Site Closeout of the Linde FUSRAP Site, Tonawanda, New York - 15441

Michelle Barker*, Steve Bousquet*, Lisa Durham**, Linda Houston*, Sunita Kamboj**, Karen Keil*, Mike Polek*, and Bob Simmington*
* US Army Corps of Engineers - Buffalo District
1776 Niagara Street, Buffalo, NY 14207, USA
** Argonne National Laboratory, Environmental Science Division
9700 South Cass Avenue, Argonne, IL 60439, USA

ABSTRACT

The US Army Corps of Engineers (USACE) Buffalo District, with assistance from Argonne National Laboratory (Argonne), prepared a Site Closeout Report (SCOR) for the Linde Formerly Utilized Sites Remedial Action Program (FUSRAP) Site in accordance with Engineer Regulation (ER) 200-1-4 [1]. Under FUSRAP, USACE is authorized to investigate, and clean up or control sites contaminated as the result of actions by the Atomic Energy Commission (AEC) and its predecessor, the Manhattan Engineer District (MED), in support of the nation's early atomic energy and weapons program.

The SCOR documents response actions conducted at the Linde FUSRAP Site between 1996 and 2013. These response actions include two non-time-critical removal actions and long-term remedies associated with the three operable units (OUs) at the site: 1) soils and structure surfaces (except Building 14), 2) Building 14, and 3) groundwater. The report summarizes the site history, previous investigations, selected remedies, remedial actions, waste disposal, community involvement, monitoring results, recycling, quality assurance/quality control practices, post-remediation dose assessment, remedial costs, and five year review requirements.

INTRODUCTION

Site Location and Description

The Linde FUSRAP Site is located in the Town of Tonawanda, Erie County, New York; approximately 14 kilometers (km) [9 miles (mi)] north of downtown Buffalo, New York and 3.4 km (1.5 mi) east of the Niagara River. The approximately 55-hectare (135-acre) Linde Site is an active industrial facility owned by Praxair, Incorporated (Praxair), and has been an industrial site for more than 60 years. This fenced property contains office buildings, fabrication facilities, warehouse storage areas, material lay down areas, and parking lots with access to the property controlled by the property owner, Praxair. A series of utility tunnels underlies the site that interconnects some of the main buildings and by an extensive network of storm and sanitary sewers. Public water and sanitary sewer services are provided to the property.

The site is bounded on the north and south by other industrial properties and small businesses, on the east by CSX railroad tracks and National Grid property and easements, and on the west by a park owned by Praxair that is open to the public. Recreational uses near the property include Sheridan Park, owned by the Town of Tonawanda's Parks and Recreation Department, which is located 0.4 kilometers (km) [quarter mile] to the northwest of the property. Two Mile Creek flows through this property. Sensitive uses within 1.6 km (one mile) of the Linde Site include five schools, two community buildings, and a senior citizens' center.

Site Operational History

Between 1942 and 1946, the MED contracted with the Linde Air Products Division of Union Carbide to separate uranium from pitchblende uranium ore and domestic ore concentrates. This was due to the Linde Air Products Corporation's experience with processing uranium to produce the salts used to color ceramic glazes. Four African pitchblende ores from the Belgian Congo and three domestic ore concentrates from the western United States (Colorado) were processed by the Linde Air Product Division. Five Linde buildings were involved in MED activities: Building 14 (built by Union Carbide in the mid 1930's) and Buildings 30, 31, 37, and 38 (built by the MED on land owned by Union Carbide).

After the MED contract was terminated, ownership of Buildings 30, 31, 37, and 38 was transferred to Linde and Union Carbide operations continued at the Linde Site [2]. Praxair acquired the property in the 1990's and continues to perform commercial industrial processes, while focusing primarily on research and development.

DESCRIPTION

Historic MED processing activities at the Linde Site resulted in elevated levels of radionuclides (specifically uranium (U-234, U-235, and U-238), thorium (Th-230 and Th-232), and radium (Ra-226 and Ra-228) in portions of the property and buildings at levels that warranted a response action to protect human health and the environment. Remedial investigations and actions to address these MED-related radionuclides at the Linde FUSRAP Site were conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [3] and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [4], as illustrated in the timeline below.

