Department of Energy
Washington, DC 20585

April 4, 2022

Mr. Syed Quadri, PMP, Remedial Project Manager
Remedial Response Section # 7
U.S. Environmental Protection Agency
77 West Jackson Blvd
Mail Code SR-6J
Chicago, IL 60604-3507

Mr. Scott Glum, Site Coordinator
Southwest District Office
Division of Environmental Response and Revitalization
Ohio Environmental Protection Agency
401 East Fifth Street
Dayton, OH 45402-2911

Subject: Summary of the 1,4-Dioxane and Perchlorate Records Search for Indications of Use at the Mound, Ohio, Site, and the Addendum to a Summary of Per- or Polyfluorinated Alkyl Substances Records Search for Indications of Use at the Mound, Ohio, Site.

Dear Mr. Quadri and Mr. Glum:

Enclosed are the Summary of the 1,4-Dioxane and Perchlorate Records Search for Indications of Use at the Mound, Ohio, Site, and the Addendum to a Summary of Per- or Polyfluorinated Alkyl Substances (PFAS) Records Search for Indications of Use at the Mound site.

The summary report and the addendum document the results of research on historical Mound Site records pertaining to use of 1,4-dioxane, perchlorate, and PFAS at the site. Both investigations used the same three step procedure:

1. Identifying the processes and activities that took place in a building or area of the site.
2. Comparing the processes and activities for each building with those that typically involved the emerging contaminant.
3. For buildings identified in step 2, reviewing the chemical inventory for the emerging contaminant.

The summary written report determined that both 1,4-dixoane and perchlorate were purchased and used in a variety of processes housed in various buildings at the site. The Addendum to the previous PFAS report identified that a 3-gallon container of a certain type of PFAS was purchased and used as a lubricant in one building. PFAS was not identified in use in association with any other metals plating or plastics production at the Mound site. Products that may have contained 1,4-dioxane, perchlorate or PFAS were used or purchased for use in many of the buildings identified in this review, but these chemicals may not have been listed on product labels or Material Data Sheets.

This letter satisfies documentation of two of the Issues and Recommendations identified as a result of the Fifth Five-Year Review Report for the Mound site, dated September 2021. The information provided in this report can be discussed further at the next Core Team Meeting.

Please contact me at (636) 485-0036 or Tiffany.Drake@lm.doe.gov if you have any questions. Please send any correspondence to:

U.S. Department of Energy
Office of Legacy Management
7295 Highway 94 South
St. Charles, MO 63304

Sincerely,

Tiffany L. Drake

Digitally signed by Tiffany L. Drake
Date: 2022.04.04 08:39:31 -05'00'

Tiffany Drake, P.E.
Mound Site Manager

Enclosures

cc w/enclosures via email:
Cliff Carpenter, DOE-LM
Greg Lupton, RSI
Becky Cato, RSI
DOE Read File
File: E/19/584 F/20/205

LMS/MND/S38331

Summary of the 1,4-Dioxane and Perchlorate Records Search for Indications of Use at the Mound, Ohio, Site

March 2022

U.S. DEPARTMENT OF ENERGY | Legacy Management

This document has been designed for online viewing.

Contents

Figure

Appendixes

Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
Ohio EPA	Ohio Environmental Protection Agency
OU-1	Operable Unit 1

1.0 Introduction

As part of the *Fifth Five-Year Review for the Mound, Ohio, Site, Miamisburg, Ohio* (DOE 2021), emerging contaminants were evaluated as part of the remedy protectiveness review process. U.S. Environmental Protection Agency (EPA) maintains a list of emerging contaminants that should be evaluated at cleanups performed at federal facilities (https://www.epa.gov/fedfac/emerging-contaminants-and-federal-facility-contaminants-concern). EPA considers that the listed contaminants present unique issues and challenges to the environmental community and EPA at contaminated federal facility sites. The list includes 1,4-dioxane and perchlorate as emerging contaminants.

1.1 Purpose

This report documents the results of a historical records search that was performed to determine whether 1,4-dioxane and perchlorate were purchased and used at the Mound, Ohio, Site, and if so, to identify in which processes and buildings these chemicals, or products that may contain these chemicals, were used. The evaluation methodology and conclusions regarding the records search are outlined in this report.

1.2 Objective

The objective of this evaluation is to determine through a records search whether 1,4-dioxane and perchlorate were purchased and used at the Mound site. Information from this review will be used by the Mound Core Team (U.S. Department of Energy [DOE], EPA, and Ohio EPA) for a determination regarding the protectiveness of the site conditions with respect to these emerging contaminants.

1.3 Background

The Mound site was established in 1948 by the U.S. Atomic Energy Commission, a predecessor to DOE, to support the early atomic weapons programs. It later grew into an integrated research, development, and production facility performing work in support of DOE weapons and energy programs, with emphasis on explosives and nuclear technology. Materials and components were not manufactured on a large scale but rather were produced in small batches and assembled by hand. Small quantities of materials were purchased at any time and used for specific phases of production at the site.

2.0 Evaluation Methodology

This evaluation used information presented in the EPA emerging contaminant fact sheets (Appendix A) for 1,4-dioxane and perchlorate. Review of processes and activities performed in each building was done to identify if there was the potential for use of either chemical. After identifying the processes and activities performed in the buildings and areas, determination was made if 1,4-dioxane or perchlorate were purchase and used.

The evaluation of the use of 1,4-dioxane and perchlorate consisted of three tasks:

- **Task A**: *Building and area use review*—identify the processes and activities that took place in the buildings or areas at the Mound site
- **Task B**: *Process or activity review*—compare the processes and activities identified for each building to those outlined as typically involving the use of 1,4-dioxane and perchlorate
- **Task C**: *Chemical inventory review*—for those buildings retained from Task B, review the chemical inventory for 1,4-dioxane and perchlorate.

Information from the EPA emerging contaminant fact sheets was reviewed and used to determine typical industries and processes where these two chemicals, or products containing these chemicals, may have been used. Many site references and databases were reviewed focusing on 1,4-dioxane and perchlorate. This section describes the results of the evaluation. The references used for this evaluation are presented in Appendix B.

2.1 Building and Area Use Review

An extensive review of was performed to detail the processes and other activities that were performed in each building. A total of 127 buildings (listed in Appendix C, Table C-1) were thoroughly reviewed to identify building-specific processes and activities performed to support work at the Mound site.

The Operable Unit 1 (OU-1) landfill area covers 4 acres on the Mound site. It includes the former landfill site that comprises the initial landfill that received plant waste materials (general trash and liquid waste) from 1948 to 1974 and the former sanitary landfill where much of the waste from the initial landfill was later moved and encapsulated in 1977. There were known releases of volatile organic compounds from the former landfill into the underlying groundwater.

2.2 Process or Activity Review

A review of the lists in the EPA emerging contaminant fact sheets and other resources identified several uses or processes that occurred at the Mound site that may have included the use of 1,4-dioxane, perchlorate, or products that may have included these chemicals (Table 1).

Table 1. Processes or Products with Potential Emerging Contaminants

1,4 Dioxane	Perchlorate
• Industrial solvent and solvent stabilizer, primarily for 1,1,1-trichloroethane • Additive in products such as paint and varnish, paint and varnish strippers, dyes, greases, automotive fluids, loosening fluids, rust removers, plastics, and adhesives • Laboratory reagent and liquid scintillation medium • Plastics and polymer production—rubber and plastics industries	• Perchlorate-based chemicals used as an oxidizing agent in production of munitions, explosives, pyrotechnics, matches, and flares • Electroplating

A full list of the processes and activities performed in each building is summarized in Appendix C, Table C-1. A comparison of the processes and uses identified for each building with those in Table 1 identified 22 buildings that may have potentially used 1,4-dioxane or 1,4dioxane-containing products and 16 buildings that may have potentially used perchlorate or perchlorate-containing products as part of research, development, or production at the Mound site. A summary of these buildings is provided in Table 2 and the locations of these buildings are depicted in Figure 1. All the buildings listed in Table 2, except for T Building and Building 105, were demolished according to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements.

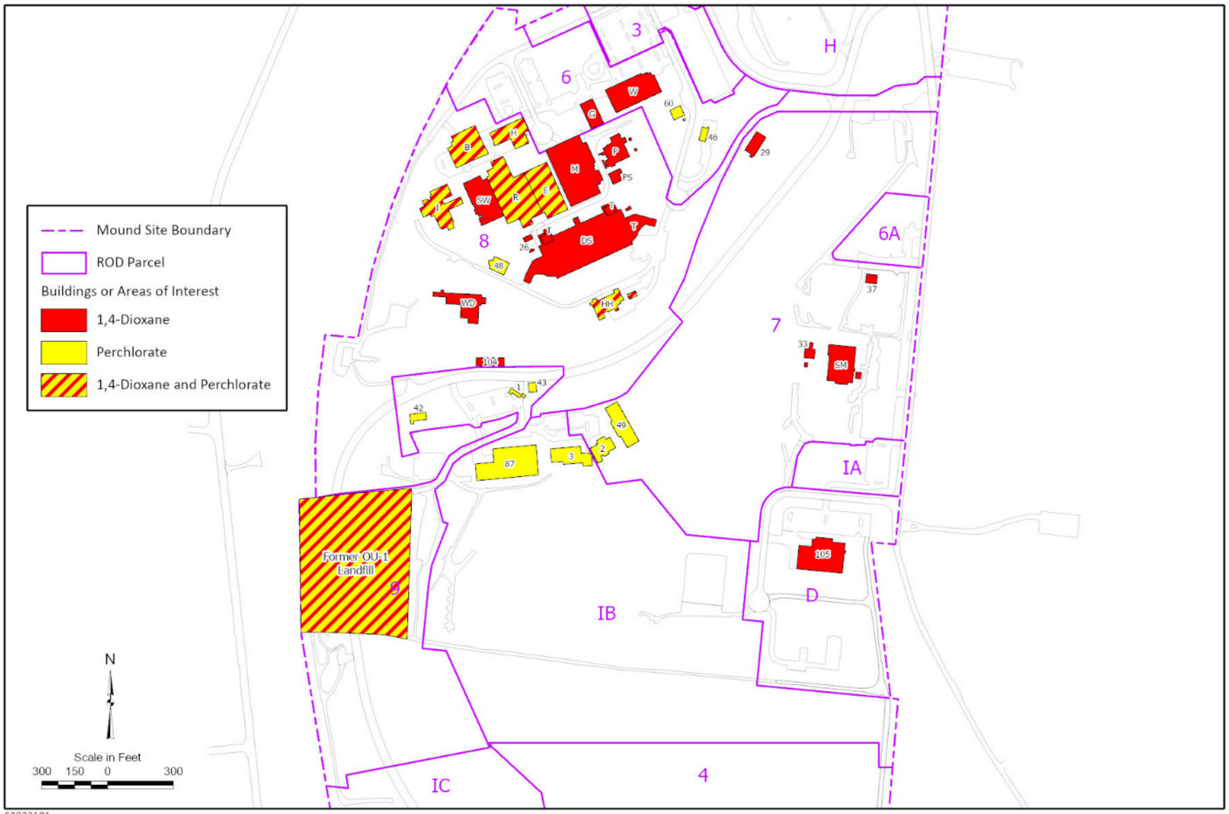
Table 2. Building Summary

DOE Building ID			
1,4-Dioxane		**Perchlorate**	
B	SM	B	3
DS	SW	DS	42
E and E Annex	T	E and E Annex	43
G	W	H	46
H	WD	HH	48
HH	26	I	49
I	29	R	60
M	33	1	87
P	37	2	
PS	104		
R	105		

General trash and some liquid wastes generated from the plant operations were disposed of in the former OU-1 landfill. It is likely that empty containers from products containing these chemical or materials, such as rags, personal protective equipment, and secondary containers, that came in contact with these products were disposed of in the former landfill. As part of the CERCLA cleanup, most of the radiological source material was removed from the former landfill area in 2005. The OU-1 landfill was later excavated in two phases from 2007 through 2010 as part of non-CERCLA work to support future redevelopment of the property by the Mound Development Corporation. It was verified that the excavation remediated the former landfill to EPA's risk-based standards for industrial or commercial use.

2.3 Chemical Inventory and Other Record Review

Chemical inventories and other records were reviewed for each building listed in Table 2 to determine whether 1,4-dioxane or perchlorate were used. The chemical inventories for Buildings DS, E, H, and HH listed both perchlorate and *p*-dioxane (another name for 1,4-dioxane). The list of products that could have 1,4-dioxane or perchlorate used as an additive is extensive, and the review of the chemical inventories for the buildings listed in Table 2 indicated that products that typically contain low-level amounts of 1,4-dioxane were used at the Mound site. Records indicated an incident in the R Building that resulted from the use of perchloric acid. As part of a laboratory research project, perchloric acid was used for complete oxidation of materials. During this step, the reaction got out of control and a small explosion occurred. No environmental releases were documented from this incident. The list of solvents or acids that may have contained perchlorate is extensive and these types of materials may have been used in the buildings listed in Table 2 as part of the research, development, and production at the Mound site.



S3833101

Abbreviations: PFAS = per- and polyfluorinated alkyl substances; ROD = Record of Decision

Figure 1. Locations of Buildings Where 1,4-Dioxane or Perchlorate May Have Been Used

3.0 Conclusions

After review of research, development, and production activities; powerhouse and waste treatment operations; chemical inventories; and general plant operations and maintenance records the following can be concluded:

- Chemicals or products that potentially contained 1,4-dioxane were purchased and used as part of the research, development, and production of materials and equipment at the Mound site.
- 1,4-Dioxane was used as a reagent and liquid scintillation medium in laboratory analyses.
- Chemicals or products that used perchlorate were purchased and used as part of the research, development, and production of explosive materials and devices at the Mound site.
- Purchase and use of *p*-dioxane and perchlorate were confirmed from the review of chemical inventories for Buildings DS, E, H, and HH.
- The buildings identified in Section 2.2 should be considered as potential areas where perchlorate, perchlorate-containing products, 1,4-dioxane, and 1,4-dioxane containing products could have been used. It has been noted from review of the chemical inventories

and process documents that chemicals were purchased and used in limited amounts and access was allowed only for approved uses or processes. Products that may have contained these chemicals were used or purchased for use in many of the buildings identified in this review because these chemicals may not have been listed on the product labels or Safety Data Sheets.

- Materials that may have been used with or contaminated by chemicals or products that potentially contained 1,4-dioxane or perchlorate were likely disposed of in the former OU-1 landfill. It has been noted from review of the chemical inventories and process documents that these chemicals were purchased and used in limited amounts and consumed upon use. The potential presence of 1,4-dioxane or perchlorate would likely be the result of residual amounts on materials within the former landfill.

4.0 Reference

DOE (U.S. Department of Energy), 2021. *Fifth Five-Year Review for the Mound, Ohio, Site, Miamisburg, Ohio*, LMS/MND/S31971, Office of Legacy Management, September.

Appendix A

EPA Emerging Contaminant Fact Sheets for 1,4-Dioxane and Perchlorate

United States Environmental Protection Agency

Technical Fact Sheet – 1,4-Dioxane

November 2017

TECHNICAL FACT SHEET – 1,4-DIOXANE

At a Glance

- Flammable liquid and a fire hazard. Potentially explosive if exposed to light or air.
- Found at many federal facilities because of its widespread use as a stabilizer in certain chlorinated solvents, paint strippers, greases and waxes.
- Short-lived in the atmosphere, may leach readily from soil to groundwater, migrates rapidly in groundwater and is relatively resistant to biodegradation in the subsurface.
- Classified by EPA as "likely to be carcinogenic to humans" by all routes of exposure.
- Short-term exposure may cause eye, nose and throat irritation; long-term exposure may cause kidney and liver damage.
- Federal screening levels, state health-based drinking water guidance values and federal occupational exposure limits have been established.
- Modifications to existing sample preparation procedures may be required to achieve the increased sensitivity needed for detection of 1,4-dioxane.
- Common treatment technologies include advanced oxidation processes and bioremediation.
- No federal maximum contaminant level (MCL) has been established for 1,4-dioxane in drinking water.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the emerging contaminant 1,4-dioxane, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet is intended for use by site managers who may address 1,4-dioxane at cleanup sites or in drinking water supplies and for those in a position to consider whether 1,4-dioxane should be added to the analytical suite for site investigations.

1,4-Dioxane is a likely human carcinogen and has been found in groundwater at sites throughout the United States. The physical and chemical properties and behavior of 1,4-dioxane create challenges for its characterization and treatment. It is highly mobile and does not readily biodegrade in the environment.

What is 1,4-dioxane?

- 1,4-Dioxane is a synthetic industrial chemical that is completely miscible in water (EPA 2006; ATSDR 2012).
- Synonyms include dioxane, dioxan, p-dioxane, diethylene dioxide, diethylene oxide, diethylene ether and glycol ethylene ether (EPA 2006; ATSDR 2012; Mohr 2001).
- 1,4-Dioxane is unstable at elevated temperatures and pressures and may form explosive mixtures with prolonged exposure to light or air (EPA 2006; HSDB 2011).
- 1,4-Dioxane is a likely contaminant at many sites contaminated with certain chlorinated solvents (particularly 1,1,1-trichloroethane [TCA]) because of its widespread use as a stabilizer for chlorinated solvents (EPA 2013a; Mohr 2001). Historically, the main use (90 percent) of 1,4-dioxane was as a stabilizer of chlorinated solvents such as TCA (ATSDR 2012). Use of TCA was phased out under the 1995 Montreal Protocol and the use of 1,4-dioxane as a solvent stabilizer was terminated (ECJRC 2002; NTP 2016). Lack of recent reports for other previously reported uses suggest that many other industrial, commercial and consumer uses were also stopped.

United States Environmental Protection Agency | Office of Land and Emergency Management (5106P) | EPA 505-F-17-011 November 2017

- It is a by-product present in many goods, including paint strippers, dyes, greases, antifreeze and aircraft deicing fluids, and in some consumer products (deodorants, shampoos and cosmetics) (ATSDR 2012; Mohr 2001).
- 1,4-Dioxane is used as a purifying agent in the manufacture of pharmaceuticals and is a by-product in the manufacture of polyethylene terephthalate (PET) plastic (Mohr 2001).
- Traces of 1,4-dioxane may be present in some food supplements, food containing residues from packaging adhesives or on food crops treated with pesticides that contain 1,4-dioxane (ATSDR 2012; DHHS 2011).

