLLW (4). The facility waste stream profile (FWSP) for Building 4501 contains the derived isotopic distribution (see Table II) for the facility. The FWSP was established using a combination of process knowledge and analytical results. Due to the dimensions and the rigid frames (both wood and steel) of the filters, only nine of the spent HEPA filters could be placed in a standard 2.7 cubic meter (96 cubic feet) waste box.

An industrial shredder (Model ST-50, manufactured by Shred-Tech, Limited) was used to volume-reduce the filters. A standard waste box was place directly beneath the unit to receive the debris passing through the shredder. A volume reduction factor of 2.5 was achieved with no compaction capability. A MicroShield® model was constructed using a standard waste box and applied to the shredded HEPA filter debris using the isotopic distribution for the facility. The nuclide quantities inside the containers were calculated using the MicroShield® model. The containers of HEPA filter debris were certified to BJC for disposal under the ORNL WCP.

Spent HEPA filters originating from the Radiochemical Engineering and Development Center (REDC) are included as components of transuranic (TRU) waste. The REDC is the primary generator of TRU waste on the Oak Ridge Reservation. The newly generated (NG) TRU waste from the hot cells and support laboratories fall into one of two subcategories, contact handled (CH) or remote handled (RH) based on the surface dose rate reading of the package. RH TRU waste is greater than 2 mSv/hr (>200 mrem/hr) and CH TRU waste is less than 2 mSv/hr (<200 mrem/hr) at the surface of the container.

The radiological characterization for both the CH TRU and RH TRU waste at REDC was approached in much the same manner as the SLLW. The REDC (5) isotopic distribution for the hot cells and support laboratories was derived from both process knowledge and sample analysis (see Table III). The gamma emitting nuclides, in their respective fractions, were used as the source material for the MicroShield® model. The CH TRU model was constructed using a 208-liter (55-gallon) stainless steel drum as the waste container. RH TRU waste is packaged in a 2.4 meters (8 feet) high cylindrical high-density concrete cask with 0.11 meter (4.5 inch) and 0.3 meter (12 inch) wall thickness. The high-density concrete shields much of the gamma emitters, by design, but has little effect on the spontaneous fission neutrons emitted by Cf-252.

A neutron model was developed to calculate the quantity of Cf-252 present in the RH TRU waste cask based on Monte Carlo Neutron/Photon (MCNP) modeling of a Cf-252 source positioned in several locations inside an empty cask (12). The results generated by the MCNP model were verified by making field measurements using a 102 microgram Cf-252 source. The area with the highest neutron emissions was located on the loaded cask and the neutron dose rate measurement was recorded. A second neutron rate was measured and recorded from the opposite side of the cask. The two neutron dose rates were averaged to move the neutron source to the theoretical center of the RH TRU cask. The 102 microgram Cf-252 source was divided by the average dose rate from the both sides of the RH TRU cask to determine a microgram to dose rate conversion coefficient for the Cf-252. The neutron dose rate from a loaded RH TRU waste cask was multiplied by the conversion coefficient to calculate the Cf-252 content inside the cask. The fraction of Cf-252 to the total activity of the distribution was used to calculate the remaining quantities of the nuclides in the isotopic distribution. The spent HEPA filters in both the CH and RH TRU waste containers were certified to BJC for disposal under the ORNL WCP.

At present, all TRU waste on the ORR requires repackaging and certification before being shipped to the Waste Isolation Pilot Plant (WIPP). A TRU waste processing and repackaging facility is under construction by Foster Wheeler Environmental Corporation (FWEC). The FWEC facility will provide treatment of TRU waste sludge, as well as sorting, volume reduction, and WIPP certification for legacy CH and RH TRU waste in storage.

Table I. Methods for Calculating Activities Present in Solid Low-Level Waste (SLLW)

<table>
<tr><th colspan="5">Contact Contamination</th><th colspan="2">Volume Contamination</th></tr>
<tr><th colspan="3">Gamma Ray Emitters Present</th><th colspan="2">No Gamma Ray Emitters Present</th><th rowspan="2">Gamma Ray Emitters Present</th><th rowspan="2">No Gamma Ray Emitters Present</th></tr>
<tr><th colspan="2">Gamma Rays Not Shielded by Waste Matrix</th><th>Gamma Rays Shielded by Waste Matrix</th><th>Accessible Waste Surfaces</th><th>Non-Accessible Waste Surfaces</th></tr>
<tr><td>Nonstandard Geometry</td><td>Standard Geometry</td><td>Non-accessible Waste Surface</td><td rowspan="2">Use Method 2

Surface radiation measurements</td><td rowspan="2">Use Method 5

Scrapings, smears, or leaching</td><td rowspan="2">Use Method 6

Correlate gamma measurements with limited laboratory analyses</td><td rowspan="2">Use Method 7

Laboratory analysis of representative samples</td></tr>
<tr><td>Use Method 1

Nonstandard geometry with gamma measurements and surface radiation measurements as required</td><td>Use Method 4

Standard geometry with gamma measurements</td><td>Use Method 3

Nonstandard geometry with gamma measurements and scrapings, smears, or leaching as required</td></tr>
</table>

Table II. Solid Low-Level Waste (SLLW) Isotopic Distribution for the Building 4501 Facility Waste Stream Profile