1980 - Linde Designated as a FUSRAP Site (USDOE)
1993 - Remedial Investigation/Feasibility Study Reports and Proposed Plan for Linde Site (USDOE)
1996 - Approval Memorandum for Interim Actions (USDOE)
1996 – Demolition of Building 38 (USDOE)
1996/1997 – Decontamination of Bldgs 14 and 31 (USDOE)
1996/1997 – Excavation of Contaminated Soil near Bldg 90 (USDOE)
1997 - Responsibility for Administration/Execution of FUSRAP Transferred from USDOE to USACE
1998 - Approval Memorandum for Interim Actions at Building 30 (USACE)
1998/1999 – Demolition of Building 30 (USACE)
1999 - Feasibility Study Addendum/Proposed Plan (USACE)
2000 – Record of Decision (ROD) for the Linde Site (USACE)
2000-2010 & 2010-2013 - Remediation of Contaminated Soils & Surface Structures (USACE)
2002 – Proposed Plan for Building 14 (USACE)
2003 – ROD for Building 14 (USACE)
2004/2005 – Demolition of Building 14 (USACE)
2004 – Feasibility Study for Groundwater (USACE)
2005 – Feasibility Study Addendum for Groundwater (USACE)
2006 – Proposed Plan and No Action Record of Decision for Groundwater (USACE)
2010 – Five-Year Review Report (USACE)

Note: **Remedial activities (i.e., interim and long term remedial actions) are in bold**.

Fig. 1. Chronology of CERCLA Remediation of the Linde FUSRAP Site.

REMEDIES SELECTED FOR THE LINDE SITE

The Linde Site is comprised of the following three OUs. The remedy for each OU, and two prior non-time-critical removal actions, is summarized below.

- Soils and Structure Surfaces (except for Building 14),
- Building 14, and
- Groundwater.

Non-Time-Critical Removal Action of Building 38 (USDOE)

The remedy selected by USDOE for interim removal actions at the Linde Site [5] was demolition of Building 38 and shipment of building rubble and stored soil that exceed cleanup guidelines to a permitted or licensed disposal facility.

In accordance with DOE guidelines [6] and Regulatory Guide1.86 [7] for commercial nuclear operations at that time, the allowable average, maximum, and removable radioactivity levels for uranium for unrestricted use of buildings and equipment was 5,000 disintegrations per minute per 100 square centimeters (dpm/100cm^2), 15,000 dpm/100cm^2, and 1,000 dpm/100 cm^2, respectively.

There were no specific guidelines at that time for allowable residual uranium in soil. General guidance from DOE guidelines [6], that were in effect at that time, stated that the exposure of members of the public to radiation sources shall not cause an effective dose equivalent greater than100 millirem per year (mrem/yr). A highly conservative (i.e. resident farming) scenario model predicted that 150 pCi/g of residual uranium could be left in soil without exceeding a 100 mrem/yr dose. After applying an as low as reasonably achievable (ALARA) approach, DOE proposed a site-specific uranium guideline of 60 pCi/g total U and 28.4 pCi/g for U-238. For residual radium (Ra-226 and Ra-228) and thorium (Th-230 and Th-232) in soil, DOE Order 5400.5 [6] specified an isotopic limit of 5 pCi/g averaged over the first 15 centimeters (cm) [6 inches (in)] below the surface and 15 pCi/g averaged over 15-cm (6-in) thick layers of soil more than 15 cm (6 in) below the surface.

Although no data were available to assess the concentration of residual radioactivity in the stored soil, a removal action was warranted due to the sources of the material and the likelihood that a portion exceeded the 60 pCi/g criterion for uranium and/or the 5 pCi/g criterion for radium and thorium. If the site use was altered, the stored soil could have potentially migrated and the risk to human health or the environment would have increased.