Exhibit 1: Physical and Chemical Properties of 1,4-Dioxane (ATSDR 2012)

Property	1,4-Dioxane
Chemical Abstracts Service (CAS) number	123-91-1
Physical description (physical state at room temperature)	Clear, flammable liquid with a faint, pleasant odor
Molecular weight (g/mol)	88.11
Water solubility	Miscible
Melting point (^{o}C)	11.8
Boiling point (^{o}C) at 760 mm Hg	101.1
Vapor pressure at 25^{o}C (mm Hg)	38.1
Specific gravity	1.033
Octanol-water partition coefficient (log K_{ow})	-0.27
Organic carbon partition coefficient (log K_{oc})	1.23
Henry's law constant at 25 ^{o}C (atm-m^3/mol)	4.80 X 10^{-6}

Abbreviations: g/mol – grams per mole; ^{o}C – degrees Celsius; mm Hg – millimeters of mercury; atm-m^3/mol – atmosphere-cubic meters per mole

Existence of 1,4-dioxane in the environment

- 1,4-Dioxane is typically found at some solvent release sites and PET manufacturing facilities (ATSDR 2012; Mohr 2001).
- It is short-lived in the atmosphere, with an estimated 1- to 3-day half-life due to photooxidation (ATSDR 2012; DHHS 2011).
- Migration to groundwater is weakly retarded by sorption of 1,4-dioxane to soil particles; it is expected to move rapidly from soil to groundwater (EPA 2006; ATSDR 2012).
- It is relatively resistant to biodegradation in water and soil, although recent studies have identified degrading bacteria (Inoue 2016; Pugazhendi 2015; Sales 2013).
- It does not bioaccumulate, biomagnify, or bioconcentrate in the food chain (ATSDR 2012; Mohr 2001).
- 1,4-Dioxane is frequently present at sites with TCA contamination (Mohr 2001; Adamson 2014).
- It may migrate rapidly in groundwater, ahead of other contaminants (DHHS 2011; EPA 2006).
- Where delineated, 1,4-dioxane is frequently found within previously delineated chlorinated solvent plumes and existing monitoring networks (Adamson 2014).
- As of 2016, 1,4-dioxane had been identified at more than 34 sites on the EPA National Priorities List (NPL); it may be present (but samples were not analyzed for it) at many other sites (EPA 2016b).

What are the routes of exposure and the potential health effects of 1,4-dioxane?

- Exposure may occur through ingestion of contaminated food and water, or dermal contact. Worker exposures may include inhalation of vapors (ATSDR 2012; DHHS 2011; EU 2002).
- Potential exposure could occur during production and use of 1,4-dioxane as a stabilizer or solvent (DHHS 2011; EU 2002).
- Short-term exposure to high levels of 1,4-dioxane may result in nausea, drowsiness, headache, and irritation of the eyes, nose and throat (ATSDR 2012; EPA 2013b; NIOSH 2010; EU 2002). 1,4-Dioxane is readily absorbed through the lungs and gastrointestinal tract. Some 1,4-dioxane may also pass through the skin, but studies indicate that much of it will evaporate before it is absorbed. Distribution is rapid and uniform in the lung, liver, kidney, spleen, colon and skeletal muscle tissue (ATSDR 2012).
- 1,4-Dioxane is weakly genotoxic and reproductive effects in humans are unknown; however, a developmental study on rats indicated that 1,4-dioxane may be slightly toxic to the developing fetus (ATSDR 2012; Giavini and others 1985).
- Animal studies showed increased incidences of nasal cavity, liver and gall bladder tumors after exposure to 1,4-dioxane (ATSDR 2012; DHHS 2011; EPA IRIS 2013).
- EPA has classified 1,4-dioxane as "likely to be carcinogenic to humans" by all routes of exposure (EPA IRIS 2013).
- The U.S. Department of Health and Human Services states that "1,4-dioxane is reasonably anticipated to be a human carcinogen based on sufficient evidence of carcinogenicity from studies in experimental animals" (DHHS 2011).
- The National Institute for Occupational Safety and Health (NIOSH) considers 1,4-dioxane a potential occupational carcinogen (NIOSH 2010).
- The European Union has classified 1,4-dioxane as having limited evidence of carcinogenic effect (EU 2002).

Are there any federal and state guidelines and health standards for 1,4-dioxane?

- EPA's Integrated Risk Information System (IRIS) database includes a chronic oral reference dose (RfD) of 0.03 milligrams per kilogram per day (mg/kg/day) based on liver and kidney toxicity in animals and a chronic inhalation reference concentration (RfC) of 0.03 milligrams per cubic meter (mg/m^3) based on atrophy and respiratory metaplasia inside the nasal cavity of animals (EPA IRIS 2013).
- The cancer risk assessment for 1,4-dioxane is based on an oral slope factor of 0.1 mg/kg/day and the drinking water unit risk is 2.9×10^{-6} micrograms per liter (µg/L) (EPA IRIS 2013).
- EPA risk assessments indicate that the drinking water concentration representing a 1×10^{-6} cancer risk level for 1,4-dioxane is 0.35 µg/L (EPA IRIS 2013).
- No federal maximum contaminant level (MCL) for drinking water has been established (EPA 2012).
- 1,4-Dioxane is included on the fourth drinking water contaminant candidate list and is included in the Third Unregulated Contaminant Monitoring Rule (EPA 2009; EPA 2016a).
- EPA's drinking water equivalent level is 1 mg/L (EPA 2012). EPA has calculated a screening level of 0.46 µg/L for tap water, based on a 1 in 10^{-6} lifetime excess cancer risk (EPA 2017b).
- EPA established a 1-day health advisory of 4.0 milligrams per liter (mg/L) and a 10-day health advisory of 0.4 mg/L in drinking water for a 10-kilogram child and a lifetime health advisory of 0.2 mg/L in drinking water (EPA 2012).
- EPA has calculated a residential soil screening level (SSL) of 5.3 milligrams per kilogram (mg/kg) and an industrial SSL of 24 mg/kg. The soil-to-groundwater risk-based SSL is 9.4×10^{-5} mg/kg (EPA 2017b).
- EPA has calculated a residential air screening level of 0.56 micrograms per cubic meter ($\mu g/m^3$) and an industrial air screening level of 2.5 $\mu g/m^3$ (EPA 2017b).
- A reportable quantity of 100 pounds has been established under the Comprehensive Environmental Response, Compensation, and Liability Act (EPA 2011).
- The Occupational Safety and Health Administration (OSHA) established a permissible

exposure limit (PEL) for 1,4-dioxane of 100 parts per million (ppm) or 360 mg/m^3 as an 8-hour time weighted average (TWA). While OSHA has established a PEL for 1,4-dioxane, OSHA has recognized that many of its PELs are outdated and inadequate for ensuring the protection of worker health. OSHA recommends that employers follow the California OSHA limit of 0.28 ppm, the NIOSH recommended exposure limit of 1 ppm as a 30-minute ceiling, or the American Conference of Governmental Industrial Hygienists threshold limit value of 20 ppm (OSHA 2017).

- Various states have established drinking water and groundwater guidelines, including the following:

State	Guideline (µg/L)	Source
Alaska	77	AL DEC 2016
California	1.0	Cal/EPA 2011
Colorado	0.35	CDPHE 2017
Connecticut	3.0	CTDPH 2013
Delaware	6.0	DE DNR 1999
Florida	3.2	FDEP 2005
Indiana	7.8	IDEM 2015
Maine	4.0	MEDEP 2016
Massachusetts	0.3	MADEP 2004
Mississippi	6.09	MS DEQ 2002
New Hampshire	0.25	NH DES 2011
New Jersey	0.4	NJDEP 2015
North Carolina	3.0	NCDENR 2015
Pennsylvania	6.4	PADEP 2011
Texas	9.1	TCEQ 2016
Vermont	3.0	VTDEP 2016
Washington	0.438	WA ECY 2015
West Virginia	6.1	WV DEP 2009

What detection and site characterization methods are available for 1,4-dioxane?

- As a result of the limitations in the analytical methods to detect 1,4-dioxane, it has been difficult to identify its occurrence in the environment. The miscibility of 1,4-dioxane in water causes poor purging efficiency and results in high detection limits (ATSDR 2012; EPA 2006; Mohr 2001).
- The Contract Laboratory Program SOW SOM02.3 includes a CRQL of 2.0 µg/L in water, 67 µg/kg in low soil and 2,000 µg/kg in medium soil (EPA 2013c).
- Conventional analytical methods can detect 1,4-dioxane only at concentrations 100 times greater than the concentrations of volatile organic compounds. Modifications of existing analytical methods and their sample preparation procedures may be needed to achieve lower detection limits for 1,4-dioxane (EPA 2006; Mohr 2001).
- High-temperature sample preparation techniques improve the recovery of 1,4-dioxane. These techniques include purging at elevated temperature (EPA SW-846 Method 5030); equilibrium headspace analysis (EPA SW-846 Method 5021); vacuum distillation (EPA SW-846 Method 8261); and azeotropic distillation (EPA SW-846 Method 5031) (EPA 2006).
- NIOSH Method 1602 uses gas chromatography – flame ionization detection (GC-FID) to determine the concentration of 1,4-dioxane in air (ATSDR 2012; NIOSH 2010).
- EPA SW-846 Method 8015D uses gas chromatography (GC) to determine the concentration of 1,4-dioxane in environmental samples. Samples may be introduced into the GC column by a variety of techniques including the injection of the concentrate from azeotropic distillation (EPA SW-846 Method 5031). The lower quantitation limits for 1,4-dioxane in aqueous matrices by azeotropic microdistillation are 12 µg/L (reagent water), 15 µg/L (groundwater) and 16 µg/L (leachate) (EPA 2003).
- EPA SW-846 Method 8260B detects 1,4-dioxane in a variety of solid waste matrices using GC and mass spectrometry (MS). The detection limit

depends on the instrument and choice of sample preparation method (ATSDR 2012).

- ❖ A laboratory study is underway to develop a passive flux meter (PFM) approach to enhance the capture of 1,4-dioxane in the PFM sorbent to improve accuracy. Results to date show that the PFM is capable of quantifying low absorbing compounds such as 1,4-dioxane (DoD SERDP 2013b).
- ❖ EPA Method 1624 uses isotopic dilution gas chromatography – mass spectrometry (GC-MS) to detect 1,4-dioxane in water, soil and municipal discharges. The detection limit for this method is 10 µg/L (ATSDR 2012; EPA 2001b).
- ❖ EPA SW-846 Method 8270 uses liquid-liquid extraction and isotope dilution by capillary column GC-MS. This method is often modified for the detection of low levels of 1,4-dioxane in water (EPA 2007).
- ❖ EPA Method 522 uses solid phase extraction and GC-MS with selected ion monitoring for the detection of 1,4-dioxane in drinking water with detection limits as low as 0.02 µg/L (EPA 2008).
- ❖ GC-MS detection methods using solid phase extraction followed by desorption with an organic solvent have been developed to remove 1,4-dioxane from the aqueous phase. Detection limits as low as 0.03 µg/L have been achieved by passing the aqueous sample through an activated carbon column, following by elution with acetone-dichloromethane (ATSDR 2012; Kadokami and others 1990).
- ❖ Lab studies indicate effective methods for monitoring growth of dioxane-degrading bacteria in culture (Gedalanga 2014).
- ❖ Studies are underway to develop and assess methods for performing compound-specific isotope analysis (CSIA) on low levels of 1,4-dioxane in groundwater (DoD SERDP 2016).

What technologies are being used to treat 1,4-dioxane?

- ❖ Pump-and-treat remediation can treat dissolved 1,4-dioxane in groundwater and control groundwater plume migration, but requires ex-situ treatment tailored for the unique properties of 1,4-dioxane (e.g., its low octanol-water partition coefficient makes 1,4-dioxane hydrophilic) (EPA 2006; Kiker and others 2010).
- ❖ Commercially available advanced oxidation processes using hydrogen peroxide with ultraviolet light or ozone can be used to treat 1,4-dioxane in wastewater (Asano and others 2012; EPA 2006).
- ❖ Peroxone and iron activated persulfate oxidation of 1,4-dioxane might aid in the cleanup of VOC-contaminated sites (Eberle 2015; Zhong 2015; Li 2016; SERDP 2013d).
- ❖ In-situ chemical oxidation can be successfully combined with bioaugmentation for managing dioxane contamination (DoD SERDP 2013d; Adamson 2015).
- ❖ Ex-situ bioremediation using a fixed-film, moving-bed biological treatment system is also used to treat 1,4-dioxane in groundwater (EPA 2006).
- ❖ Electrical resistance heating may be an effective treatment method (Oberle 2015).
- ❖ Phytoremediation is being explored as a means to remove the compound from shallow groundwater. Pilot-scale studies have demonstrated the ability of hybrid poplars to take up and effectively degrade or deactivate 1,4-dioxane (EPA 2001a, 2013a; Ferro and others 2013).
- ❖ Microbial degradation in engineered bioreactors has been documented under enhanced conditions or where selected strains of bacteria capable of degrading 1,4-dioxane are cultured, but the impact of the presence of chlorinated solvent co-contaminants on biodegradation of 1,4-dioxane needs to be further investigated (EPA 2006, 2013a; Mahendra and others 2013).
- ❖ Results from a 2012 laboratory study found 1,4-dioxane-transforming activity to be relatively common among monooxygenase-expressing bacteria; however, both TCA and 1,1-dichloroethene inhibited 1,4-dioxane degradation by bacterial isolates (DoD SERDP 2012).
- ❖ Isobutane-metabolizing bacteria can consistently degrade low (<100 ppb) concentrations of 1,4-dioxane, often to concentrations <1 ppb. These organisms also can degrade many chlorinated co-contaminants such as TCA and 1,1-dichoroethene (1,1-DCE) (DoD SERDP 2013c).
- ❖ Ethane effectively serves as a cometabolite for facilitating the biodegradation of 1,4-dioxane at relevant field concentrations (DoD SERDP 2013f).
- ❖ Biodegradation rates are subject to interactions among transition metals and natural organic ligands in the environment. (Pornwongthong 2014; DoD SERDP 2013e).

- Photocatalysis has been shown to remove 1,4-dioxane in aqueous solutions. Laboratory studies documented that the surface plasmon resonance of gold nanoparticles on titanium dioxide (Au – TiO2) promotes the photocatalytic degradation of 1,4-dioxane (Min and others 2009; Vescovi and others 2010).
- Other in-well combined treatment technologies being assessed include air sparging; soil vapor extraction (SVE); enhanced bioremediation-oxidation; and dynamic subsurface groundwater circulation (Odah and others 2005).
- 1,4-Dioxane was reduced by greater than 90 percent in the treatment zone with no apparent downward migration of 1,4-dioxane using enhanced or extreme SVE, which uses a combination of increased air flow, sweeping with drier air, increased temperature, decreased infiltration and more focused vapor extraction to enhance 1,4-dioxane remediation in soils (DoD SERDP 2013a).

Where can I find more information about 1,4-dioxane?

- Adamson, D. Mahendra S., Walker, K, Rauch, S., Sengupta, S., and C. Newell. 2014. "A Multisite Survey to Identify the Scale of the 1,4-Dioxane Problem at Contaminated Groundwater Sites." Environmental Science and Technology. Volume 1 (5). Pages 254 to 258.
- Adamson, D., Anderson R., Mahendra, S., and C. Newell. 2015. "Evidence of 1,4-Dioxane Attenuation at Groundwater Sites Contaminated with Chlorinated Solvents and 1,4-Dioxane." Environmental Science and Technology. Volume 49 (11). Pages 6510 to 6518.
- Alaska Department of Environmental (AL DEC). 2008. "Groundwater Cleanup Levels." dec.alaska.gov/spar/csp/guidance_forms/docs/Groundwater_Cleanup_Levels.pdf
- Asano, M., Kishimoto, N., Shimada, H., and Y. Ono. 2012. "Degradation of 1,4-Dioxane Using Ozone Oxidation with UV Irradiation (Ozone/UV) Treatment." Journal of Environmental Science and Engineering. Volume A (1). Pages 371 to 379.
- Agency for Toxic Substances and Disease Registry (ATSDR). 2012. "Toxicological Profile for 1,4-Dioxane." www.atsdr.cdc.gov/toxprofiles/TP.asp?id=955&tid=199
- California Department of Public Health (CDPH). 2011. "1,4-Dioxane." Drinking Water Systems. www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/14-Dioxane.shtml
- Colorado Department of Public Health and the Environment (CDPHE). 2017. "The Basic Standards and Methodologies for Surface Water." https://www.colorado.gov/pacific/sites/default/files/31_2017-03.pdf
- Connecticut Department of Public Health (CTDEP). 2013. "Action Level List for Private Wells." www.ct.gov/dph/lib/dph/environmental_health/eoha/groundwater_well_contamination/110916_ct_action_level_list_nov_2016_update.pdf
- Delaware Department of Natural Resources and Environmental Control (DE DNREC). 1999. "Remediation Standards Guidance." www.dnrec.state.de.us/DNREC2000/Divisions/AWM/sirb/DOCS/PDFS/Misc/RemStnd.pdf
- European Chemicals Bureau. 2002. European Union Risk Assessment Report 1,4-Dioxane. echa.europa.eu/documents/10162/a4e83a6a-c421-4243-a8df-3e84893082aa
- Ferro, A.M., Kennedy, J., and J.C. LaRue. 2013. "Phytoremediation of 1,4-Dioxane-Containing Recovered Groundwater." International Journal of Phytoremediation. Volume 15. Pages 911 to 923.
- Gedalanga, P., Pornwongthong, P., Mora, R., Chiang, S., Baldwin, B., Ogles, D., and S. Mahendra. 2014. "Identification of Biomarker Genes to Predict Biodegradation of 1,4-Dioxane." Applied and Environmental Microbiology. Volume 10. Pages 3209 to 3218.
- Giavini, E., Vismara, C., and M.L Broccia. 1985. "Teratogenesis Study of Dioxane in Rats." Toxicology Letters. Volume 26 (1). Pages 85 to 88.
- Hazardous Substances Data Bank (HSDB). 2011. "1,4-Dioxane." toxnet.nlm.nih.gov/
- Indiana Department of Environmental Management (IDEM). 2016. "IDEM Screening and Closure Levels." www.in.gov/idem/landquality/files/risc_screening_table_2016.pdf
- Inoue, D., Tsunoda, T., Sawada, K., Yamamoto, N., Saito, Y., Sei, K., and M. Ike. 2016. "1,4-Dioxane degradation potential of members of the genera *Pseudonocardia* and *Rhodococcus*." Biodegradation. Volume 27. Pages 277 to 286.