Isotope	Activity (Bq/g)	Activity (Ci/g)	Total Act. (%)	Gamma Act. (%)
Ni-59	3.51E+03	9.49E-08	0.00028%	
Ni-63	4.58E+05	1.24E-05	0.03605%	
Co-60[a]	6.37E+06	1.72E-04	0.50199%	3.63248%
Sr-85[a]	1.10E+06	2.98E-05	0.08687%	0.62862%
Sr-90	1.05E+09	2.83E-02	82.35850%	
Tc-99	7.98E+04	2.16E-06	0.00629%	
I-129	7.44E+01	2.01E-09	0.00001%	
Cs-134[a]	4.89E+05	1.32E-05	0.03852%	0.27874%
Cs-137[a]	1.40E+08	3.77E-03	11.00414%	79.62693%
Eu-152[a]	1.59E+07	4.31E-04	1.25657%	9.09267%
Eu-154[a]	7.60E+06	2.05E-04	0.59890%	4.33367%
Eu-155[a]	2.25E+06	6.09E-05	0.17757%	1.28492%
Ac-227	7.45E+05	2.01E-05	0.05868%	
Th-232	2.23E+04	6.03E-07	0.00176%	
U-232	4.98E+03	1.35E-07	0.00039%	
U-233	1.31E+06	3.55E-05	0.10346%	
U-234	1.68E+04	4.54E-07	0.00132%	
U-236	4.98E+03	1.35E-07	0.00039%	
U-238	1.33E+05	3.60E-06	0.01051%	
Np-237[b]	4.26E+02	1.15E-08	0.00003%	
Pu-238[b]	3.26E+06	8.82E-05	0.25725%	
Pu-239[b]	1.36E+06	3.68E-05	0.10742%	
Pu-240[b]	1.63E+05	4.40E-06	0.01283%	
Pu-241	8.51E+06	2.30E-04	0.67068%	
Am-241[a,b]	1.97E+06	5.32E-05	0.15505%	1.12193%
Am-243[a, b]	7.16E+01	1.94E-09	0.00001%	0.00004%
Cm-244	3.24E+07	8.76E-04	2.55367%	
Cf-250	5.32E+03	1.44E-07	0.00042%	
Cf-252	5.64E+03	1.53E-07	0.00044%	
Total Act.	1.27E+09	3.43E-02	100.00000%	
Gamma Act.	1.75E+08	4.74E-03		100.00000%

[a] Gamma Emitting Nuclides

[b] Transuranic (TRU) Nuclides

Table III. Isotopic Distribution of Newly Generated (NG) TRU Waste Generated from the Hot Cell and Support Laboratories at REDC

Nuclide	Ave. Act. (Bq/total)	Ave. Act. (Ci/total)	Total Act. (%)	Gamma Act. (%)
Co-60[a]	2.01E+03	5.43E-08	0.0170%	0.31%
Sr-90	1.87E+06	5.05E-05	15.4930%	
Zr-95	2.72E+04	7.35E-07	0.2250%	
Ru-103	5.03E+04	1.36E-06	0.4170%	
Ru-106[a]	2.27E+05	6.15E-06	1.8840%	34.56%
Ag-110m	3.79E+03	1.02E-07	0.0310%	
Sb-125[a]	1.33E+04	3.60E-07	0.1100%	2.02%
Cs-134[a]	1.93E+04	5.22E-07	0.1600%	2.94%
Cs-137[a]	2.53E+05	6.83E-06	2.0950%	38.43%
Ce-141	1.07E+05	2.89E-06	0.8860%	
Ce-144	3.45E+04	9.32E-07	0.2860%	
Eu-152[a]	7.39E+03	2.00E-07	0.0610%	1.12%
Eu-154[a]	3.65E+04	9.87E-07	0.3020%	5.55%
Eu-155[a]	2.64E+04	7.13E-07	0.2190%	4.01%
Np-239	9.66E+03	2.61E-07	0.0800%	
Pu-238[b]	5.10E+04	1.38E-06	0.4230%	
Pu-239[b]	2.49E+04	6.74E-07	0.2070%	
Pu-240[a]	4.39E+04	1.19E-06	0.3640%	
Pu-241	6.09E+05	1.65E-05	5.0490%	
Pu-242[b]	6.36E+02	1.72E-08	0.0050%	
Am-241[a, b]	6.79E+04	1.84E-06	0.5630%	10.32%
Am-243[a, b]	4.85E+03	1.31E-07	0.0400%	0.74%
Cm-242	3.72E+04	1.01E-06	0.3090%	
Cm-244	8.36E+06	2.26E-04	69.2450%	
Cm-246[b]	5.83E+04	1.58E-06	0.4830%	
Cm-248[b]	1.56E+02	4.22E-09	0.0010%	
Cf-249[b]	7.47E+01	2.02E-09	0.0010%	
Cf-250	3.17E+03	8.56E-08	0.0260%	
Cf-251[b]	1.38E+01	3.74E-10	0.0001%	
Cf-252	1.23E+05	3.32E-06	1.0180%	
Total Act.	1.21E+07	3.26E-04	100.00%	
Gamma Act.	6.58E+05	1.78E-05		100.00%

[a] Gamma Emitting Nuclides

[b] Transuranic (TRU) Nuclides

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