Non-Time-Critical Removal Action of Building 30 (USACE)

The remedy selected by USACE for the non-time-critical removal action of Building 30 at the Linde Site [8] was demolition of the building and shipment of building rubble that exceeded cleanup guidelines to a licensed disposal facility. The same allowable average, maximum, and removable radioactivity levels for uranium for unrestricted use of buildings and equipment used for the demolition of Building 38 were used for the demolition of Building 30.

Soils and Structure Surfaces OU (USACE)

The remedy selected by USACE for the soils and surface structures OU at the Linde Site [9] was complete excavation and decontamination with off-site disposal. Building 14, and the soils beneath it, were not included in the scope of the ROD [9].

The USACE determined that the USEPA's health and environmental protection standards for uranium and thorium mill tailings found in Title 40, Part 192, Subpart B of the Code of Federal Regulations (40 CFR 192) and the NRC standards for the domestic licensing of source material found in Title 10, Part 40, Appendix A, Criterion 6(6) of the Code of Federal Regulations (10 CFR 40) were relevant and appropriate for cleanup of FUSRAP-contamination in the soils and surface structures OU at the Linde Site.

Subpart B of 40 CFR Part 192 sets standards for residual concentrations of Ra-226 in soil. It requires that radium concentrations shall not exceed background by more than 5 pCi/g in the top 15 cm (6 in) of soil or 15 pCi/g in any 15 cm (6 in) layer below the top layer, averaged over an area of 100 m^2 (1,076 ft^2). Subpart B also provides standards for any occupied or habitable building associated with the soils beneath or surrounding the building, not the equipment or surfaces within the building. These standards require that the remedial action will:

- Achieve an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 working level (WL). In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL, and that
- The level of gamma radiation shall not exceed the background level by more than 20 microroentgens per hour (µR/hr).

10 CFR 40, Appendix A, Criterion 6(6) requires that residual radioactive materials remaining after remediation will not result in a total effective dose equivalent (TEDE), considering all radionuclides present (e.g., radium, thorium, and uranium) to the average member of the critical group exceeding a benchmark dose established based on cleanup to the radium standards of 5 pCi/g in the top 15 cm (6 in) and 15 pCi/g in subsequent 15 cm (6 in) layers below the top layer and must be ALARA. This benchmark dose is then used to establish allowable surface and subsurface soil concentration levels for the various radionuclides present other than radium.

USACE computed the benchmark doses for the cleanup of surface and subsurface soil. The results of the evaluation found that the surface and subsurface cleanup benchmark doses for a commercial/industrial worker scenario were 8.8 mrem/yr and 4.1 mrem/yr, respectively. The various radionuclide concentration limits, above background, within a 100 m^2 (1,076 ft^2) area for the surface cleanup benchmark dose were 554 pCi/g of total U, 5 pCi/g of Ra-226 and 14 pCi/g of Th-230. The various radionuclide concentration limits, above background, within a 100 m^2 (1,076 ft^2) area for the subsurface cleanup benchmark dose were 3,021 pCi/g of total U, 15 pCi/g of Ra-226 and 44 pCi/g of Th-230. These criteria applied to the soils remediated at Linde. The surface criteria were developed for specific buildings or surfaces based on likely exposure scenarios and meeting the surface cleanup benchmark dose of 8.8 mrem/yr.

The Remedial Action Objectives (RAOs) for the Soils OU at the Linde Site were to:

- Remove soils exceeding the 40 CFR 192 standards for radium, which includes consideration of thorium, when averaged over 100 m^2 (1,076 ft^2);
- Remove soils with residual radionuclide concentrations within a 100 m^2 (1,076 ft^2) area that result in exceeding unity for the sum of ratios (SOR) of Ra-226, Th-230, and total U concentrations to the associated concentration limits, above background, as described in Table 1 for surface and subsurface soil cleanups;
- Remove residual radioactive materials from building and structure surfaces necessary to meet the benchmark dose for surfaces of 8.8 mrem/yr based on the specific location of the surfaces and exposure scenarios; and
- Remediate the Linde Site to ensure that no concentration of total U exceeding 600 pCi/g above background would remain in the site soils.