Where can I find more information about 1,4-dioxane? (continued)

- Kadokami, K., Koga, M., and A. Otsuki. 1990. “Gas Chromatography/Mass Spectrometric Determination of Traces of Hydrophilic and Volatile Organic Compounds in Water after Preconcentration with Activated Carbon.” Analytical Sciences. Volume 6 (6). Pages 843 to 849.
- Kiker, J.H., Connolly, J.B., Murray, W.A., Pearson, S.C., Reed, S.E., and R.J. Robert. 2010. “Ex-Situ Wellhead Treatment of 1,4-Dioxane Using Fenton's Reagent.” Proceedings of the Annual International Conference on Soils, Sediments, Water and Energy. Volume 15, Article 18.
- Li, B., and J. Zhu. 2016. “Simultaneous Degradation Of 1,1,1-Trichloroethane and Solvent Stabilizer 1,4-Dioxane by a Sono-Activated Persulfate Process.” Chemical Engineering Journal. Volume 284 (15). Pages 750 to 763.
- Mahendra, S., Grostern, A., and L. Alvarez-Cohen. 2013. “The Impact of Chlorinated Solvent Co-Contaminants on the Biodegradation Kinetics of 1,4-Dioxane.” Chemosphere. Volume 91 (1). Pages 88 to 92.
- Maine Department of Environmental Protection (MEDEP). 2016. “Maine Remedial Action Guidelines (RAGs) for Sites Contaminated with Hazardous Substances.” www.maine.gov/dep/spills/publications/guidance/rags/ME-RAGS-Revised-Final_020516.pdf
- Massachusetts Department of Environmental Protection (Mass DEP). 2012. “Standards and Guidelines or Contaminants in Massachusetts Drinking Waters.” www.mass.gov/eea/agencies/massdep/water/drinking/standards/standards-and-guidelines-for-drinking-water-contaminants.html
- Min, B.K., Heo, J.E., Youn, N.K., Joo, O.S., Lee, H., Kim, J.H., and H.S. Kim. 2009. “Tuning of the Photocatalytic 1,4-Dioxane Degradation with Surface Plasmon Resonance of Gold Nanoparticles on Titania.” Catalysis Communications. Volume 10 (5). Pages 712 to 715.
- Mississippi Department of Environmental Quality (MS DEQ). 2002. “Risk Evaluation Procedures for Voluntary Cleanup and Redevelopment of Brownfield Sites.” www.deq.state.ms.us/MDEQ.nsf/pdf/GARD_brownfieldrisk/$File/Proced.pdf
- Mohr, T.K.G. 2001. “1,4-Dioxane and Other Solvent Stabilizers White Paper.” Santa Clara Valley Water District of California. San Jose, California.
- National Institute for Occupational Safety and Health (NIOSH). 2010. “Dioxane.” NIOSH Pocket Guide to Chemical Hazards. www.cdc.gov/niosh/npg/npgd0237.html
- New Hampshire Department of Environmental Services (NH DES). 2011. “Change in Reporting Limit for 1,4-Dioxane.” www.des.nh.gov/organization/divisions/waste/hwrb/sss/hwrp/documents/report-limits14dioxane.pdf
- New Jersey Department of Environmental Protection (NJDEP). 2015. “Interim Ground Water Quality Standards.” www.nj.gov/dep/wms/bears/gwqs_interim_criteria_table.htm
- North Carolina Department of Environmental Quality (NCDEQ). 2013. “Groundwater Classification and Standards.” https://deq.nc.gov/about/divisions/water-resources/water-resources-rules/nc-administrative-code-statutes
- Oberle, D. Crownover, E., and M. Kluger. 2015. “In Situ Remediation of 1,4-Dioxane Using Electrical Resistance Heating.” Remediation Journal. Volume 25 (2). Pages 35 to 42.
- Odah, M.M., Powell, R., and D.J. Riddle. 2005. “ART In-Well Technology Proves Effective in Treating 1,4-Dioxane Contamination.” Remediation Journal. Volume 15 (3). Pages 51 to 64.
- Occupational Safety and Health Administration (OSHA). 2017 Permissible Exposure Limits – Annotated Tables, Table Z-1. www.osha.gov/dsg/annotated-pels/index.html
- Pornwongthong, P., Mulchandani A., Gedalanga, P.B., and S. Mahendra. 2014. “Transition Metals and Organic Ligands Influence Biodegradation of 1,4-Dioxane.” Applied Biochemistry and Biotechnology. Volume 173 (1). Pages 291 to 306.

Where can I find more information about 1,4-dioxane? (continued)

- Pugazhendi, A., Banu, J., Dhavamani, J., and I. Yeom. 2015. "Biodegradation of 1,4-dioxane by *Rhodanobacter* AYS5 and the Role of Additional Substrates." Annals of Microbiology. Volume 645. Pages 2201 to 2208.
- Sales, C., Grostrem, A., Parales, J., Parales, R., and L. Alvarez-Cohen. 2013. "Oxidation of the Cyclic Ethers 1,4-Dioxane and Tetrahydrofuran by a Monooxygenase in Two *Pseudonocardia* species." Applied and Environmental Microbiology. Volume 79. Pages 7702 to 7708.
- Texas Commission on Environmental Quality. 2016. "Texas Risk Reduction Program (TRRP) Protective Concentration Levels (PCLs)." www.tceq.texas.gov/remediation/trrp/trrppcls.html
- U.S. Department of Defense (DoD). Strategic Environmental Research and Development Program (SERDP). 2012. "Oxygenase-Catalyzed Biodegradation of Emerging Water Contaminants: 1,4-Dioxane and N-Nitrosodimethylamine." ER-1417. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-1417
- DoD SERDP. 2013a. "1,4-Dioxane Remediation by Extreme Soil Vapor Extraction (XSVE)." ER-201326. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-201326
- DoD SERDP. 2013b. "Development of a Passive Flux Meter Approach to Quantifying 1,4-Dioxane Mass Flux." ER-2304. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2304
- DoD SERDP. 2013c. "Evaluation of Branched Hydrocarbons as Stimulants for In Situ Cometabolic Biodegradation of 1,4-Dioxane and Its Associated Co-Contaminants." ER-2303. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2303
- DoD SERDP. 2013d. "Facilitated Transport Enabled In Situ Chemical Oxidation of 1,4-Dioxane-Contaminated Groundwater." ER-2302. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2302
- DoD SERDP. 2013e. "In Situ Biodegradation of 1,4-Dioxane: Effects of Metals and Chlorinated Solvent Co-Contaminants." ER-2300. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2300
- DoD SERDP. 2013f. "In Situ Bioremediation of 1,4-Dioxane by Methane Oxidizing Bacteria in Coupled Anaerobic-Aerobic Zones." ER-2306. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2306
- DoD SERDP. 2016. "Extending the Applicability of Compound-Specific Isotope Analysis to Low Concentrations of 1,4-Dioxane." ER-2535. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-2535/ER-2535
- U.S. Department of Health and Human Services (DHHS). 2014. "Report on Carcinogens, Twelfth Edition." Public Health Service, National Toxicology Program. 13th Edition. ntp.niehs.nih.gov/ntp/roc/content/profiles/dioxane.pdf
- U.S. Environmental Protection Agency (EPA). 1996a. "Method 8260B: Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)." www.epa.gov/sites/production/files/2015-12/documents/8260b.pdf
- EPA. 2001a. "Brownfields Technology Primer: Selecting and Using Phytoremediation for Site Cleanup." EPA 542-R-01-006. www.brownfieldstsc.org/pdfs/phytoremprimer.pdf
- EPA. 2001b. "Appendix A To Part 136—Methods For Organic Chemical Analysis Of Municipal And Industrial Wastewater, Method 1624." Code of Federal Regulations. Code of Federal Regulations. 40 CFR Part 136.
- EPA. 2003. "Method 8015D: Nonhalogenated Organics Using GC/FID." SW-846. www.epa.gov/sites/production/files/2015-12/documents/8015d_r4.pdf

Where can I find more information about 1,4-dioxane? (continued)

- EPA. 2006. "Treatment Technologies for 1,4-Dioxane: Fundamentals and Field Applications." EPA 542-R-06-009. clu-in.org/download/remed/542r06009.pdf
- EPA. 2007. "Method 8270D: Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS)." www.epa.gov/sites/production/files/2015-07/documents/epa-8270d.pdf
- EPA. 2008. "Method 522: Determination of 1,4-Dioxane in Drinking Water By Solid Phase Extraction (SPE) and Gas Chromatography/Mass Spectrometry (GC/MS) with Selected Ion Monitoring (SIM)." EPA/600/R-08/101. cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=199229
- EPA. 2009. "Drinking Water Contaminant Candidate List 3 – Final." Federal Register Notice. www.federalregister.gov/articles/2009/10/08/E9-24287/drinking-water-contaminant-candidate-list-3-final
- EPA. 2011. "Reportable Quantities of Hazardous Substances Designated Pursuant to Section 311 of the Clean Water Act. Code of Federal Regulations." 40 CFR 302.4. www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol28/pdf/CFR-2011-title40-vol28-sec302-4.pdf
- EPA. 2012. "2012 Edition of Drinking Water Standards and Health Advisories." www.epa.gov/sites/production/files/2015-09/documents/dwstandards2012.pdf
- EPA. 2013a. "1,4-Dioxane." clu-in.org/contaminantfocus/default.focus/sec/1,4-Dioxane/cat/Overview/
- EPA. 2013b. "1,4-Dioxane (1,4-Diethyleneoxide)." Technology Transfer Network Air Toxics Website. semspub.epa.gov/work/09/2129341.pdf
- EPA. 2013c. "EPA Contract Laboratory Program Statement of Work for Organic Superfund Methods SOM02.3." www.epa.gov/clp/epa-contract-laboratory-program-statement-work-organic-superfund-methods-multi-media-multi-0
- EPA. 2016a. "Contaminant Candidate List 4-CCL 4." www.epa.gov/ccl/draft-contaminant-candidate-list-4-ccl-4
- EPA. 2016b. Superfund Information Systems. Superfund Site Information. cumulis.epa.gov/supercpad/cursites/srchsites.cfm
- EPA. 2017b. Regional Screening Level (RSL) Summary Table. www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016
- EPA. Integrated Risk Information System (IRIS). 2013. "1,4-Dioxane (CASRN 123-91-1)." cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=326
- Vermont Department of Environmental Conservation (VTDEC). 2016. "Interim Groundwater Quality Standards." dec.vermont.gov/sites/dec/files/documents/interimgwqstandards_2016.pdf
- Vescovi, T., Coleman, H., and R. Amal. 2010. "The Effect of pH on UV-Based Advanced Oxidation Technologies - 1,4-Dioxane Degradation." Journal of Hazardous Materials. Volume 182. Pages 75 to 79.
- Washington Department of Ecology (ECY). 2015. "Groundwater Methods B and A ARARs." fortress.wa.gov/ecy/clarc/FocusSheets/Groundwater%20Methods%20B%20and%20A%20and%20ARARs.pdf
- West Virginia Department of Environmental Protection (WV DEP). 2009. "Voluntary Remediation and Redevelopment Rule." www.dep.wv.gov/dlr/oer/voluntarymain/Documents/60CSR3%20VRRA%20rule%206-5-09.pdf
- Zhong, H., Brusseau, M., Wang, Y., Yan, N., Quiq, L., and G. Johnson. 2015. "In-Situ Activation of Persulfate by Iron Filings and Degradation of 1,4-Dioxane" Water Research. Volume 83. Pages 104 to 111.

Contact Information

If you have any questions or comments on this fact sheet, please contact: Mary Cooke, FFRRO, at cooke.maryt@epa.gov.

United States Environmental Protection Agency

Technical Fact Sheet – Perchlorate

November 2017

At a Glance

- Both naturally occurring and man-made anion.
- Contamination has been found at sites involved in the manufacture, maintenance, use and disposal of ammunition and rocket fuel.
- Highly soluble in water; migrates quickly from soil to groundwater.
- Primary pathways for human exposure include ingestion of contaminated food and drinking water.
- Affects thyroid gland by interfering with iodide uptake.
- EPA issued Interim Drinking Water Health Advisory.
- Various states have screening values or cleanup goals for perchlorate in drinking water or groundwater.
- Various detection methods available.
- Common treatment technologies include ion exchange, bioremediation and membrane technologies.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a summary of the contaminant perchlorate, including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and additional sources of information. This fact sheet provides basic information on perchlorate to site managers and other field personnel who are addressing perchlorate contamination at cleanup sites or in drinking water supplies.

What is perchlorate?

- Perchlorate is a naturally occurring and man-made anion that consists of one chlorine atom bonded to four oxygen atoms (ClO_4^-). Manufactured forms of perchlorate include perchloric acid and salts such as ammonium perchlorate, sodium perchlorate and potassium perchlorate (EPA FFRRO 2005; ITRC 2005).
- Perchlorate is commonly used in solid rocket propellants, munitions, fireworks, airbag initiators for vehicles, matches and signal flares (EPA FFRRO 2005; ITRC 2005). It is also used in some electroplating operations (ATSDR 2008; ITRC 2005).
- Of the domestically produced perchlorate, 90 percent is manufactured for use in the defense and aerospace industries, primarily in the form of ammonium perchlorate (GAO 2005; ITRC 2005).
- Perchlorate may occur naturally, particularly in arid regions such as the southwestern United States (Rao and others 2007).
- Perchlorate is found as a natural impurity in nitrate salts from Chile, which are imported and used to produce nitrate fertilizers, explosives and other products (EPA FFRRO 2005; ITRC 2005).

Exhibit 1: Physical and Chemical Properties of Perchlorate Compounds
(ATSDR 2008; EPA FFRRO 2005; ITRC 2005; NIOSH 2014)

Property	Ammonium Perchlorate	Sodium Perchlorate	Potassium Perchlorate	Perchloric Acid
Chemical Abstracts Service (CAS) numbers	7790-98-9	7601-89-0	7778-74-7	7601-90-3
Physical description (physical state at room temperature)	White orthorhombic crystal	White orthorhombic deliquescent crystal	Colorless orthorhombic crystal or white crystalline powder	Colorless, oily liquid
Molecular weight (g/mol)	117.49	122.44	138.55	100.47
Water solubility (g/L at 25°C)	200	2,100	15	Miscible in cold water
Melting / Boiling point* (°C)	Melting point: 130	Melting point: 471 to 482	Melting point: 400 to 525	Melting point: -112 Boiling point: 19
Vapor pressure at 25°C (mm Hg)	Very low	Very low	Very low	N/A
Specific gravity (g/cm^3)	1.95	2	2.52	1.77
Octanol-water partition coefficient (log K_{ow})	-5.84	-7.18	-7.18	-4.63

*Different melting point temperatures are identified in literature.
Abbreviations: g/mol – grams per mole; g/L – grams per liter; °C – degrees Celsius; mm Hg – millimeters of mercury; g/cm^3 – grams per cubic centimeter.

Existence of perchlorate in the environment

- Perchlorate is highly soluble in water, and relatively stable and mobile in surface and subsurface aqueous systems. As a result, perchlorate plumes in groundwater can be extensive (ITRC 2005). For example, the perchlorate plume at a former safety flare manufacturing site (the Olin Flare Facility) in Morgan Hill, California, extends 10 miles (Cal/EPA 2016b).
- Because of their low vapor pressure, perchlorate compounds and the perchlorate anion do not volatilize from water or soil surfaces to air (ATSDR 2008; ITRC 2005).
- Perchlorate released directly to the atmosphere is expected to readily settle through wet or dry deposition (ATSDR 2008).
- High concentrations of perchlorate have been detected at current and Formerly Used Defense Sites historically involved in the manufacture, testing and disposal of ammunition and rocket fuel or at industrial sites where perchlorate is manufactured or used as a reagent during operations (ATSDR 2008; ITRC 2005).
- Types of military and defense-related facilities with known releases include missile ranges and missile and rocket manufacturing facilities. However, since site-specific documentation may not be available and based on historical uncertainties, it is generally difficult to identify specific military sites with known perchlorate releases (ITRC 2005).
- From 1997 to 2009, the Department of Defense reported perchlorate detections at 284 (almost 70 percent) of its installations sampled (GAO 2010).
- In addition, the past disposal of munitions in either burial pits or by open burning and open detonation may have resulted in releases to the environment. The amount of perchlorate released can vary depending on the length of time the disposal area was used and the types of munitions disposed of in the area (ITRC 2005).
- Nitrate is commonly found as a co-contaminant in water with perchlorate because ammonium nitrate is a main component in rocket fuel and explosives (DoD ESTCP 2013).
- Studies have shown perchlorate accumulates in some food crop leaves, tobacco plants and in broad-leaf plants (ATSDR 2008).
- Surveys conducted by the U.S. Food and Drug Administration have detected perchlorate in food crops and milk (Murray and others 2008).

- As of October 2009, perchlorate had been detected at varying levels in drinking water, groundwater, surface water, soil or sediment at private and federal facilities in 45 states, three U.S. territories and Washington D.C. The maximum concentrations reported in any media ranged from less than 4 parts per billion (ppb) to 2.6 million ppb (GAO 2010).
- EPA reported perchlorate detections at 40 hazardous waste sites on the EPA National Priorities List as of June 2010 (GAO 2010).

What are the routes of exposure and the potential health effects of perchlorate?

- Primary pathways for human exposure to perchlorate are ingestion of contaminated food and drinking water (ATSDR 2008; EPA FFRRO 2005).
- After perchlorate is ingested, it quickly passes through the stomach and intestines and enters the bloodstream (ATSDR 2008).
- The thyroid gland is the primary target of perchlorate toxicity in humans. Thyroid hormones play an important role in regulating metabolism and are critical for normal growth and development in fetuses, infants and young children. Perchlorate can interfere with iodide uptake into the thyroid gland at high enough exposures, disrupting the functions of the thyroid and potentially leading to a reduction in the production of thyroid hormones (ATSDR 2008; Cal/EPA 2015; National Research Council 2005).
- Potassium perchlorate was historically used to treat hyperthyroidism because of its ability to inhibit thyroid iodide uptake (ATSDR 2008; National Research Council 2005).
- Studies conducted on rodents showed that perchlorate concentrations below that required to alter thyroid hormone equilibrium are unlikely to cause thyroid cancer in human beings (ATSDR 2008; EPA IRIS 2005).
- Short-term exposure to high doses of ammonium, sodium or potassium perchlorate may cause eye, skin and respiratory tract irritation, coughing, nausea, vomiting and diarrhea. Perchloric acid is corrosive to the eyes, skin and respiratory tract, and short-term exposure to high doses may cause sore throat, coughing, labored breathing, deep burns, loss of vision, abdominal pain, vomiting or diarrhea (NIOSH 2014).

Are there any federal and state guidelines and health standards for perchlorate?

- EPA assigned perchlorate a chronic oral reference dose (RfD) of 0.0007 milligrams per kilogram per day (mg/kg/day). The RfD is an estimate of a daily exposure level that is likely to be without non-cancer health effects over a lifetime (EPA IRIS 2005).
- The Agency for Toxic Substances and Disease Registry (ATSDR) has established a minimal risk level (MRL) of 0.0007 mg/kg/day for chronic-duration oral exposure (365 days or more) to perchlorate. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure (ATSDR 2008, 2016).
- In 2011, EPA determined that perchlorate meets the Safe Drinking Water Act criteria for regulation as a contaminant. EPA then worked with the FDA to develop a dose-response model to analyze the effects of perchlorate on thyroid hormone production. In 2017, EPA completed a peer review to evaluate EPA's draft dose-response model. A future peer review will evaluate EPA's draft approach for deriving a Maximum Contaminant Level Goal (MCLG) for perchlorate in drinking water (EPA 2017a).
- In 2008, EPA established an Interim Drinking Water Health Advisory of 15 micrograms per liter (µg/L) for perchlorate. Exposure to this level for more than 30 days, but less than a year, is not expected to cause any adverse non-cancer effects. Health Advisories serve as informal guidance to assist managers of water systems; they are not legally enforceable standards (EPA 2008, 2012).
- EPA has calculated a tapwater screening level of 14 µg/L for perchlorate and perchlorate salts (EPA 2017b).
- EPA's Office of Land and Emergency Management recommends a preliminary remedial goal (PRG) of 15 µg/L at Superfund sites where there is an actual or potential drinking water exposure pathway, and where no applicable or relevant and appropriate requirements exist under federal or state laws (EPA 2009).
- California (6 µg/L) and Massachusetts (2 µg/L) have established enforceable standards for

perchlorate in drinking water (Cal/EPA 2016c; Massachusetts DEP 2016).

- Various states have adopted screening values or cleanup goals for perchlorate in drinking water or groundwater, ranging from 0.8 to 71 µg/L:

State	Guideline (µg/L)	Source
Alabama	24.5	ADEM 2008
California	1 (public health goal)	Cal/EPA 2016a
Colorado	4.9	CDPHE 2016
Florida	4	FDEP 2005
Illinois	4.9	IL EPA 2016
Indiana	15	IDEM 2016
Kansas	11 (residential) 71 (non-residential)	KDHE 2015
Maine	0.8	MDEP 2016
Maryland	2.6	MDE 2008
Nebraska	6.4	NDEQ 2012
Nevada	18	NDEP 2015
New Mexico	25.6	NMED 2012
Pennsylvania	15	PADEP 2011
Texas	17	TCEQ 2016
Utah	14	UDEQ 2012
Vermont	2 (interim preventive action level); 4 (interim enforcement standard)	VTDEC 2015
Virginia	15	VDEQ 2014
West Virginia	11	WVDEP 2014
Wyoming	23.3	WDEQ 2016

- EPA has calculated soil screening levels of 55 milligrams per kilogram (mg/kg) for residential areas and 820 mg/kg for industrial areas for perchlorate and perchlorate salts (ammonium, potassium, sodium and lithium) (EPA 2016b).
- Various states have adopted screening values or cleanup goals for perchlorate in soil, ranging from 0.1 to 150 mg/kg for residential areas, and from 5 to 2,000 mg/kg for industrial areas.

What detection and site characterization methods are available for perchlorate?

- Drinking water, groundwater and surface water:
  - EPA Method 314.0 - Ion Chromatography (EPA 2016a)
  - EPA Method 314.1 Rev 1.0 - Inline Column Concentration/Matrix Elimination Ion Chromatography with Suppressed Conductivity Detection (EPA 2016a)
  - EPA Method 314.2 - Two-Dimensional Ion Chromatography with Suppressed Conductivity Detection (EPA 2016a)
  - EPA Method 331.0 Rev. 1.0 - Liquid Chromatography/Electrospray Ionization/Mass Spectrometry (EPA 2016a)
- Drinking water: EPA Method 332.0 - Ion Chromatography with Suppressed Conductivity and Electrospray Ionization Mass Spectrometry (EPA 2016a)
- Surface water, groundwater, wastewater, salt water and soil: EPA SW-846 Method 6850 - High Performance Liquid Chromatography/Electrospray Ionization/Mass Spectrometry (EPA 2016c)
- Surface water, groundwater, salt water and soil: EPA SW-846 Method 6860 - Ion Chromatography/ Electrospray Ionization/Mass Spectrometry (EPA 2016c)
- The presence of high amounts of other anions, such as chloride, sulfate or carbonate, may interfere with the analysis of perchlorate (EPA 1999).
- Researchers have developed methods to distinguish man-made and natural sources of perchlorate in water samples using chlorine and oxygen stable isotope ratio analysis (Bŏhlke and others 2005; ITRC 2005; Sturchio and others 2014).

What technologies are being used to treat perchlorate?

- **Ex Situ Treatment**
  - Ion exchange using perchlorate-selective or nitrate-specific resins is a proven method for removal of perchlorate from drinking water, groundwater, and surface water (ITRC 2008).
  - Ex situ bioremediation is being used to treat a large perchlorate plume in southern Nevada (NDEP 2017).
  - Membrane technologies including electrodialysis and reverse osmosis have been used to remove perchlorate from groundwater, surface water and wastewater; however, these all require subsequent disposal of the perchlorate removed (EPA FFRRO 2005; ITRC 2008).
  - Although standard granular activated carbon (GAC) does not efficiently remove perchlorate, the adsorptive capacity of GAC may be increased through the addition of a surface-active coating to produce a modified or tailored GAC. Tailored GAC has proven to be effective for treating perchlorate in water; however, it

produces a waste stream requiring management (Hou and others 2013; ITRC 2008).

- Laboratory-study results indicate that an electrically switched ion exchange system using a conductive carbon nanotube nanocomposite material could be used for the large-scale treatment of wastewater and drinking water. This approach would produce less secondary waste than conventional ion exchange processes (DoD SERDP 2011).
- A recent field study demonstrated the effective treatment of perchlorate-contaminated groundwater to below detection limits using a large-scale weak base anion resin ion exchange system. This system allows efficient and economical regeneration of the spent resin (DoD ESTCP 2012b).
- A fluidized bed biological reactor treatment train successfully treated low concentrations of perchlorate in groundwater to meet the California drinking water standards (6 µg/L) in a field study. The microbial process completely destroyed the perchlorate molecules, so no subsequent treatment or waste disposal was needed (DoD ESTCP 2009b).
- Laboratory study results indicate that ultraviolet laser reduction can be used to decompose low levels of perchlorate (below 100 µg/L) in water. This technology is currently undergoing laboratory testing and has not yet been commercialized or used in full-scale systems (ITRC 2008). One laboratory study found that ultraviolet light and sulfite are able to degrade perchlorate when used together, but not when used alone (Vellanki and others 2013).

❖ **In Situ Treatment**

- Enhanced in situ bioremediation using ubiquitous perchlorate-reducing microbes can be an effective method for degrading perchlorate in groundwater and soil, at a lower cost than ex situ methods (DoD SERDP 2002; ITRC 2008; Stroo and Ward 2008).
- A laboratory study found that adding acetate or hydrogen as electron donors can increase perchlorate removal efficiency in groundwater (Wang and others 2013).
- Field study demonstration results indicate that a horizontal flow treatment well system can effectively deliver electron donor and promote the in situ biological reduction of perchlorate in groundwater (DoD ESTCP 2009c).
- A field study evaluated the use of gaseous electron donor injection technology for the anaerobic biodegradation of perchlorate in vadose zone soil. Results showed an average perchlorate destruction of more than 90 percent within the targeted 10-foot radius of influence within five months (DoD ESTCP 2009d).
- A field study evaluated the use of an emulsified oil biobarrier to enhance the in situ anaerobic biodegradation of perchlorate and chlorinated solvents in groundwater. Within 5 days of injection, perchlorate was degraded from an initial concentration range of 3,100 to 20,000 µg/L to below detection limits (less than 4 µg/L) in the injection and nearby monitoring wells (DoD SERDP 2008).
- A field study demonstrated that enhanced in situ bioremediation of perchlorate-impacted groundwater is effective using either an active or semi-passive approach. The active approach used on-going groundwater recirculation and delivery of an electron donor; perchlorate concentrations as high as 4,300 µg/L were reduced to less than 4 µg/L within 50 feet of the electron donor delivery/recharge well. The semi-passive approach involved periodic delivery of electron donor; perchlorate concentrations were reduced from levels over 800 µg/L to an average concentration of 3.4 µg/L (DoD ESTCP 2009a, 2012a).
- Laboratory and field studies have demonstrated the potential for using monitored natural attenuation to treat perchlorate in groundwater (DoD ESTCP 2010).
- Several bench-scale tests have demonstrated the potential effectiveness of phytoremediation and constructed wetlands to treat perchlorate-contaminated media; limited field study demonstrations have been implemented (ITRC 2008). Recent laboratory study results indicate that the wetland plant, *Eichhornia crassipes*, may be an effective plant for constructing a wetland to remediate high levels of perchlorate in water based on its high tolerance and accumulation ability (He and others 2013).

❖ DoD's environmental research programs have funded many projects to research the remediation of perchlorate. For more information, see www.serdp-estcp.org/Featured-Initiatives/Cleanup-Initiatives/Perchlorate and www.serdp-estcp.org/Tools-and-Training/Environmental-Restoration/Perchlorate.

Where can I find more information about perchlorate?

- Agency for Toxic Substances and Disease Registry (ATSDR). 2008. “Toxicological Profile for Perchlorates.” www.atsdr.cdc.gov/toxprofiles/tp162.pdf
- ATSDR. 2016. “Minimal Risk Levels (MRLs).” www.atsdr.cdc.gov/mrls/index.asp
- Alabama Department of Environmental Management (ADEM). 2008. “Alabama Risk-Based Corrective Action Guidance Manual.” adem.alabama.gov/programs/land/landforms/arbcamanual.pdf
- Bohlke, J.K., Sturchio, N.C., Gu, B., Horita, J., Brown, G.M., Jackson, W.A., Batista, J., and P.B. Hatzinger. 2005. “Perchlorate Isotope Forensics.” Analytical Chemistry. Volume 77. Pages 7838 to 7842. pubs.acs.org/doi/abs/10.1021/ac051360d
- California Environmental Protection Agency (Cal/EPA). 2015. “Public Health Goal: Perchlorate in Drinking Water.” oehha.ca.gov/water/public-health-goal-fact-sheet/final-technical-support-document-public-health-goal-perchlorate
- Cal/EPA. 2016a. “A Compilation of Water Quality Goals.” www.waterboards.ca.gov/water_issues/programs/water_quality_goals/
- Cal/EPA. 2016b. “Olin Perchlorate Site.” www.waterboards.ca.gov/rwqcb3/water_issues/programs/olin_corp/index.shtml
- Cal/EPA. 2016c. “Perchlorate in Drinking Water.” www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Perchlorate.shtml
- Colorado Department of Public Health and Environment (CDPHE). 2016. “The Basic Standards for Ground Water.” 5 CCR 1002-41. www.colorado.gov/pacific/sites/default/files/41_2016%2812%29.pdf
- Florida Department of Environmental Protection (FDEP). 2005. “Groundwater and Surface Water Cleanup Target Levels.” www.dep.state.fl.us/waste/quick_topics/rules/documents/62-777/62-777_TableI_GroundwaterCTLs.pdf
- He, H., Gao, H., Chen, G., Li, H., Lin, H., and Z. Shu. 2013. “Effects of Perchlorate on Growth of Four Wetland Plants and Its Accumulation in Plant Tissues.” Environmental Science and Pollution Research. Volume 20 (10). Pages 7301 to 7308. link.springer.com/article/10.1007/s11356-013-1744-4
- Hou, P., Cannon, F.S., Brown, N.R., Byrne, T., Gu, X., and C.N. Delgado. 2013. “Granular Activated Carbon Anchored with Quaternary Ammonium/Epoxide-Forming Compounds to Enhance Perchlorate Removal from Groundwater.” Carbon. Volume 53. Pages 197 to 207. www.sciencedirect.com/science/article/pii/S0008622312008615
- Illinois Environmental Protection Agency (IL EPA). 2016. “Non-TACO Class I and Class II Groundwater Objectives.” www.epa.illinois.gov/topics/cleanup-programs/taco/other-chemicals/index
- Indiana Department of Environmental Management (IDEM). 2016. “Remediation Closure Guide.” Table A-6: IDEM OLQ 2016 Screening Levels. www.in.gov/idem/landquality/files/risc_screening_table_2016.pdf
- Interstate Technology Regulatory Council (ITRC). 2005. “Perchlorate: Overview of Issues, Status, and Remedial Options.” www.itrcweb.org/GuidanceDocuments/PERC-1.pdf
- ITRC. 2008. “Remediation Technologies for Perchlorate Contamination in Water and Soil.” www.itrcweb.org/GuidanceDocuments/PERC-2.pdf
- Kansas Department of Health and Environment (KDHE). 2015. “Risk-Based Standards For Kansas: RSK Manual – 5th Version.” www.kdheks.gov/remedial/download/RSK_Manual_15.pdf
- Maine Department of Environmental Protection (MDEP). 2016. “Maine Remedial Action Guidelines (RAGs) for Sites Contaminated with Hazardous Substances.” www.maine.gov/dep/spills/publications/guidance/rags/ME-RAGS-Revised-Final_020516.pdf
- Maryland Department of the Environment (MDE). 2008. “Cleanup Standards for Soil and Groundwater.” www.phaseonline.com/assets/Site_18/files/MDE%20June%202008%20VCP%20Cleanup%20Standards.pdf
- Massachusetts Department of Environmental Protection (DEP). 2016. Water Resources: Perchlorate Information. www.mass.gov/eea/agencies/massdep/water/drinking/perchlorate-information.html

Where can I find more information about perchlorate? (continued)

- Murray, C.W., Egan, S.K., Kim, H., Beru, N., and P.M. Bolger. 2008. “US Food and Drug Administration’s Total Diet Study: Dietary Intake of Perchlorate and Iodine.” Journal of Exposure Science and Environmental Epidemiology. Volume 18. Pages 571 to 580. www.nature.com/jes/journal/v18/n6/pdf/7500648a.pdf
- National Research Council. 2005. “Health Implications of Perchlorate Ingestion.” www.nap.edu/catalog/11202/health-implications-of-perchlorate-ingestion
- National Institute for Occupational Safety and Health (NIOSH). 2014. International Chemical Safety Cards (ICSC). www.cdc.gov/niosh/ipcs/default.html
- Nebraska Department of Environmental Quality (NDEQ). 2012. “VCP Remediation Goals.” deq.ne.gov/Publica.nsf/xsp/.ibmmodres/domino/OpenAttachment/Publica.nsf/D243C2B56E34EA8486256F2700698997/Body/ATTIY3JX.pdf
- Nevada Division of Environmental Protection (NDEP). 2015. “Defining a Perchlorate Drinking Water Standard.” ndep.nv.gov/uploads/env-sitecleanup-active-bmi-perchlorate/perchlorate-drinking-water-standard.pdf
- NDEP. 2017. “Black Mountain Industrial (BMI) Complex: Perchlorate.” ndep.nv.gov/environmental-cleanup/site-cleanup-program/active-cleanup-sites/bmi-complex/perchlorate
- New Mexico Environment Department (NMED). 2012. “Risk Assessment Guidance for Site Investigations and Remediation.” www.env.nm.gov/HWB/documents/NMED_RA_Guidance_for_SI_and_Remediation_Feb_2012_.pdf
- Pennsylvania Department of Environmental Protection (PADEP). 2011. “Statewide Health Standards.” www.dep.pa.gov/Business/Land/LandRecycling/Standards-Guidance-Procedures/Pages/Statewide-Health-Standards.aspx
- Rao, B., Anderson, T.A., Orris, G.J., Rainwater, K.A., Rajagopalan, S., Sandvig, R.M., Scanlon, B.R., Stonestrom, D.A., Walvoord, M.A, and W.A. Jackson. 2007. “Widespread Natural Perchlorate in Unsaturated Zones of the Southwest United States.” Environmental Science & Technology. Volume 41 (13). Pages 4522 to 4528. pubs.acs.org/doi/abs/10.1021/es062853i
- Stroo, H.F., and C.H. Ward, Eds. 2008. “In Situ Bioremediation of Perchlorate in Groundwater.” www.springer.com/us/book/9780387849201
- Sturchio, N.C., Beloso, A., Heraty, L.J., Wheatcraft, S., and R. Schumer. 2014. “Isotopic Tracing of Perchlorate Sources in Groundwater from Pomona, California.” Applied Geochemistry. Volume 43. Pages 80 to 87. www.sciencedirect.com/science/article/pii/S0883292714000225
- Texas Commission on Environmental Quality (TCEQ). 2016. “TRRP Protective Concentration Levels.” www.tceq.texas.gov/remediation/trrp/trrppcls.html
- U.S. Department of Defense (DoD) Environmental Security Technology Certification Program (ESTCP) (Cox, E., Krug, T., and D. Bertrand). 2009a. “Comparative Demonstration of Active and Semi-Passive In Situ Bioremediation Approaches for Perchlorate-Impacted Groundwater (Longhorn Army Ammunition Plant).” ER-200219. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200219/ER-200219
- DoD ESTCP (Webster, T.S., and P. Togna). 2009b. “Demonstration of a Full-Scale Fluidized Bed Bioreactor for the Treatment of Perchlorate at Low Concentrations in Groundwater.” ER-200543. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200543
- DoD ESTCP (Hatzinger, P., and J. Diebold). 2009c. “In Situ Bioremediation of Perchlorate in Groundwater.” ER-200224. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200224/ER-200224/(language)/eng-US
- DoD ESTCP (Evans, P., Cai, H., Hopfensperger, K., Opitz, E., Titus, T., and R. Brennan). 2009d. “In Situ Bioremediation of Perchlorate in Vadose Zone Soil Using Gaseous Electron Donors.” ER-200511. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200511/ER-200511
- DoD ESTCP (Lieberman, T.M., Knox, S.L., and R.C. Borden). 2010. “Evaluation of Potential for Monitored Natural Attenuation of Perchlorate in Groundwater (Indian Head).” ER-200428. www.serdp-estcp.org/index.php/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200428/ER-200428

Where can I find more information about perchlorate? (continued)