TABLE I. Derived Concentration Guideline Levels (DCGLs) - Elevated Measurement Comparison ($DCGL_{emc}$) for Constituents of Concern (COCs) in soils at the Linde Site

COCs	Average Site Background Concentrations (pCi/g)[d]	$DCGL_{emc}$ for Commercial/Industrial Worker Protection (pCi/g)[a,b]	
		Surface: 8.8 mrem/yr	Subsurface: 4.1 mrem/yr
Ra-226	1.1	5	15
Th-230	1.4	14	44
total U[c]	6.1	554	3,021

[a] These cleanup goals represent COC concentrations above average site background averaged over a 100 m^2 (1,076 ft^2) area.

[b] If a mixture of radionuclides was present, then the SOR applied per the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). For example, using the residual concentration limits for soil, the following SOR equation is obtained for surface soil (SS) and subsurface soil (SB):

$$SOR_{SS} = \frac{Ra\text{-}226}{5} + \frac{Th\text{-}230}{14} + \frac{total\ U}{554}$$

$$SOR_{SB} = \frac{Ra\text{-}226}{15} + \frac{Th\text{-}230}{44} + \frac{total\ U}{3{,}021}$$

Ra-226 = net Ra-226 soil concentrations
Th-230 = net Th-230 soil concentrations
total U = net total U soil concentrations

Note: Net soil concentrations exclude average background.

[c] Total U is the sum of the isotopes (uranium-234 (U-234), uranium-235 (U-235), and U-238).

[d] Average site background concentrations [9][10].

The selected remedy addressed the principal threat from FUSRAP-eligible COCs at the site by removing radioactively contaminated soil from the site that may pose a future threat to the health of persons at the site. Implementation of this remedy was intended to meet the release criteria defined in the ARARs discussed above for a commercial/industrial worker, which was identified as the current and anticipated future land user. The selected remedy only addressed FUSRAP-eligible COCs, and did not address any other hazardous substances that may have been present at the site. The determination of the need for and performance of response actions related to other potential releases of hazardous substances at this site was not within the authority of USACE under FUSRAP.

Building 14 OU (USACE)

The remedy selected by USACE for the Building 14 OU at the Linde Site [11] was demolition of the building and shipment of building rubble that exceeded cleanup guidelines to a licensed disposal facility. The utility tunnel located beneath Building 14 was relocated to allow for removal of contamination within and around the tunnel structure. Building components and soils under the building were surveyed to determine the material and soils radioactively contaminated with COCs above the cleanup criteria. All contaminated materials and soils were disposed of at a permitted or licensed disposal facility.

The USACE determined that cleanup standards found in 40 CFR 192, the standards of cleanup of the uranium mill sites designated under the Uranium Mill Tailings Radiation Control Act, along with the NRC standards for decommissioning of licensed uranium and thorium mills found in 10 CFR 40,

Appendix A, Criterion 6(6) were relevant and appropriate for cleanup of FUSRAP-eligible contamination in the Building 14 OU at the Linde Site.

USACE also determined that the New York State Department of Labor (NYSDOL) Regulations for Ionizing Radiation Protection, 12 New York Codes, Rules, and Regulations (NYCRR) Part 38 were relevant and appropriate to the cleanup of any building or structural surface if such building or structural surface were to remain in place after the building was removed. Compliance with these requirements required that such building or structural surface be remediated in accordance with Table 1 of 12 NYCRR Part 38 or removal of FUSRAP-eligible residual radioactive materials from such surfaces as would be necessary to meet the benchmark dose for surfaces of 8 mrem/yr in accordance with 10 CFR 40, Appendix A, Criterion 6(6), based on the specific location of the surfaces and exposure scenarios, whichever was more stringent.

The RAOs for the Building 14 OU at the Linde Site were to:

- Remove FUSRAP-eligible soil exceeding the 40 CFR 192 standards for radium (see Table I), which included consideration of thorium, when averaged over 100 m^2 (1,076 ft^2);
- Remove Building 14, so that no contaminated occupied or habitable building remained;
- Remove soils with residual radionuclide concentrations within a 100 m^2 (1,076 ft^2) area that resulted in exceeding unity for the SOR of Ra-226, Th-230, and total U concentrations to the associated concentration limits, above background, as described in Table I for surface and subsurface soil cleanups;
- Remove residual radioactive materials from surfaces necessary to meet the benchmark dose for surfaces of 8.8 mrem/yr based on the specific location of the surfaces and exposure scenarios; and
- Remediate the Linde Site to insure that no concentration of total U exceeding 600 pCi/g above background would remain in the site soils.

The selected remedy for the Building 14 OU addressed the principal threat from FUSRAP-eligible COCs at the site by eliminating radioactive contamination in soils and on building structures that may pose a future threat to the health of persons at the site. Because it was expected that this remedy would not result in FUSRAP-eligible hazardous substances, pollutants, or contaminants remaining at the Building 14 OU above levels that allow for unlimited use and unrestricted exposure (UU/UE), a five-year review was not required for this remedial action.

Groundwater OU (USACE)

Groundwater at the Linde Site is not used as a drinking water source. The Niagara River is the water source for the Town of Tonawanda municipal water system. USACE issued a No Action ROD for the groundwater OU at the Linde Site [12]. USACE concluded that no complete pathways to human or environmental receptors exist for current or future exposure to FUSRAP-eligible constituents in affected groundwater at Linde. This conclusion was based on USACE's determination that naturally-occurring concentrations of constituents in groundwater at the Linde Site preclude its use without treatment, and treatment to remove naturally-occurring constituents would also remove any of the FUSRAP-eligible constituents that may be present. Since no actions were warranted, there was no need for further CERCLA reviews and/or monitoring of the groundwater OU.

REMEDIAL ACTION SUMMARIES FOR THE LINDE SITE

Non-Time-Critical Removal Action of Building 38 (USDOE)

The demolition of Building 38 was accomplished by USDOE in August 1996. Approximately 208.14 metric tons (229.44 tons) [612 m^3 (800 yd^3)] of low-level radioactively contaminated debris was contained in 34 intermodals and shipped by rail to Energy Solutions' Clive, Utah, disposal facility (formerly Envirocare of Utah) in October 1996.

Additionally, USDOE shipped the resulting 4,428 metric tons (4,881 tons) [2,870 m^3 (3,754 yd^3)] of contaminated soil and soil-like material by rail to Energy Solutions' Clive, Utah, disposal facility (formerly Envirocare of Utah) between October 6 and December 4, 1997. This waste resulted from the excavation of stored soil and decontamination activities associated with Buildings 14 and 31.

Non-Time-Critical Removal Action of Building 30 (USACE)

USACE shipped a total of 1,964.27 metric tons (2,165.24 tons) of radioactively contaminated debris from Building 30 by rail then trucked to the Clean Harbors' (formerly Safety-Kleen) landfill in Buttonwillow, California, for disposal between 1998 and 1999. The majority of this material was wood (90% wood and 10% masonry). In addition, 1,163.60 metric tons (1,282.65 tons) of radioactively contaminated soil and debris were shipped by rail to Energy Solutions' Clive, Utah, disposal facility (formerly Envirocare of Utah), for a total of 3,127.87 metric tons (3,447.89 tons) of radioactive waste shipped off site.

Soils and Structure Surfaces OU (USACE)

The selected remedy for the soils and surface structures OU included:

- Demolition of buildings (i.e. Buildings 57, 67, 73, 73B, 75, and 76 including slabs and foundations) necessary to remediate soil at the site;
- Removal of slabs from former Buildings 30 and 38, along with tank saddles north of former Building 30;
- Removal of a wall in Building 31 to access sub slab and sub-footing soils exceeding ROD criteria (The entirety of Building 31 was removed during remedial action to access impacted soils beneath);
- Remediation of radiologically contaminated soils above ROD criteria on adjacent National Grid and CSX properties, which may have been released from the Linde Site;
- Removal of contaminated sediments from drain lines and sumps;
- Removal of contaminated soil from a blast wall structure located east of Building 58; and
- Remediation of a subsurface vault structure located west of Building 73.