- DoD ESTCP (Cox, E., and T. Krug). 2012a. "Comparative Demonstration of Active and Semi-Passive In Situ Bioremediation Approaches for Perchlorate Impacted Groundwater: Active In Situ Bioremediation Demonstration (Aerojet Facility)." ER-200219. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200219/ER-200219
- DoD ESTCP (Rine, J., Coppola, E., and A. Davis). 2012b. "Demonstration of Regenerable, Large-Scale Ion Exchange System Using WBA Resin in Rialto, CA." ER-201168. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-201168
- DoD ESTCP (Evans, P., Smith, J., Singh, T., Hyung, H., Arucan, C., Berokoff, D., Friese, D., Overstreet, R., Vigo, R., Rittman, B., Ontiveros-Valencia, A., Zhao, H.-P., Tang, Y., Kim, B.-O., Van Ginkel, S., and R. Krajmalnik-Brown). 2013. "Perchlorate Destruction and Potable Water Production Using Membrane Biofilm Reduction." ER-200541. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-200541/ER-200541
- DoD Strategic Environmental Research and Development Program (SERDP) (Cox, E.). 2002. "In Situ Bioremediation of Perchlorate-Impacted Groundwater." ER-1164. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-1164
- DoD SERDP (Borden, R.C). 2008. "Development of Permeable Reactive Barriers Using Edible Oils." ER-1205. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/ER-1205/ER-1205/(language)/eng-US
- DoD SERDP (Lin, Y.). 2011. "Novel Electrochemical Process for Treatment of Perchlorate in Waste Water." ER-1433. www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminants-on-Ranges/ER-1433
- U.S. Environmental Protection Agency (EPA). 1999. "Method 314.0 Determination of Perchlorate in Drinking Water Using Ion Chromatography." Revision 1.0. www.epa.gov/dwanalyticalmethods/analytical-methods-developed-epa-analysis-unregulated-contaminants
- EPA. 2008. "Interim Drinking Water Health Advisory For Perchlorate." EPA 822-R-08-025. nepis.epa.gov
- EPA. 2009. "Revised Assessment Guidance for Perchlorate." www.epa.gov/fedfac/revised-assessment-guidance-perchlorate
- EPA. 2012. "2012 Edition of the Drinking Water Standards and Health Advisories." EPA 822-S-12-001. www.epa.gov/dwstandardsregulations/drinking-water-contaminant-human-health-effects-information
- EPA. 2016a. "Analytical Methods Developed by EPA for Analysis of Unregulated Contaminants." www.epa.gov/dwanalyticalmethods/analytical-methods-developed-epa-analysis-unregulated-contaminants
- EPA. 2016c. "Validated Test Methods Recommended for Waste Testing." www.epa.gov/hw-sw846/validated-test-methods-recommended-waste-testing
- EPA. 2017a. Perchlorate in Drinking Water. www.epa.gov/dwstandardsregulations/perchlorate-drinking-water
- EPA. 2017b. Regional Screening Levels (RSLs) – Generic Tables (June 2017). www.epa.gov/risk/regional-screening-levels-rsls
- EPA Federal Facilities Restoration and Reuse Office (FFRRO). 2005. "Perchlorate Treatment Technology Update – Federal Facilities Forum Issue Paper." EPA 542-R-05-015. www.epa.gov/remedytech/perchlorate-treatment-technology-update
- EPA. Integrated Risk Information System (IRIS). 2005. "Perchlorate (ClO4) and Perchlorate Salts." cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=1007
- U.S. Government Accountability Office (GAO). 2005. "Perchlorate: A System to Track Sampling and Cleanup Results Is Needed." GAO-05-462. www.gao.gov/new.items/d05462.pdf
- U.S. GAO. 2010. "Perchlorate: Occurrence Is Widespread but at Varying Levels; Federal Agencies Have Taken Some Actions to Respond to and Lessen Releases." GAO-10-769. www.gao.gov/assets/310/308652.pdf

Where can I find more information about perchlorate? (continued)

- Utah Department of Environmental Quality (UDEQ). 2012. "UDEQ Voluntary Cleanup Program Frequently Asked Questions." www.deq.utah.gov/ProgramsServices/programs/cercla/voluntarycleanup/docs/2012/02Feb/vcp-faqs.pdf
- Vellanki, B.P., Batchelor, B., and A. Abdel-Wahab. 2013. "Advanced Reduction Processes: A New Class of Treatment Processes." Environmental Engineering Science. Volume 30 (5). Pages 264 to 271. online.liebertpub.com/doi/abs/10.1089/ees.2012.0273
- Vermont Department of Environmental Conservation (VTDEC). 2015. "Interim Groundwater Quality Standards." dec.vermont.gov/water/laws
- Virginia Department of Environmental Quality (VDEQ). 2014. "VRP Table 2.6: Selection of Contaminants of Concern." www.deq.state.va.us/Portals/0/DEQ/Land/RemediationPrograms/VRPRisk/Screen/vrp26.xlsx
- Wang, R., Chen, M., Zhang, J.W., Liu, F., and H.H. Chen. 2013. "Microbial Perchlorate Reduction in Groundwater with Different Electron Donors." Applied Mechanics and Materials. Volumes 295 to 298. Pages 1402 to 1407. www.scientific.net/AMM.295-298.1402
- West Virginia Department of Environmental Protection (WVDEP). 2014. "VRP Table §60-3B, De Minimis Table." www.dep.wv.gov/dlr/oer/voluntarymain/Pages/default.aspx
- Wyoming Department of Environmental Quality (WDEQ). 2016. "VRP Soil and Groundwater Cleanup Level Tables." deq.wyoming.gov/shwd/voluntary-remediation-program/resources/fact-sheets/

Additional information on perchlorate can be found at EPA's www.cluin.org/perchlorate.

Contact Information

If you have any questions or comments on this fact sheet, please contact: Mary Cooke, FFRRO, at cooke.maryt@epa.gov.

Appendix B

Reference List for Records Search

Attachment A-1
List of References Consulted during Research

1. Comprehensive Environmental Assessment and Response Program (CEARP), Phase I – Installation Assessment, Mound, April 1986, Draft

2. Installation Assessment, Mound, April 1986, Draft

3. Preliminary Review - Visual Site Inspection for RCRA Facility Assessment of Mound Plant, July 1988

4. Environmental Survey, Final Report, Mound Plant, June 1990 (US DOE, Environment, Safety, and Health, Office of Environmental Audit)

5. Limited Field Investigation Operable Unit 3, Miscellaneous Sites Health and Safety Plan, Final, February 1991

6. Operable Unit 9, Site Scoping Report Volume 6 - Photo History Report. February 1992 Final.

7. Operable Unit 9, Site Scoping Report: Volume 11 - Spills and Response Actions. March 1992 Final. Revision 0.

8. Remedial Investigation/Feasibility Study Operable Unit 9, Site-Wide Work Plan. Volume 2. May 1992 Final

9. Remedial Investigation/Feasibility Study Operable Unit 9, Site-Wide Work Plan. Volume 1. May 1992 Final

10. Closure Report, Building 34, Aviation Fuel Storage Tank. Final. Revision 0. August 1992

11. Operable Unit 9, Site Scoping Report: Volume 7 - Waste Management. August 1993. Final. Revision 0.

12. Operable Unit 3 Limited Field Investigation Report Mound Plant Miamisburg Closure Project May 1993 Final

13. Operable Unit 3, Miscellaneous Sites Limited Field Investigation Report, Volume 1 LFI Report Text (Sections 1-6), July 1993 Final, Revision 0.

14. Action Memorandum/Removal Site Evaluation. Operable Unit 5 Fire Fighting Training Area (FFTA) Site. January 1994 Final.

15. Fire Fighting Training Area Removal Action, Operable Unit 5, OU-5, Work Plan, Volume 1 - Text and Appendices A,B,C,D, Final, Revision 0, June 1994

16. Fire Fighting Training Area (FFTA) Removal Action Operable Unit 5 Work Plan. Volume 3 - Appendices F and G. Final. Revision 0, June 1994

17. Fire Fighting Training Area (FFTA) Removal Action Operable Unit 5 Work Plan. Volume 2 - Appendix E. Final. Revision 0, June 1994

18. Comments/Responses: Fire Fighting Training Area (FFTA) Removal Action Memorandum. July 1994

19. Operable Unit 9 Site Scoping Report: Volume 12 - Site Summary Report. December 1994 Final.

20. Risk-Based Guideline Values. Final. Revision 0; Exposure Scenario Equations and Exposure Variable Documentation. Draft. Revision 3; Draft. Revision 2; Guideline Value Tables. Draft. Revision 3; Oak Ridge National Laboratory Tritium Inhalation Laboratory. December 1995

21. Fire Fighting Training Area Response Action On-Scene Coordinator (OSC) Report. Release Block J, Potential Release Site, PRS 18, Final, Revision 0, February 1996

22. Volume 1 Environmental Appraisal Report of the Mound Plant March 1996

23. Volume 2 Environmental Appraisal Report of the Mound Plant March 1996

24. Volume 3 Environmental Appraisal Report of the Mound Plant March 1996

25. Volume 4 Environmental Appraisal Report of the Mound Plant March 1996

26. Volume 5 Environmental Appraisal Report of the Mound Plant March 1996

27. Volume 6 Environmental Appraisal Report of the Mound Plant March 1996

28. Volume 7 Environmental Appraisal Report of the Mound Plant March 1996

29. Volume 8 Environmental Appraisal Report of the Mound Plant March 1996

30. Volume 9 Environmental Appraisal Report of the Mound Plant March 1996

31. Volume 10 Environmental Appraisal Report of the Mound Plant March 1996

32. Volume 11 Environmental Appraisal Report of the Mound Plant March 1996

33. Volume 12 Environmental Appraisal Report of the Mound Plant March 1996

34. Mound Plant Potential Release Site Package PRS 19, Final, Revision 1, November 1996

35. Mound Plant Potential Release Site Package PRS 18, Final, Revision 1, November 1996

36. Mound Plant, Potential Release Site Package, PRS 17, Building 34 Oil Burn Structure, Release Block J, Final, Revision 1, February 1997

37. Mound Plant Potential Release Site Package PRS 20 Aviation Fuel Storage Tank Release Block J, Final, Revision 1, February 1997

38. Mound Plant Potential Release Site Package. Release Block F, PRS 307, Soil Contamination, Building 29, Plastics Formulation Facility. Public Release. Revision 0, April 1997

39. Mound Plant, Building Data Package. Magazines 5, 6, 7, 10, 11, 20, 53, 54. Located Within Release Block C, E, R, Q. Final, November 1997

40. Closure Certification of the Burn Area at the Mound Plant U.S. Department of Energy Mound Plant-Miamisburg, Ohio EPA I.D. No. OH68900089B4 Ohio 1.0. No. 05-57-0677, Final, January 1998

41. Work Plan For Environmental Restoration of the DOE Mound Site, The Mound 2000 Approach, February 1999

42. Action Memorandum Engineering Evaluation/Cost Analysis, E-Building, Electronics Laboratory, Removal Action, April 2000, Final, Revision 0, April 2000

43. Action Memorandum Engineering Evaluation/Cost Analysis (EECA), Buildings R, SW, 58 & 68 Slab Removal Action, Public Review Draft, November 2002 Revision 0

44. Mound Plant Action Memorandum Engineering Evaluation/Cost Analysis (EE/CA), B-Building Removal Action, Final, March 2002.

45. Mound Plant, Building Data Package (BDP), Building 42, Explosives Component Fabrication Facility, Public Review Draft, May 2002.

46. Mound Plant, Building Data Package (BDP), Building 29, Plastics Formulation Facility, Final, June 2002. Addendum included with this report.

47. DOE (U.S. Department of Energy), 1998. Closure Certification of the Burn Area at the Mound Plant U.S. Department of Energy Mound Plant- Miamisburg, Ohio EPA I.D. No. OH68900089B4 Ohio 1.0. No. 05-57-0677, January.

48. DOE (U.S. Department of Energy), 2015. Operations and Maintenance Plan for the U.S. Department of Energy, Mound, Ohio, Site, LMS/MND/S08406, January.

49. DOE (U.S. Department of Energy), 1999. Work Plan for Environmental Restoration of the DOE Mound Site, The Mound 2000 Approach, Final, Revision 0, 1505-9902220003, February.

50. DOE (U.S. Department of Energy), 2003. Phase I Proposed Plan Public Review Draft Miamisburg Closure Project, March.

51. DOE (U.S. Department of Energy), 2003. Phase I Residual Risk Evaluation Miamisburg Closure Project, Final, March.

52. DOE (U.S. Department of Energy), 2003. Phase I Record of Decision, Miamisburg Closure Project, Final, July.

53. DOE (U.S. Department of Energy), 2003. Phase I Environmental Summary CERCLA 120(h) Summary Notice of Hazardous substances Miamisburg Closure Project, Final, December.

54. Mound Plant, Building Data Package (BDP), Building SST, Salt Storage Shed, Final, August 2002.

55. Mound Plant, Building Data Package, Building 42, Explosives Component Fabrication Facility, Final, August 2002.

56. Mound Plant Closeout Report, Building 29, Final, August 2002.

57. Mound Plant, Building Data Package, (BDP) Building 98, Central Fire Station, Final, September 2002.

58. On-Scene Coordinator (OSC) Report, E-Building, Electronics Laboratory, Removal Action, Final, Revision 0, October 2002.

59. Mound Plant, Building 42, Explosives Component Fabrication Facility, Closeout Report, Final, October 2002.

60. Mound Plant Closeout Report, Building 98, Central Fire Station, Final, October 2002.

61. Miamisburg Closure Project, Building Data Package (BDP), T-Building, Technical Building, Public Review Draft, February 2003.

62. Action Memorandum Engineering Evaluation/Cost Analysis (EE/CA), T-Building Removal Action, February 2003.

63. Phase I Proposed Plan Public Review Draft Miamisburg Closure Project March 2003.

64. Phase I Residual Risk evaluation Miamisburg Closure Project Final March 2003.

65. Miamisburg Closure Project, Building Data Package, Building 61, Logistical Support Warehouse, Final, March 2003.

66. Mound Plant, Building Data Package, (BDP), Building 94, Materials Compatibility, Final, May 2003.

67. Miamisburg Closure Project, T-Building, Technical Building, Building Data Package (BDP), Final, June 2003.

68. Miamisburg Closure Project, Building Data Package, Building 49, Explosive Fabrication Facility, Final, June 2003.

69. Miamisburg Closure Project, Building 49, Explosive Fabrication Facility, Closeout Report, Final, June 2003.

70. Phase I Record of Decision Miamisburg Closure Project, Final, July 2003.

71. Action Memorandum Engineering Evaluation Cost Analysis (EE/CA), T-Building Removal Action, Final, June 2003.

72. Miamisburg Closure Project, Building 47, Building Data Package, Old Central Fire Station (Demolition), Final, July 2003.

73. Miamisburg Closure Project, Building Data Package (BDP), Building 28 (Transition), Ceramic Production/Plastics Development, Final, September 2003.

74. Phase I Environmental Summary CERCLA 120(h) Summary Notice of Hazardous substances Miamisburg Closure Project Final December 2003.

75. Miamisburg Closure Project, Building Data Package (BDP), Building 48 (Demolition), Process Mechanization Facility/Explosive Surveillance, Final, March 2004.

76. Miamisburg Closure Project, Building 47, Old Central Fire Station (Demolition) Closeout Report, Final, Revision 1, April 2005.

77. PRS 17 Removal Action OSC Report March 2006 Final U.S. Department of Energy Miamisburg Closure Project.

78. Building 34 Footprint Removal Action, On-Scene Coordinator (OSC) Report. This Report Closes Building 34 Footprint. Final, May 2006.

79. RSWB Removal Action On-Scene Coordinator (OSC) Report. Closes PRS 131 through PRS 146, PRS 209, PRS 234, PRS 249-254, 327-329, 425, 437-438 and 440. Closes slab/soil for Buildings R, SW, 58, 62, 68, B-Stack, T-Stack and B-Building structure/slab/soil July 2006 Final U.S. Department of Energy Miamisburg Closure Project.

80. Emerging Contaminants – Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA) March 2014 U.S. EPA.

81. Perfluorinated Compounds (PFCs) and Human Health Concerns April 2009 Global Health & Science Initiative.

82. Department of Labor web site for DOE facilities at http://sem.dol.gov/expanded/index.cfm

83. Department of Ecology State of Washington http://www.ecy.wa.gov

84. Agency for Toxic Substances & Disease Registry Toxic substances Portal – Perfluoroalkls December 2015 http://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=1117&tid=237

85. ENVIRONMENTAL PROTECTION AGENCY 40 CFR Part 721 Perfluoroalkyl Sulfonates; Proposed Significant New Use Rule March 10, 2006 www.gpo.gov/fdsys/pkg/FR-2006-03-10/pdf/E6-3444.pdf

86. Integrated Environmental Assessment and Management Perfluoroalkyl and polyfluoroalkyl substances in the environment: Terminology, classification, and origins September 2001

http://onlinelibrary.wiley.com/doi/10.1002/ieam.258/abstract;jsessionid=0B217E2E8608B5775C970B5B40615F09.f02t01

87. United States Department of Labor Site Exposure Matrices (SEM)
http://sem.dol.gov/expanded/index.cfm

Appendix C

Building Process and Use Summary

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-Dioxane and Perchlorate[a]