The demolition of Buildings 8 East Annex, 8A, 31, 58, 73A, and 90, and several building slabs and utility tunnels, were not included in the ROD [9], but deemed necessary during remediation activities to access contaminated soils underneath the buildings.

During remedial action, impacted soils were present at varying depths, ranging from approximately 0.9 to 5.5 m (3 to 18 ft) below ground surface [13]. By 2010, a total of 312,551 metric tons (344,529 tons) [approximately 131,710 m^3 (172,265 yd^3)] of radiologically contaminated soil and debris associated with the soil and structure surfaces OU were transported via rail to permitted or licensed facilities outside of New York State. Between 2010 and 2013, USACE shipped a total of 23,079 metric tons (25,440 tons) of additional contaminated soil and debris that did not meet free release criteria to US Ecology Idaho's Grand View facility for disposal.

Building 14 OU (USACE)

USACE shipped a total of 4,735 metric tons (5,220 tons) of Building 14 demolition debris and 7,981 metric tons (8,798 tons) of soil by rail to Waste Control Specialists in Andrews, Texas, for disposal between 2005 and 2005.

WASTE DISPOSAL SUMMARY

Table II summarizes the off-site permitted or licensed facilities that received contaminated soil and/or debris from the Linde Site associated with removal/remedial actions discussed above.

TABLE II. Waste disposal summary (1996-2013)

Linde Removal/Remedial Actions	Permitted/Licensed Facility	Tons Shipped	Cubic Yards Shipped
Non-Time-Critical Removal Action (1996) -Demolition of Building 38	Energy Solutions (Clive, Utah)	229	800
Non-Time-Critical Removal Action (1996-1997) -Excavation of Stored Contaminated Soil -Decontamination of Bldgs 14 and 31	Energy Solutions (Clive, Utah)	4,881	3,754
Non-Time-Critical Removal Action (1998-1999) -Demolition of Building 30	Clean Harbors (Buttonwillow, California)	2,165	6,165
	Energy Solutions (Clive, Utah)	1,283	2,700
Remedial Action (1999-2010)[a] -Soils OU	International Uranium Corporation (IUC) (Blanding, Utah)	118,687	172,265
	Waste Control Specialists, LLC (WCS) (Andrews, Texas)	138,360	
	US Ecology Idaho, Inc. (Grand View, Idaho)	87,482	
Remedial Action (2004-2005) -Building 14 OU	Waste Control Specialists, LLC (Andrews, Texas)	14,018	14,202
Remedial Action (2010-2013) -Soils OU	US Ecology Idaho, Inc. (Grand View, Idaho)	25,440	19,569[b]
	Total	**392,545**	**219,455**

[a] IUC and WCS were used simultaneously as disposal facilities because IUC could only accept a percentage of the total shipments as debris mixed with radiologically contaminated soils. WCS would allow all debris or debris mixed with a lower radioactive content. US Ecology was used exclusively later in the project due to their waste acceptance criteria, which accepted both radiologically contaminated soils and debris.

[b] Cubic yards shipped estimate assumes 1.3 tons per cubic yard.

RESIDUAL DOSE ASSESSMENT SUMMARY

A post-remediation radiological dose assessment was conducted by Argonne using residual concentrations of FUSRAP-eligible COCs (i.e. Ra-226, Th-230, and total U) in soil to determine the potential radiation dose to the critical group (i.e. a commercial/industrial worker) at the Linde Site. The drinking and irrigation water pathways were not incorporated into this dose assessment since water was assumed to be obtained from the nearby Niagara River. Additionally, the naturally occurring levels of salts in the groundwater preclude its use without treatment [12].

The USACE identified 40 CFR 192 and 10 CFR 40, Appendix A, Criterion 6(6) in the ROD [9] as ARARs for the soils and structure surfaces OU at the Linde Site. In compliance with these standards, the Linde Site would be protective of the commercial/industrial worker if residual radionuclide concentrations, above background and within a 100 m^2 (1,076 ft^2) area, did not exceed unity for the SOR of Ra-226, Th-230, and total U concentrations (using the surface and subsurface soil cleanup criteria in Table I).

The gross site-wide average residual Ra-226, Th-230, and total U concentrations in soil at the Linde Site were all below average background concentrations (as shown in Table III). Since residual FUSRAP-eligible COCs in soil do not contribute to radiological dose, over naturally-occurring background radiation, the post-remediation radiological dose assessment conservatively used gross residual concentrations (i.e. included contribution from background) to demonstrate compliance with the ROD [9].

TABLE III. Residual soil concentrations and resultant dose

Linde FUSRAP Site	Soil Concentrations (pCi/g)			Annual Residual Dose to Commercial/Industrial Worker (mrem)[b,c]
	Ra-226	Th-230	Total U [a]	
Site-Wide Average Gross Residual Soil Concentrations	**0.97**	**1.31**	**3.00**	**2.02**
Average Site Background Concentrations[d]	**1.1**	**1.4**	**6.1**	**-**

[a] Total U is the sum of the uranium isotopes (i.e. U-234, U-235, and U-238).
[b] The resultant dose includes background.
[c] The resultant dose, including background, to a construction worker was 0.50 mrem/yr.
[d] Average site background concentrations [9][10].

The residual dose to a commercial/industrial worker, including contribution from background, did not exceed the surface or subsurface benchmark dose of 8.8 mrem/yr and 4.1 mrem/yr, respectively, as specified in the ROD [9].

Additionally, since residual Ra-226, Th-230, and total U in soil at the Linde Site are indistinguishable from background (i.e. naturally-occurring, non-impacted) radionuclide concentrations, residual soil concentrations not only met, but exceeded RAOs and cleanup standards for the project. In other words, due to precise excavation and rigorous scanning methods, no FUSRAP-eligible hazardous substances, pollutants, or contaminants remain at the Linde Site that would preclude UU/UE. Therefore, the Linde site is deemed protective for unrestricted use and no five-year reviews are required.

PLACEBACK SOILS

Overburden soil and construction debris, excavated to gain access to deposits of subsurface contamination or to maintain safe and stable remedial excavations, were stockpiled during remedial action for potential reuse as backfill.

For the 2000-2010 remedial action of the soils and structure surfaces OU, construction debris was segregated from soil and a biased composite sample was collected from each 15 m^3 (20 yd^3) stockpile using a gamma scan trigger level of 18,000 counts per minute (cpm) on a sodium iodide detector. Samples were sent off site for radiological analysis by alpha spectroscopy and radon emanation methods. Analytical results were compared against the beneficial reuse criteria agreed upon between Praxair, New York State Department of Environmental Conservation (NYSDEC), and USACE. The gross concentration of each radionuclide was evaluated against the surface DCGLs using background ranges prescribed by NYSDEC of 2 pCi/g, 2 pCi/g, and 5 pCi/g for Ra-226, Th-230, and U-238, respectively. Samples were also analyzed, as prescribed by NYSDEC, for the toxicity characteristic leaching procedure (TCLP) for metals, pesticides, herbicides, volatiles, and semivolatiles to ensure that the overburden soil met the NYSDEC beneficial use standard (6 NYCRR Part 360-1.15(b)(8)).