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
1	A	Office Space	Administration (A) Building Administrative offices Medical services Janitorial supplies	No
2	B	Biological testing Inert assembly of nonexplosive devices Laser **welding** and marking **Mold shop** PVD Transducer production Industrial hygiene laboratory	Biological (B) Building Originally used for biological testing then converted to detonator manufacturing Organic solvent use Ethylene diamine called out as used Nondestructive testing of devices (*Environmental Appraisal Report*, Vol. 2)[b] (*Mound Site Radionuclides by Location*)[c]	Yes Perchlorate 1,4-dioxane
3	C	Cafeteria	Cafeteria Conference/meeting rooms Paper file storage	No
4	DS	**Metrology** processes **Explosives** development and production	Energetic materials development Detonator and timer development and production PVD lab Tape processing lab (flexible printed circuits) Welding labs **Perfluoro polyether (PFAS)** was used as a high temp, liquid lubricant Chemical inventory lists *p*-dioxane and perchlorate, with 3 gallons of *p*-dioxane listed in Room 131B (*Environmental Appraisal Report,* Vol. 2)[b]	Yes Perchlorate 1,4-dioxane
5	E and E Annex	Analytical laboratories Products assembly	Environmental (E) Building Environmental and biological analysis Electronics (E) Building (later redesignation) Analysis of soil, water, vegetation, and biota Use of **standards and tracers** Electronics and **explosives** research **Explosives** laboratory Detonator production **Plastics** and adhesives R&D Chemical inventory lists *p*-dioxane and perchlorate (*Environmental Appraisal Report,* Vol. 2)[b] (*Mound Site Radionuclides by Location*)[c]	Yes Perchlorate 1,4-dioxane
6	G	Fleet and heavy machinery service Storage of supplies (janitorial and grounds)	Garage used for **servicing, repairing, and painting** vehicles and equipment. Waste oils noted (*Environmental Appraisal Report*, Vol. 2)[b]	Yes 1,4-dioxane
7	GH	Visitor control point Office space	Mound transition center (*Environmental Appraisal Report*, Vol. 2)[b]	No
8	GIS	Guard post	Checkpoint for site access (*Environmental Appraisal Report*, Vol. 2)[b]	No
9	GP-1	Office and general-purpose space Firing range Communications center	Security training Noted that tear gas was used (*Environmental Appraisal Report*, Vol. 2)[b]	No
10	GP-5	Guard post	(*Environmental Appraisal Report*, Vol. 3)[b]	No
11	GP-8	Guard post	(*Environmental Appraisal Report*, Vol. 3)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
12	GP-44	Guard post	Equipment room Uniform (security) laundry (*Environmental Appraisal Report*, Vol. 3)[b]	No
13	GW	Office space Record storage	(*Environmental Appraisal Report*, Vol. 3)[b]	No
14	H	Laundry service **Maintenance shop** Laboratories	Laundry of both contaminated (hot) and clean (cold clothing Bioassay and environmental analysis Hydride storage module Distillation columns Equilibrator and uranium bed Cryogenic distillation module Chemical inventory lists *p*-dioxane and perchlorate (*Environmental Appraisal Report*, Vol. 3)[b] (*Mound Site Radionuclides by Location*)[c]	Yes Perchlorate 1,4-dioxane
15	HH	Hydrolysis of bismuth chloride Hydrolysis of aluminum chloride Waste treatment	Hydrolysis House (HH) Stable gaseous isotope separation by diffusion (gaseous and liquid) Cryogenic processes Waste oils noted Treatment of T Building polonium wastes Chemical inventory lists *p*-dioxane and perchlorate (*Environmental Appraisal Report*, Vol. 3)[b] (*Mound Site Radionuclides by Location*)[c]	Yes Perchlorate 1,4-dioxane
16	I	Loading and testing of **explosive** actuators Development and production using energetic materials Laboratories	Isolation (I) Building Use of MOCA noted Detonator production **Plastics** and **ceramics** R&D and production Bioassay and environmental analysis Health physics analysis (*Environmental Appraisal Report*, Vol. 3)[c] (*Mound Site Radionuclides by Location*)[b]	Yes Perchlorate 1,4-dioxane
17	M	**Machine shop** **Electroplating** operations Electronics maintenance Electrical substation	Machining of ^{238}U (*Environmental Appraisal Report*, Vol. 3)[b]	Yes 1,4-dioxane
18	Modular 4	Office space	Contractor training (*Environmental Appraisal Report*, Vol. 3)[b]	No
19	OSE	Office space Photographic services Computer facilities Cafeteria	(*Environmental Appraisal Report*, Vol. 3)[b]	No
20	OSW	Office space CAD production and processing	(*Environmental Appraisal Report*, Vol. 4)[b]	No
21	P	Centralized processes and breathing air Steam and condensate: boilers and chillers Chilled water supply and return Potable water treatment Electric power distribution: electrical substations	Powerhouse Plant steam and chiller production and distribution Domestic water treatment, chlorination, softening, and distribution Fuel oils and lubricants used (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	Yes 1,4-dioxane
22	PH	Fuel oil pumps to powerhouse Steam line condensate pumps Brine line to Building 24	Pump house (PH) (*Environmental Appraisal Report*, Vol. 4)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
23	PS	**Paint** facilities	**Paint Shop** (PS) Brush painting Spray painting: Ohio EPA permitted spray booth Sanding, priming, drying Computer generated signs (*Environmental Appraisal Report*, Vol. 4)[b]	Yes 1,4-dioxane
24	PP	Plutonium production Fabrication Recovery Waste treatment Analytical laboratories Research and development	Plutonium Processing (PP) Building Several processes: PMC, PPO, and variations on PPO Processes from SM Building were transferred to PP Building Treatment of aqueous wastes, caustic solutions, ammonium hydroxides Laboratory analysis for corrosive vaporization processes, caustic scrubber, and reagents for scrubbing (*Mound Site Radionuclides by Location*)[c]	No
25	R	Tritium recovery Analytical support laboratories R&D laboratories Office space	Research (R) Building Nuclear Operations R&D Pilot-scale work for T Building processes Tritiated solvents and nickel carbonyl used Tritium recovery using heat-up reactor **Plating** of metals for alpha source production Thorium and helium separation **Electroplate** deposition of polonium (pilot-scale) Several processes: PMC and PPO **Welding** operations: ^{234}U program Analytical laboratory used X-ray diffraction and gas synthesis systems for metal tritides, surface area analysis, differential analysis, infrared spectrometry, and ion chromatography Incident report identified perchlorate (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	Yes Perchlorate 1,4-dioxane
26	SD	**Sanitary treatment** operations	Sewage disposal (SD) (*Environmental Appraisal Report*, Vol. 4)[b]	No
27	SM	Plutonium production Fabrication Recovery Waste treatment Analytical laboratories Research and development	Special Metallurgical (SM) Building Heat source program Plutonium metals production Microsphere process using plasma torch Recovery of plutonium using acids ^{234}U separation Waste treatment: plutonium (*Environmental Appraisal Report*. Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	Yes 1,4-dioxane
28	SST	Storage of road salt	Salt storage for site roads (*Environmental Appraisal Report*, Vol. 4)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
29	SW	Tritium recovery and purification Tritium component development Waste treatment Support laboratories Research and development	Materials testing R&D for Pu, U, Th, and protactinium Semi works pilot studies **Plastics** and adhesives R&D Tritium enrichment by thermal diffusion Scrap recovery and waste solidification Hot gas facility **Ceramics** facility Cooling tower and chillers Effluent removal system Radionuclide refining and separation Uranium recovery using acid dissolution Component testing: thermal and shock Metallurgical analysis that involved cutting Wastewater treatment Environmental laboratories **Plastics** potting program **Plating** of metals for alpha source production (Environmental Appraisal Report – Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	Yes 1,4-dioxane
30	T	Tritium operations: purification and recovery Research and development Calorimetry production Heat source calibration X-ray and safeguards gamma scanning Polonium-210 purification Radionuclide extraction (bismuth and beryllium) Nickel carbonyl vapor preposition process Hydrogen isotope separation Neuron activation analysis Storage of transuranic materials Polonium and tritium decontamination **Machine shop**	Technical (T) Building Polonium processing and separation Polonium recovery using induction heaters Neutron source program Neutron irradiation with neutron accelerator Hydrogen isotope separation program Poodle heat source program: fuel capsule assembly R&D of polonium processing and fuel production Testing: environmental using gamma and mass spectroscopy Testing: assay laboratory for Safeguards Verification Facility Testing: bioassay laboratory Testing: nuclear measurement Decontamination using solvents and alcohol Maintenance and hot and cold **machine shop** Fabrication and maintenance of tritium monitors (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	Yes 1,4-dioxane
31	W	**Plastics** manufacturing Office space Trade shops	Original **plastics** manufacturing, which was later moved to Building 29 **Plastics** formulation **Plastics** testing Roll milling, mixing dry **plastics** process Carpentry **Sheet metal work** Pipefitter and **welding** heating, ventilation, and air conditioning Electrical Tool and materials storage (*Environmental Appraisal Report*, Vol. 5)[b]	Yes 1,4-dioxane

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
32	WD	**Wastewater treatment** Analytical laboratory Bench-scale testing	Waste Disposal (WD) Building LSA wastewater from Buildings SW, R, PP, SM, HH, T, B, and H Treatment of both alpha and beta Treatment by precipitation, coagulation, filtering, and sludge solidification. Supernatant neutralized to proper pH (*Environmental Appraisal Report*, Vol. 5)[b] (*Mound Site Radionuclides by Location*)[c]	Yes 1,4-dioxane
33	WDA	**Wastewater treatment** Waste incineration	Waste Disposal Alpha (WDA) Building Treatment of plutonium wastewater from Buildings SM and PP Treatment of beta wastewater from Buildings SW, R, and HH Treatment by clariflocculation tanks, ultrafiltration, and reverse osmosis Separation of isotopes from wastewater Cyclone incinerators Tank and equipment cleaning (*Environmental Appraisal Report*, Vol. 5)[b] (*Mound Site Radionuclides by Location*)[c]	No
34	WH	Water pumps Muriatic acid treatment	Well house (WH) (*Environmental Appraisal Report*, Vol. 5)[b]	No
35	WH-2	Water pumps	(*Environmental Appraisal Report*, Vol. 5)[b]	No
36	WH-3	Water pumps	(*Environmental Appraisal Report*, Vol. 5)[b]	No
37	1	Research and testing of **energetic** materials Processing and blending of explosive powders Packaging of energetic materials	(*Environmental Appraisal Report*, Vol. 5)[b]	Yes Perchlorate
38	2	Destructive testing of **energetic** materials X-ray and photographic testing	(*Environmental Appraisal Report*, Vol. 5)[b]	Yes Perchlorate
39	3	Destructive testing Environmental testing laboratory Office space Fabrication and assembly	Testing, fabrication, and assembly of detonators (*Environmental Appraisal Report*, Vol. 5)[b]	Yes Perchlorate
40	13	Remote monitoring of Burn Area	Monitoring of energetic materials destruction (*Environmental Appraisal Report*, Vol. 5)b	No
41	14	Observation post	Burn area (*Environmental Appraisal Report*, Vol. 5)[b]	No
42	17	Chemical storage and staging Sampling and testing of drummed chemicals	Bonded storage of chemicals (*Environmental Appraisal Report*, Vol. 5)[b]	No
43	21	Thorium sludge consolidation Thorium drum storage	Warehouse 15 Storage of thorium-232 sludge from Monex project Corrosive Designed to be self-containing and leak proof Leakage reported (*Environmental Appraisal Report*, Vol. 5)[b] (*Mound Site Radionuclides by Location*)[c]	No
44	22	Storage of solid LLW	(*Environmental Appraisal Report*, Vol. 5)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
45	23	Warehouse	Staging and shipping of LLW Staging and shipping of TRU and mixed waste Floor coated to contain spills (*Environmental Appraisal Report*, Vol. 6)[b]	No
46	24	Raw water treatment	Zeolite softening beds Chemical injection equipment (*Environmental Appraisal Report*, Vol. 6)[b]	No
47	25	Meteorological station Telephone switching	(*Environmental Appraisal Report*, Vol. 6)[b]	No
48	26	**Welding** shop Storage Office space	(*Environmental Appraisal Report*, Vol. 6)[b]	Yes 1,4-dioxane
49	28	**Ceramics** development and production	(*Environmental Appraisal Report*, Vol. 6)[b]	No
50	29	**Plastics** manufacturing	Plastics formulation Plastics testing Roll milling, mixing dry plastics process Solvent supply Asbestos slurry kettle Varnish kettles Materials mixers Acetone pumps (*Environmental Appraisal Report*, Vol. 6)[b]	Yes 1,4-dioxane
51	30	Radiological counting laboratory	Tritium and gross alpha counting **Liquid scintillation** Gamma scanning: tritium and gross alpha/beta (*Environmental Appraisal Report*, Vol. 6)[b]	No
52	31 31-A	Storage and staging of radiological wastes	LLW, TRU, and LSA wastes (*Environmental Appraisal Report*, Vol. 6)[b]	No
53	33	Equipment **maintenance**	Heavy equipment repair/maintenance Equipment storage (*Environmental Appraisal Report*, Vol. 6)[b]	Yes 1,4-dioxane
54	34	Firefighter training “Bioremediation farm”	“Burning Building” Performed burning of various fuels and flammable materials for training Area where site soils were brought for bioremediation treatment (*Environmental Appraisal Report*, Vol. 6)[b]	No
55	35	Nondestructive testing californium-232 multiplier	Detonator testing X-ray and eddy current testing of materials Control room for multiplier (*Environmental Appraisal Report*, Vol. 6)[b]	No
56	36	Heat source/ RTG operations	Testing High temperature bakeout of graphite modules Cleaning of modules from bakeout (*Environmental Appraisal Report*, Vol. 6)[b]	No
57	37	Heat source/ RTG operations	Research and development **Machine shop** for heat source program: machining, cleaning, and heat treating (*Environmental Appraisal Report*, Vol. 7)[b]	Yes 1,4-dioxane
58	38	Heat source/ RTG operations	Production, assembly, and testing of RTGs Analytical facilities Health physics equipment calibration Waste recharacterization and repackaging (*Environmental Appraisal Report*, Vol. 7)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
59	39	Maintenance shop	**Machine shop** Storage: paints and solvents Fiberglass wooden box production (*Environmental Appraisal Report*, Vol. 7)[b]	No
60	40	Print shop	Presses Developing Microfiling Reproduction Document assembly (*Environmental Appraisal Report*, Vol. 7)[b]	No
61	42	Pyrotechnics and thermite operations	**Pyrotechnics and thermite** production Component testing **Pyrotechnics** assembly **Energetic materials** assembly (*Environmental Appraisal Report*, Vol. 7)[b]	Yes Perchlorate
62	43	Thermite operations	**Thermite** research and development (*Environmental Appraisal Report*, Vol. 7)[b]	Yes Perchlorate
63	44	Cafeteria	Food preparation and service Office space (*Environmental Appraisal Report*, Vol. 7)[b]	No
64	45	Health physics calibration	Instrumentation Personnel detectors Beta calibration X-ray calibration Calibration equipment repair (*Environmental Appraisal Report*, Vol. 7)[b]	No
65	46	Welding shop Machine shop	**Energetic materials** Support to the heat source program (*Environmental Appraisal Report*, Vol. 7)[b]	Yes Perchlorate
66	47	Administration	Security administration office Weapons storage Classified wastes storage (*Environmental Appraisal Report*, Vol. 7)[b]	No
67	48	Materials testing	**Energetic materials** analytical testing Cutting of materials for testing (*Environmental Appraisal Report*, Vol. 8)[b]	Yes Perchlorate
68	49	Laboratory analysis	Production laboratory for **energetic** materials Material staging facility (*Environmental Appraisal Report*, Vol. 8)[b]	Yes Perchlorate
69	50	Fabrication testing	Assembly and testing of RTGs (*Mound Site Radionuclides by Location*)[c]	No
70	51	Incinerator Thermite production Carbon production	Documented as limited use for incineration of: Nonradiological wastes Paints, oils, and solvents Thermite and carbon production for lithium battery capacitors (*Environmental Appraisal Report*, Vol. 8)[b]	No
71	55	Wastewater testing	Testing and storage of testing equipment and supplied (*Environmental Appraisal Report*, Vol. 8)[b]	No
72	56	Pumping station	(*Environmental Appraisal Report*, Vol. 8)[b]	No
73	57	Wastewater treatment	SD Building Wastewater treatment plant (WWTP) Control house for treatment processes (*Environmental Appraisal Report*, Vol. 8)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
74	58	Filter systems	Semi Works (SW) Building support systems alpha and beta filter bank Exhaust plenum HEPA filters (*Environmental Appraisal Report*, Vol. 8)[b]	No
75	59	Neutron radiography	CFX process: neutron radiography for detection of explosives Pneumatic transfer of neutron source to uranium plates Subcritical assembly of equipment (*Environmental Appraisal Report*, Vol. 8)[b] (*Mound Radionuclides by Location*)[c]	No
76	60	Nondestructive testing	**Ceramics** research and development (*Environmental Appraisal Report*, Vol. 8)[b]	Yes Perchlorate
77	61	Warehouse	Central Warehouse Gas cylinder storage Flammable materials storage (*Environmental Appraisal Report*, Vol. 8)[b]	No
78	63-E 63-W	Testing laboratory	Spin-testing facility Product quality testing Environmental storage (*Environmental Appraisal Report*, Vol. 8)[b]	No
79	65	Office space	(*Environmental Appraisal Report*, Vol. 8)[b]	No
80	66	Office space	(*Environmental Appraisal Report*, Vol. 8)[b]	No
81	67	Office space	(*Environmental Appraisal Report*, Vol. 8)[b]	No
82	68	Storage area	D&D operations: LSA waste from R and SW for shipping Plant operations: storage area for parts and materials (*Environmental Appraisal Report*, Vol. 9)[b]	No
83	69	Office space	(*Environmental Appraisal Report*, Vol. 9)[b]	No
84	70	Office space	(*Environmental Appraisal Report*, Vol. 9)[b]	No
85	71	Chemical storage	Flammable liquids (*Environmental Appraisal Report*, Vol. 9)[b]	No
86	72	Storage area	Hazardous waste (*Environmental Appraisal Report*, Vol. 9)[b]	No
87	73	Storage area	Compressed gas cylinders (*Environmental Appraisal Report*, Vol. 9)[b]	No
88	74	Storage area	Final packaging for explosives shipping (*Environmental Appraisal Report*, Vol. 9)[b]	No
89	79	Office space	(*Environmental Appraisal Report*, Vol. 9)[b]	No
90	85	Building unused	Class I powder processing facility: never used (*Environmental Appraisal Report*, Vol. 9)[b]	No
91	87	Materials testing	Destructive testing of **explosives** Fabrication of electronic test systems (*Environmental Appraisal Report*, Vol. 9)[b]	Yes Perchlorate
92	88	Office space	Administration and office building for RTC program (*Environmental Appraisal Report*, Vol. 9)[b]	No
93	89	Storage area	Storage of **energetic** materials (*Environmental Appraisal Report*, Vol. 9)[b]	No
94	90	Control systems	Systems for unit controls and waste feed for the retort unit (rotary kiln) in Burn Area (*Environmental Appraisal Report*, Vol. 9)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
95	92	Training Office space	Training for production support Soldering certification (*Environmental Appraisal Report*, Vol. 9)[b]	No
96	93	Office space	(*Environmental Appraisal Report*, Vol. 10)[b]	No
97	94	Office space Storage area Laboratory analysis	Environmental laboratory Soil and water sampling storage LSA storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
98	95	Remote chiller water plant	Support for SM and PP Buildings (*Environmental Appraisal Report*, Vol. 10)[b]	No
99	96	Unknown	Prefab building: sold and moved offsite (*Environmental Appraisal Report*, Vol. 10)[b]	No
100	98	Fire station	Office areas Classroom training facilities Operations center Vehicle storage (fire, ambulance, and hazardous materials unit) (*Environmental Appraisal Report*, Vol. 10)[b]	No
101	99	Office space Locksmith shop	Site security operations Emergency operations center (*Environmental Appraisal Report*, Vol. 10)[b]	No
102	100	Office space	Site security officers Weapons storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
103	101	Office space Storage area	Small tool storage Maintenance chemical storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
104	102	Office space	Engineering support (*Environmental Appraisal Report*, Vol. 10)[b]	No
105	104	**Maintenance shop** Office space	Electronics and small parts assembly and fabrication (*Environmental Appraisal Report*, Vol. 10)[b]	Yes 1,4-dioxane
106	105	**Machine shop**	Parts machining (*Environmental Appraisal Report*, Vol. 10)b	Yes 1,4-dioxane
107	106	Sand filters Storage area	Houses sand filters for SD facility Monitoring equipment General storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
108	113	Wastewater treatment	WWTP: part of the SD facility (Buildings 57 and 112) Dewatering: sludge press Chemical storage Equipment storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
109	120	Office space	Administrative offices for D&D groups Radiological Assistance Team supply storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
110	Generator 1	Backup/standby generator	Diesel generator (*Environmental Appraisal Report*, Vol. 11)[b]	No
111	Generator 6	Backup/standby generator	Diesel generator (*Environmental Appraisal Report*, Vol. 11)[b]	No
112	Magazine 5	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
113	Magazine 6	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
114	Magazine 7	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No

Table C-1. Summary of Building Processes and Uses and Potential for 1,4-dioxane and Perchlorate (continued)

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
115	Magazine 8	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
116	Magazine 10	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
117	Magazine 11	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
118	Magazine 20	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
119	Magazine 52	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
120	Magazine 53	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
121	Magazine 54	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
122	Magazine 64	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
123	Magazine 80	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
124	Magazine 81	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
125	Magazine 82	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
126	Magazine 83	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
127	Magazine 84	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No

Notes:
[a] Boldface terms indicate notable building uses or processes associated with the subject emerging contaminants.
[b] EG&G Mound Applied Technologies, 1996. *Environmental Appraisal Report of the Mound Plant*, Vols. 1–11, March.
[c] DOE (U.S. Department of Energy), 1995. *Technical Manual MD-22153, Mound Site Radionuclides by Location, Issue 1*, June.

Abbreviations:
CAD = computer aided drafting
CFX = californium multiplier
D&D = Decontamination and Decommissioning
HEPA = high-efficiency particulate air
LLW = low-level waste
LSA = low specific activity
MOCA = 4,4'-methylene-bis(2-chloroaniline)
PFAS = per- and polyfluorinated alkyl substances
PMC = plutonium-molybdenum cermet
PPO = pressed plutonium oxide
Pu = plutonium
PVD = physical vapor deposition
R&D = research and development
RTG = radioisotope thermoelectric generator
Th = thorium
TRU = transuranic
U = uranium

Addendum to

A Summary of the Per- or Polyfluorinated Alkyl Substances Records Search for Indications of Use at the Mound, Ohio, Site (LMS/MND/S15235)

1.0 Introduction

Since the completion of the *Summary of the Per- or Polyfluorinated Alkyl Substances Record Search for Indications of Use at the Mound, Ohio, Site* (DOE 2016), the U.S. Environmental Protection Agency (EPA) has expanded its review of these emerging contaminants to include the broad category of polyfluorinated alkyl substances (PFAS) and PFAS-containing products. The summary report documented the research methodology and conclusions regarding the use of perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) compounds, which are subsets of PFAS, at the Mound, Ohio, Site. It was concluded in the summary report that PFOS and PFOA were not used at the Mound site.

As part of the *Fifth Five-Year Review for the Mound, Ohio, Site, Miamisburg, Ohio* (DOE 2021), emerging contaminants were evaluated as part of the review process. EPA maintains a list of emerging contaminants that should be evaluated at cleanups at federal facilities (https://www.epa.gov/fedfac/emerging-contaminants-and-federal-facility-contaminants-concern). EPA considers that these contaminants present unique issues and challenges to the environmental community and EPA at contaminated federal facility sites. The list includes PFAS as emerging contaminants.

PFAS encompass thousands of substances that can be found in an extensive list of chemicals and products used in a wide range of processes and consumer products; these substances are released into groundwater through spills or improper disposal at manufacturing or processing sites. Chemicals or products that contain small amounts of PFAS as additives may have been purchased and used individually at any site. PFAS have been produced since the 1940s and used globally in manufacturing, firefighting, and common household products. PFAS are considered emerging contaminants of concern because of their high persistence in the environment and the limited research into the harm that may cause to human health.

Review of available information regarding PFAS indicates that several processes in which PFAS or PFAS-containing products may have been used, such as metals plating and plastics production, might have occurred at the Mound site. It was recommended in the Fifth Five-Year Review (DOE 2021) that PFAS should be further evaluated.

1.1 Purpose

This addendum provides an update to the *Summary of the Per- or Polyfluorinated Alkyl Substances Record Search for Indications of Use at the Mound, Ohio, Site* (DOE 2016) that focused only on PFOA and PFOS. The evaluation methodology and conclusions regarding the records search for indications of the use of PFAS and PFAS-containing products are outlined in this report.

1.2 Objective

The objective of this evaluation was to determine through a records search whether PFAS or PFAS-containing products were purchased and used at the Mound site. Information from this review will be used by the Mound Core Team (U.S. Department of Energy [DOE], EPA, and Ohio Environmental Protection Agency) for a determination regarding the protectiveness of the site conditions with respect to PFAS.

1.3 Background

The Mound site was established in 1948 by the U.S. Atomic Energy Commission, a predecessor to DOE, to support early atomic weapons programs. The site later grew into an integrated research, development, and production facility performing work in support of DOE weapons and energy programs, with emphasis on explosives and nuclear technology. Materials and components were not manufactured on a large scale; instead, materials and components were produced in small batches and assembled by hand. Small quantities of materials were purchased at any time and used for specific phases of production at the site.

2.0 Evaluation Methodology

This evaluation used information presented in the *Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS)* (Glüge et al. 2020), a study endorsed by EPA, to identify processes or activities that typically use PFAS or PFAS-containing products. The study identified more than 200 uses in 64 industry branches or use categories for more than 1400 individual PFAS. The study laid the groundwork to identify what processes at the Mound site may have used PFAS or products that contained low concentrations of PFAS additives to enhance performance. A review of processes and activities performed in each building was done to identify if there was the potential for use of PFAS or PFAS-containing products. After identifying the buildings and areas, a determination was made whether PFAS or PFAS-containing products were used in those buildings or areas.

Evaluating the use of PFAS or PFAS-containing products consisted of three tasks:

- **Task A:** *Building and area use review*—identify the processes and activities that took place in the building or area at the Mound site
- **Task B:** *Process or activity review*—compare the processes and activities identified for each building to those outlined as typically involving the use of PFAS or PFAS-containing products
- **Task C:** *Chemical inventory review*— for those buildings retained from Task B, review the chemical inventory for PFAS and PFAS-containing products

Information from the *Summary of the Per- or Polyfluorinated Alkyl Substances Record Search for Indications of Use at the Mound, Ohio, Site* (DOE 2016) and results from the study performed by Glüge et al. (2020) were reviewed and used where appropriate. Many references and databases were reviewed again focusing on PFAS and PFAS-containing products. This section describes the results of the evaluation. The list of references used for this evaluation is presented in Attachment A-1 of the DOE (2016) summary report.

2.1 Building and Area Use Review

An extensive review was performed to detail the processes and other activities that were performed in each building. A total of 127 buildings that are listed in Appendix A, Table A-1, were thoroughly reviewed to identify building-specific processes and activities performed to support work at the Mound site.

The Operable Unit 1 (OU-1) landfill area covers 4 acres on the Mound site. It includes the initial landfill that received plant waste materials (general trash and liquid waste) from 1948 to 1974 and the former sanitary landfill where much of the waste from the initial landfill was later moved and encapsulated in 1977. There were known releases of volatile organic compounds from the former landfill into the underlying groundwater.

2.2 Process or Activity Review

A review of the lists provided in the *Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS)* (Glüge et al. 2020) includes uses and processes that occurred at the Mound site as shown in Table 1.

Table 1. Uses or Processes with Potential PFAS

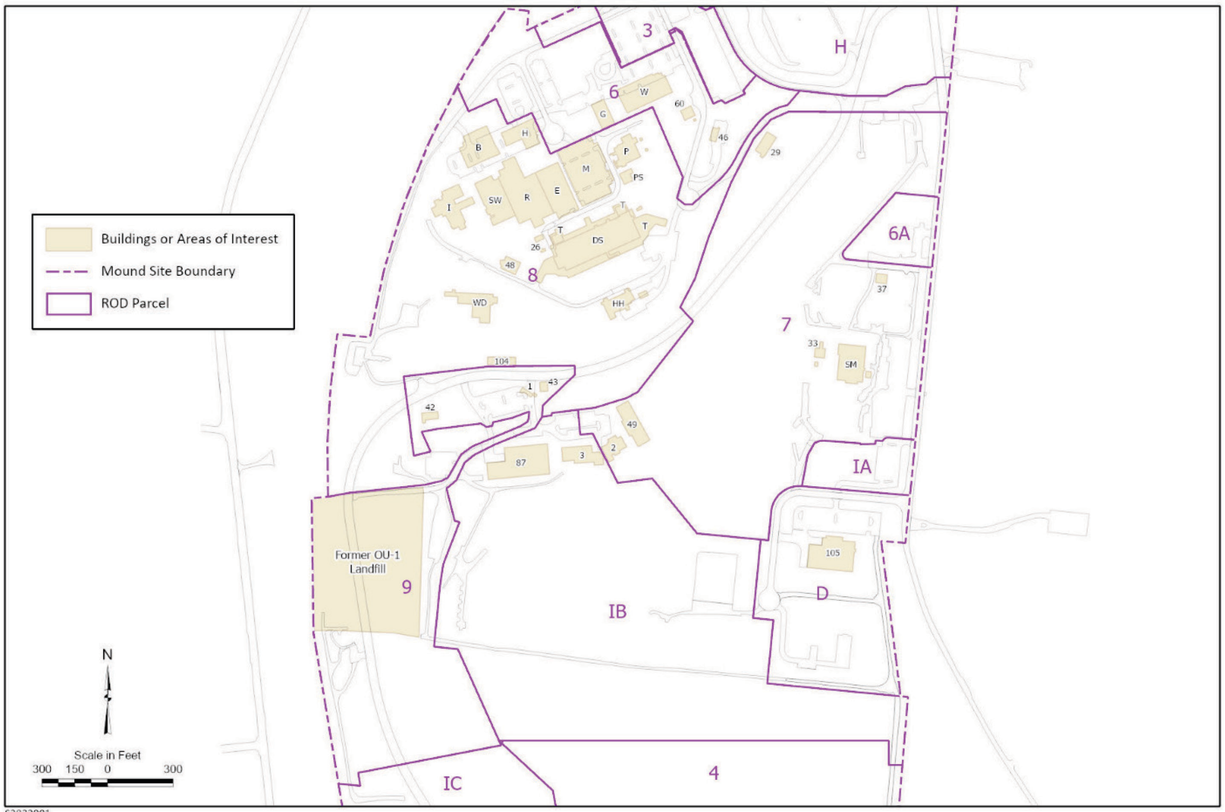
Industry Branches	Other Use Categories
• Chemical industry • Electroplating • Electronic industry • Machinery and equipment • Metal production • Plastics production	• Cleaning compositions • Coatings, paints, and varnishes • Electronic devices • Laboratory supplies and instrumentation • Lubricants and greases • Metallic and ceramic surfaces • Soldering • Wire and cable insulation

A listing of processes and activities performed in each building is summarized in Appendix A, Table A-1. A comparison of the processes and uses identified for each building with those listed in Table 1 identified that 31 buildings may have housed operations where PFAS or PFAS-containing products were potentially used as part of research, development, or production. A summary of the buildings is provided in Table 2, and the general locations of these buildings are depicted on Figure 1. All the buildings listed, except for T Building and Building 105, were demolished according to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements.

Table 2. Building Summary

DOE Building ID			
B	P	W	36
DS	PS	WD	37
E & E Annex	PP	3	38
G	R	26	39
H	SD	28	40
HH	SM	29	104
I	SW	33	105
M	T	35	

General trash and some liquid wastes generated from plant operations were disposed of in the former OU-1 landfill. It is likely that empty containers from products containing these chemicals or materials (e.g., rags, personal protective equipment, and secondary containers that came in contact with these products) were disposed of in the former landfill. As part of the CERCLA cleanup, most of the radiological source material was removed from the former landfill area in 2005. The OU-1 landfill was later excavated in two phases from 2007 through 2010 as part of non-CERCLA work to support future redevelopment of the property by the Mound Development Corporation. It was verified that the excavation remediated the former landfill to EPA's risk-based standards for industrial or commercial use.



S3833001

Abbreviation: ROD = record of decision

Figure 1. Locations of Buildings Where PFAS or PFAS-Containing Products May Have Been Used

2.3 Chemical Inventory and Other Record Review

Chemical inventories and other records were reviewed for each building listed in Table 2 to determine whether PFAS or PFAS-containing products were used. One notation in the chemical inventory for the DS Building indicates that 3 gallons of perfluoro polyether (a type of PFAS) was purchased and used. The list of products that could have PFAS used as an additive is extensive, and the review of the chemical inventories indicated that the types of products that typically contained low-level amounts of unnamed PFAS were used at the Mound site.

3.0 Conclusions

After review of research, development, and production activities; powerhouse and waste treatment operations; chemical inventories; and general plant operations and maintenance records, the following can be concluded:

- Chemicals or products were purchased that may have contained low concentrations of unnamed PFAS. These were used as process materials, plating additives, plastic materials, lubricants and oils and greases and for other functions during research, development, and production activities at the Mound site.
- Purchase and use of the PFAS perfluoro polyether were confirmed from the review of chemical inventories for the DS Building. Perfluoro polyether was purchased in a small quantity (3 gallons) and used as a lubricant for high-temperature pumps.
- The 31 buildings identified in Section 2.2 should be considered as potential areas where PFAS or PFAS-containing products could have been used. It has been noted from review of the chemical inventories and process documents that chemicals were purchased and used in limited amounts and access was allowed only for approved uses or processes. Products that may have contained these chemicals were used or purchased for use in many of the buildings identified in this review because these chemicals may not have been listed on the product labels or Material Data Sheets.
- Materials that may have been used with or contaminated by chemicals or products that potentially contained PFAS were likely disposed of in the former OU-1 landfill. It has been noted from review of the chemical inventories and process documents that chemicals were purchased and used in limited amounts and consumed upon use. The potential presence of PFAS would likely be the result of residual amounts on materials within the former landfill.

4.0 References

DOE (U.S. Department of Energy), 2016. *Summary of the Per- or Polyfluorinated Alkyl Substances Record Search for Indications of Use at the Mound, Ohio, Site*, LMS/MND/S15235, Office of Legacy Management, December.

DOE (U.S. Department of Energy), 2021. *Fifth Five-Year Review for the Mound, Ohio, Site, Miamisburg, Ohio*, LMS/MND/S31971, Office of Legacy Management, September.

Glüge, J., M. Scheringer, I.T. Cousins, J.C. DeWitt, G. Goldenman, D. Herzke, R. Lohmann, C.A. Ng, X. Trier, Z. Wang, 2020. "An Overview of the Uses of Per- and Polyfluoroalkyl Substances (PFAS)," *Environmental Science: Processes & Impacts* 22(12):2345–2373.

Appendix A

Building Process and Use Summary

Table A-1. Summary of Building Processes and Uses and Potential for PFAS and PFAS-Containing Products[a]

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
1	A	Office Space	Administration (A) Building Administrative offices Medical services Janitorial supplies	No
2	B	Biological testing Inert assembly of nonexplosive devices Laser **welding** and marking **Mold shop** PVD Transducer production Industrial hygiene laboratory	Biological (B) Building Originally used for biological testing then converted to detonator manufacturing Organic solvent use Ethylene diamine called out as used Nondestructive testing of devices (*Environmental Appraisal Report*, Vol. 2)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
3	C	Cafeteria	Cafeteria Conference/meeting rooms Paper file storage	No
4	DS	**Metrology** processes **Explosives** development and production	Energetic materials development Detonator and timer development and production Physical vapor disposition lab Tape processing lab (flexible printed circuits) Welding labs **Perfluoro polyether (PFAS)** was used as a high temp, liquid lubricant Chemical inventory lists *p*-dioxane and perchlorate, with 3 gallons of *p*-dioxane listed in Room 131B (*Environmental Appraisal Report*, Vol. 2)[b]	**Yes**
5	E and E Annex	Analytical laboratories Products assembly	Environmental (E) Building Environmental and biological analysis Electronics (E) Building (later designation) Analysis of soil, water, vegetation, and biota Use of **standards and tracers** Electronics and **explosives** research **Explosives** laboratory Detonator production **Plastics** and adhesives R&D Chemical inventory lists *p*-dioxane and perchlorate (*Environmental Appraisal Report*, Vol. 2)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
6	G	Fleet and heavy machinery service Storage of supplies (janitorial and grounds)	Garage used for **servicing, repairing, and painting** vehicles and equipment Waste oils noted (*Environmental Appraisal Report*, Vol. 2)[b]	**Yes**
7	GH	Visitor control point Office space	Mound transition center (*Environmental Appraisal Report*, Vol. 2)[b]	No
8	GIS	Guard post	Checkpoint for site access (*Environmental Appraisal Report*, Vol. 2)[b]	No
9	GP-1	Office and general-purpose space Firing range Communications center	Security training Noted that tear gas was used (*Environmental Appraisal Report*, Vol. 2)[b]	No
10	GP-5	Guard post	(*Environmental Appraisal Report*, Vol. 3)[b]	No
11	GP-8	Guard post	(*Environmental Appraisal Report*, Vol. 3)[b]	No

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
12	GP-44	Guard post	Equipment room Uniform (security) laundry (*Environmental Appraisal Report*, Vol. 3)[b]	No
13	GW	Office space Record storage	(*Environmental Appraisal Report*, Vol. 3)[b]	No
14	H	Laundry service **Maintenance shop** Laboratories	Laundry of both contaminated (hot) and clean (cold) clothing Bioassay and environmental analysis Hydride storage module Distillation columns Equilibrator and uranium bed Cryogenic distillation module Chemical inventory lists p-dioxane and perchlorate (*Environmental Appraisal Report*, Vol. 3)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
15	HH	Hydrolysis of bismuth chloride Hydrolysis of aluminum chloride Waste treatment	Hydrolysis House (HH) Stable gaseous isotope separation by diffusion (gaseous and liquid) Cryogenic processes Waste oils noted Treatment of T Building polonium wastes Chemical inventory lists *p*-dioxane and perchlorate (*Environmental Appraisal Report*, Vol. 3)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
16	I	Loading and testing of **explosive** actuators Development and production using energetic materials Laboratories	Isolation (I) Building Use of MOCA noted Detonator production **Plastics** and **ceramics** R&D and production Bioassay and environmental analysis Health physics analysis (*Environmental Appraisal Report*, Vol. 3)[b] (Mou*nd Site Radionuclides by Location*)[c]	**Yes**
17	M	**Machine shop** **Electroplating** operations Electronics maintenance Electrical substation	Machining of ^{238}U (*Environmental Appraisal Report*, Vol. 3)[b]	**Yes**
18	Modular 4	Office space	Contractor training (*Environmental Appraisal Report*, Vol. 3)[b]	No
19	OSE	Office space Photographic services Computer facilities Cafeteria	(*Environmental Appraisal Report*, Vol. 3)[b]	No
20	OSW	Office space CAD production and processing	(*Environmental Appraisal Report*, Vol. 4)[b]	No
21	P	Centralized processes and breathing air Steam and condensate: boilers and chillers Chilled water supply and return Potable water treatment Electric power distribution: electrical substations	Powerhouse Plant steam and chiller production and distribution Domestic water treatment, chlorination, softening, and distribution Fuel oils and lubricants used (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
22	PH	Fuel oil pumps to powerhouse Steam line condensate pumps Brine line to Building 24	Pump house (PH) (*Environmental Appraisal Report*, Vol. 4)[b]	No
23	PS	**Paint** facilities	**Paint Shop** (PS) Brush painting Spray painting: Ohio EPA permitted spray booth Sanding/priming/drying Computer-generated signs (*Environmental Appraisal Report*, Vol. 4)[b]	**Yes**
24	PP	Plutonium production Fabrication Recovery Waste treatment Analytical laboratories Research and development	Plutonium Processing (PP) Building Several processes: PMC, PPO, and variations on PPO Processes from SM Building were transferred to PP Treatment of aqueous wastes, caustic solutions, ammonium hydroxides Laboratory analysis for corrosive vaporization processes, caustic scrubber, and reagents for scrubbing (*Mound Site Radionuclides by Location*)[c]	**Yes**
25	R	Tritium recovery Analytical support laboratories R&D laboratories Office space	Research (R) Building Nuclear Operations R&D Pilot-scale work for T Building processes Tritiated solvents and nickel carbonyl used Tritium recovery using heat-up reactor **Plating** of metals for alpha source production Thorium and helium separation **Electroplate** deposition of polonium (pilot-scale) Several processes: PMC and PPO **Welding** operations: ^{234}U program Analytical laboratory used X-ray diffraction and gas synthesis systems for metal tritides, surface area analysis, differential analysis, infrared spectrometry, and ion chromatography (Environmental Appraisal Report, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
26	SD	**Sanitary treatment** operations	Sewage disposal (SD) (*Environmental Appraisal Report*, Vol. 4)[b]	**Yes**
27	SM	Plutonium production Fabrication Recovery Waste treatment Analytical laboratories Research and development	Special Metallurgical (SM) Building Heat source program Plutonium metals production Microsphere process using plasma torch Recovery of plutonium using acids ^{234}U separation Waste treatment: plutonium (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
28	SST	Storage of road salt	Salt storage for site roads (*Environmental Appraisal Report*, Vol. 4)[b]	No

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
29	SW	Tritium recovery and purification Tritium component development Waste treatment Support laboratories Research and development	Materials testing R&D for Pu, U, Th, and protactinium Semi works pilot studies **Plastics** and adhesives R&D Tritium enrichment by thermal diffusion Scrap recovery and waste solidification Hot gas facility **Ceramics** facility Cooling tower and chillers Effluent removal system Radionuclide refining and separation Uranium recovery using acid dissolution Component testing: thermal and shock Metallurgical analysis that involved cutting Wastewater treatment Environmental laboratories **Plastics** potting program **Plating** of metals for alpha source production (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
30	T	Tritium operations: Purification and recovery Research and development Calorimetry production Heat source calibration X-ray and safeguards gamma scanning Polonium-210 purification Radionuclide extraction (bismuth and beryllium) Nickel carbonyl vapor preposition process Hydrogen isotope separation Neuron activation analysis Storage of transuranic materials Polonium and tritium decontamination **Machine shop**	Technical (T) Building Polonium processing and separation Polonium recovery using induction heaters Neutron source program Neutron irradiation with neutron accelerator Hydrogen isotope separation program Poodle heat source program: fuel capsule assembly R&D of polonium processing and fuel production Testing: environmental using gamma and mass spectroscopy Testing: assay laboratory for Safeguards Verification Facility Testing: bioassay laboratory Testing: nuclear measurement Decontamination using solvents and alcohol Maintenance and hot and cold **machine shop** Fabrication and maintenance of tritium monitors (*Environmental Appraisal Report*, Vol. 4)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
31	W	**Plastics** manufacturing Office space Trade shops	Original **plastics** manufacturing, which was later moved to Building 29 **Plastics** formulation **Plastics** testing Roll milling, mixing dry **plastics** process Carpentry **Sheet metal work** Pipefitter and **welding** Heating, ventilation, and air conditioning Electrical Tool and materials storage (*Environmental Appraisal Report*, Vol. 5)[b]	**Yes**

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
32	WD	**Wastewater treatment** Analytical laboratory Bench-scale testing	Waste Disposal (WD) Building LSA wastewater from Buildings SW, R, PP, SM, HH, T, B, and H Treatment of both alpha and beta Treatment by precipitation, coagulation, filtering, and sludge solidification. Supernatant neutralized to proper pH (*Environmental Appraisal Report*, Vol. 5)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
33	WDA	**Wastewater treatment** Waste incineration	Waste Disposal Alpha (WDA) Building Treatment of plutonium wastewater from Buildings SM and PP Treatment of beta wastewater from Buildings SW, R, and HH Treatment by clariflocculation tanks, ultra-filtration, and reverse osmosis Separation of isotopes from wastewaters Cyclone incinerators Tank and equipment cleaning (*Environmental Appraisal Report*, Vol. 5)[b] (*Mound Site Radionuclides by Location*)[c]	**Yes**
34	WH	Water pumps Muriatic acid treatment	Well house (WH) (*Environmental Appraisal Report*, Vol. 5)[b]	No
35	WH-2	Water pumps	(*Environmental Appraisal Report*, Vol. 5)[b]	No
36	WH-3	Water pumps	(*Environmental Appraisal Report*, Vol. 5)[b]	No
37	1	Research and testing of **energetic** materials Processing and blending of explosive powders Packaging of energetic materials	(*Environmental Appraisal Report*, Vol. 5)[b]	No
38	2	Destructive testing of **energetic** materials X-ray and photographic testing	(*Environmental Appraisal Report*, Vol. 5)[b]	No
39	3	Destructive testing Environmental testing laboratory Office space Fabrication and assembly	Testing, fabrication, and assembly of detonators (*Environmental Appraisal Report*, Vol. 5)[b]	**Yes**
40	13	Remote monitoring of burn Area	Monitoring of energetic materials destruction (*Environmental Appraisal Report*, Vol. 5)[b]	No
41	14	Observation post	Burn area (*Environmental Appraisal Report*, Vol. 5)[b]	No
42	17	Chemical storage and staging Sampling and testing of drummed chemicals	Bonded storage of chemicals (*Environmental Appraisal Report*, Vol. 5)[b]	No
43	21	Thorium sludge consolidation Thorium drum storage	Warehouse 15 Storage of thorium-232 sludge from Monex project Corrosive Designed to be self-containing and leak proof Leakage reported (*Environmental Appraisal Report*, Vol. 5)[b] (*Mound Site Radionuclides by Location*)[c]	No
44	22	Storage of solid LLW	(*Environmental Appraisal Report*, Vol. 5)[b]	No

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
45	23	Warehouse	Staging and shipping of LLW Staging and shipping of TRU and mixed waste Floor coated to contain spills (*Environmental Appraisal Report*, Vol. 6)[b]	No
46	24	Raw water treatment	Zeolite softening beds Chemical injection equipment (*Environmental Appraisal Report*, Vol. 6)[b]	No
47	25	Meteorological station Telephone switching	(*Environmental Appraisal Report*, Vol. 6)[b]	No
48	26	**Welding** shop Storage Office space	(*Environmental Appraisal Report*, Vol. 6)[b]	**Yes**
49	28	**Ceramics** development and production	(*Environmental Appraisal Report*, Vol. 6)[b]	**Yes**
50	29	**Plastics** manufacturing	Plastics formulation Plastics testing Roll milling, mixing dry plastics process Solvent supply Asbestos slurry kettle Varnish kettles Materials mixers Acetone pumps (*Environmental Appraisal Report*, Vol. 6)[b]	**Yes**
51	30	Radiological counting laboratory	Tritium and gross alpha counting **Liquid scintillation** Gamma scanning: tritium and gross alpha/beta (*Environmental Appraisal Report*, Vol. 6)[b]	No
52	31 31-A	Storage and staging of radiological wastes	LLW, TRU, and LSA wastes (*Environmental Appraisal Report*, Vol. 6)[b]	No
53	33	Equipment **maintenance**	Heavy equipment repair/maintenance Equipment storage (*Environmental Appraisal Report*, Vol. 6)[b]	**Yes**
54	34	Firefighter training "Bioremediation farm"	"Burning Building" Performed burning of various fuels and flammable materials for training Area where site soils were brought for bioremediation treatment (*Environmental Appraisal Report*, Vol. 6)[b]	No
55	35	Nondestructive testing californium-232 multiplier	Detonator testing X-ray and eddy current testing of materials Control room for multiplier (*Environmental Appraisal Report*, Vol. 6)[b]	**Yes**
56	36	Heat source/ RTG operations	Testing High temperature bakeout of graphite modules Cleaning of modules from bakeout (*Environmental Appraisal Report*, Vol. 6)[b]	**Yes**
57	37	Heat source/ RTG operations	Research and development **Machine shop** for heat source program: machining, cleaning, and heat treating (*Environmental Appraisal Report*, Vol. 7)[b]	**Yes**
58	38	Heat source/ RTG operations	Production, assembly, and testing of RTGs Analytical facilities Health physics equipment calibration Waste recharacterization and repackaging (*Environmental Appraisal Report*, Vol. 7)[b]	**Yes**

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
59	39	Maintenance shop	**Machine shop** Storage: paints and solvents Fiberglass wooden box production (*Environmental Appraisal Report*, Vol. 7)[b]	**Yes**
60	40	Print shop	Presses Developing Microfiling Reproduction Document assembly (*Environmental Appraisal Report*, Vol. 7)[b]	**Yes**
61	42	Pyrotechnics and thermite operations	**Pyrotechnics and thermite** production Component testing **Pyrotechnics** assembly **Energetic materials** assembly (*Environmental Appraisal Report*, Vol. 7)[b]	No
62	43	Thermite operations	**Thermite** research and development (*Environmental Appraisal Report*, Vol. 7)[b]	No
63	44	Cafeteria	Food preparation and service Office space (*Environmental Appraisal Report*, Vol. 7)[b]	No
64	45	Health physics calibration	Instrumentation Personnel detectors Beta calibration X-ray calibration Calibration equipment repair (*Environmental Appraisal Report*, Vol. 7)[b]	No
65	46	Welding shop Machine shop	**Energetic materials** Support to the heat source program (*Environmental Appraisal Report*, Vol. 7)[b]	No
66	47	Administration	Security administration office Weapons storage Classified wastes storage (*Environmental Appraisal Report*, Vol. 7)[b]	No
67	48	Materials testing	**Energetic materials** analytical testing Cutting of materials for testing (*Environmental Appraisal Report*, Vol. 8)[b]	No
68	49	Laboratory analysis	Production laboratory for **energetic** materials Material staging facility (*Environmental Appraisal Report*, Vol. 8)[b]	No
69	50	Fabrication testing	Assembly and testing of RTGs (*Mound Site Radionuclides by Location*)[c]	No
70	51	Incinerator Thermite production Carbon production	Documented as limited use for incineration of: Nonradiological wastes Paints, oils, and solvents Thermite and carbon production for lithium battery capacitors (*Environmental Appraisal Report*, Vol. 8)[b]	No
71	55	Wastewater testing	Testing and storage of testing equipment and supplied (*Environmental Appraisal Report*, Vol. 8)[b]	No
72	56	Pumping station	(*Environmental Appraisal Report*, Vol. 8)[b]	No
73	57	Wastewater treatment	SD Building Wastewater treatment plant (WWTP) Control house for treatment processes (*Environmental Appraisal Report*, Vol. 8)[b]	No

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
74	58	Filter systems	Semi Works (SW) Building support systems alpha and beta filter bank Exhaust plenum HEPA filters (*Environmental Appraisal Report*, Vol. 8)[b]	No
75	59	Neutron radiography	CFX process Pneumatic transfer of neutron source to uranium plates Subcritical assembly of equipment (Environmental Appraisal Report, Vol. 8)[b] (*Mound Radionuclides by Location*)[c]	No
76	60	Nondestructive testing	**Ceramics** research and development (*Environmental Appraisal Report*, Vol. 8)[b]	No
77	61	Warehouse	Central Warehouse Gas cylinder storage Flammable materials storage (*Environmental Appraisal Report*, Vol. 8)[b]	No
78	63-E 63-W	Testing laboratory	Spin-testing facility Product quality testing Environmental storage (*Environmental Appraisal Report*, Vol. 8)[b]	No
79	65	Office space	(*Environmental Appraisal Report*, Vol. 8)[b]	No
80	66	Office space	(*Environmental Appraisal Report*, Vol. 8)[b]	No
81	67	Office space	(*Environmental Appraisal Report*, Vol. 8)[b]	No
82	68	Storage area	D&D operations: LSA waste from R and SW for shipping Plant operations: storage area for parts and materials (*Environmental Appraisal Report*, Vol. 9)[b]	No
83	69	Office space	(*Environmental Appraisal Report*, Vol. 9)[b]	No
84	70	Office space	(*Environmental Appraisal Report*, Vol. 9)[b]	No
85	71	Chemical storage	Flammable liquids (*Environmental Appraisal Report*, Vol. 9)[b]	No
86	72	Storage area	Hazardous waste (*Environmental Appraisal Report*, Vol. 9)[b]	No
87	73	Storage area	Compressed gas cylinders (*Environmental Appraisal Report*, Vol. 9)[b]	No
88	74	Storage area	Final packaging for explosives shipping (*Environmental Appraisal Report*, Vol. 9)[b]	No
89	79	Office space	(*Environmental Appraisal Report*, Vol. 9)[b]	No
90	85	Building unused	Class I powder processing facility: never used (*Environmental Appraisal Report*, Vol. 9)[b]	No
91	87	Materials testing	Destructive testing of **explosives** Fabrication of electronic test systems (*Environmental Appraisal Report*, Vol. 9)[b]	No
92	88	Office space	Administration and office building for RTC program (*Environmental Appraisal Report*, Vol. 9)[b]	No
93	89	Storage area	Storage of **energetic** materials (*Environmental Appraisal Report*, Vol. 9)[b]	No
94	90	Control systems	Systems for unit controls and waste feed for the retort unit (rotary kiln) in Burn Area (*Environmental Appraisal Report*, Vol. 9)[b]	No

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
95	92	Training Office space	Training for production support Soldering certification (*Environmental Appraisal Report*, Vol. 9)[b]	No
96	93	Office space	(*Environmental Appraisal Report*, Vol. 10)[b]	No
97	94	Office space Storage area Laboratory analysis	Environmental laboratory Soil and water sampling storage LSA storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
98	95	Remote chiller water plant	Support for SM and PP facilities (*Environmental Appraisal Report*, Vol. 10)[b]	No
99	96	Unknown	Prefab building: sold and moved offsite (*Environmental Appraisal Report*, Vol. 10)[b]	No
100	98	Fire station	Office areas Classroom training facilities Operations center Vehicle storage (fire, ambulance, and hazardous materials unit) (*Environmental Appraisal Report*, Vol. 10)[b]	No
101	99	Office space Locksmith shop	Site security operations Emergency operations center (*Environmental Appraisal Report*, Vol. 10)[b]	No
102	100	Office space	Site security officers Weapons storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
103	101	Office space Storage area	Small tool storage Maintenance chemical storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
104	102	Office space	Engineering support (*Environmental Appraisal Report*, Vol. 10)[b]	No
105	104	**Maintenance shop** Office space	Electronics and small parts assembly and fabrication (*Environmental Appraisal Report*, Vol. 10)[b]	**Yes**
106	105	**Machine shop**	Parts machining (*Environmental Appraisal Report*, Vol. 10)[b]	**Yes**
107	106	Sand filters Storage area	Houses sand filters for SD facility Monitoring equipment General storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
108	113	Wastewater treatment	WWTP: part of the SD facility (Buildings 57 and 112) Dewatering: sludge press Chemical storage Equipment storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
109	120	Office space	Administrative offices for D&D groups Radiological Assistance Team supply storage (*Environmental Appraisal Report*, Vol. 10)[b]	No
110	Generator 1	Backup/standby generator	Diesel generator (*Environmental Appraisal Report*, Vol. 11)[b]	No
111	Generator 6	Backup/standby generator	Diesel generator (*Environmental Appraisal Report*, Vol. 11)[b]	No
112	Magazine 5	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
113	Magazine 6	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No

Item #	Building ID	Processes/Activities	Notes and Information Sources	Retain
114	Magazine 7	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
115	Magazine 8	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
116	Magazine 10	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
117	Magazine 11	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
118	Magazine 20	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
119	Magazine 52	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
120	Magazine 53	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
121	Magazine 54	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
122	Magazine 64	Storage	Pyrotechnics and energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
123	Magazine 80	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
124	Magazine 81	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
125	Magazine 82	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
126	Magazine 83	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No
127	Magazine 84	Storage	Energetic materials (*Environmental Appraisal Report*, Vol. 11)[b]	No

Notes:
[a] Boldface terms indicate notable building uses or processes associated with subject emerging contaminants.
[b] EG&G, Mound Applied Technologies, 1996. *Environmental Appraisal Report of the Mound Plant*, Vols. 1–11, March.
[c] DOE (U.S. Department of Energy), 1995. *Technical Manual MD-22153, Mound Site Radionuclides by Location, Issue 1*, June.

Abbreviations:
CAD = computer aided drafting
CFX = californium multiplier
D&D = Decontamination and Decommissioning
HEPA = high-efficiency particulate air
LLW = low-level waste
LSA = low specific activity
MOCA = 4,4'-methylene-bis(2-chloroaniline)
PMC = plutonium-molybdenum cermet
PPO = pressed plutonium oxide
Pu = plutonium
PVD = physical vapor deposition
R&D = research and development
RTG = radioisotope thermoelectric generator
TRU = transuranic
U = uranium