For 2010-2013 remedial action of the soils and structure surfaces OU, the correlation between gamma exposure rate and FUSRAP-eligible COC concentrations in soil was revised based on refined statistics from the hundreds of samples that the project collected and analyzed over the years. The revised gamma rate exposure threshold for disposal was set at 22,000 cpm with a new screening threshold for overburden soils being established for “gray” soils. The gray soils were materials exhibiting a gamma exposure rate from 18,000 cpm to 22,000 cpm. The management and evaluation techniques for various soils were as follows:

- Contaminated soils, with field screening exceeding 22,000 cpm, were transferred to a separate load-out pad for off-site disposal.
- “Clean” soils, with field screening below 18,000 cpm, were transferred to an evaluation area and isolated into approximately 92 m^3 to 382 m^3 (120 yd^3 to 500 yd^3) windrows. Each windrow was subjected to confirmatory composite radiological COC sampling.
- “Gray” soils, with field screening between 18,000 and 22,000 cpm, were transferred to an evaluation area and isolated in approximately 15 m^3 (20 yd^3) soil bins, spread to a thickness not to exceed 1 foot, and subjected to additional gamma walkover survey screening. Any identified “hot spots” (i.e., soils exceeding 22,000 cpm) were removed from each soil bin via precision excavation and discarded as radiological waste without biased sampling and analysis. Remaining soils were combined into approximately 92 m^3 to 382 m^3 (120 yd^3 to 500 yd^3) windrows and subjected to confirmatory composite radiological COC sampling.

Composite samples collected from “clean” and “gray” windrows were compared to the beneficial reuse COC criteria established during the 1999-2010 remedial action. Additionally, a minimum of three samples were collected for volatile organic compounds (VOCs) prior to aggregating each 92 m^3 to 382 m^3 (120 yd^3 to 500 yd^3) windrow into a final stockpile. Soils meeting the beneficial reuse COC and VOC criteria were aggregated into 3,822 m^3 (5,000 yd^3) stockpiles. Each stockpile was then composite sampled (10-node) and analyzed for TCLP metals, pesticides, herbicides, VOCs, and semi-volatiles to ensure the material met NYSDEC’s beneficial use standard (6 NYCRR Part 360-1.15(b)(8)).

RECYCLING

Concrete and metal debris from demolition activities was locally disposed or recycled as much as possible and/or practicable in an effort to reduce cost and minimize waste. These materials were power washed and visually inspected before receiving the required radiological screenings and surveys. Petitions, along

with the radiological screening and survey data, were provided to NYSDEC for local disposal or recycling concurrence. Table IV summarizes recycled materials.

TABLE IV. Reused and recycled materials

Remedial Action	Media	Reused or Recycled	Volume (tons)
1999-2010	Asphalt	Recycled	38
1999-2010	Concrete	Recycled	2,085
1999-2010	Metals	Recycled	416
1999-2010	Soils	Reused	24,840
2010-2013	Asphalt	Recycled	1,665
2010-2013	Concrete	Recycled	653
2010-2013	Concrete	Reused	4,100
2010-2013	Metals	Recycled	135
2010-2013	Soils	Reused	25,700
2004-2005	Mercury Debris	Recycled	0.7
			59,633

DEMONSTRATION OF CLEANUP QUALITY

USACE and the remediation contractors routinely performed many different quality assurance/quality control (QA/QC) activities. Contractor project QC was maintained through the implementation of project specific quality control plans and quality assurance project plans. Controlled copies of pertinent plans were available on site for the duration of the projects. The USACE QA process included having a USACE construction inspector and health physicist on site during the remediation to ensure that plans and proper procedures were implemented.

Upon completion of the final status survey (FSS) gamma walkover scans, a contractor QC review of the data was performed. The review included a verification of geographic position survey data, an instrument calibration check, review of standard operating procedures, and discussion of findings. Upon completion of the contractor QC process, USACE performed a QA review of the contractor data and conducted a verification gamma scan of the unit. Argonne performed an independent review of the contractor gamma walkover data including mapping and plotting verifications. NYSDEC also conducted verification gamma scans of the unit. USACE and NYSDEC gamma scans were based on professional judgment and the nature and extent of contamination that had existed in that area. Any anomalies, elevated areas or discrepancies in the data were investigated and resolved. Concurrence was received from all parties prior to USACE approval to backfill an excavation.

Systematic (and some biased) surface and subsurface FSS soil samples were collected within individual surveys units and radiologically scanned on site, before being analyzed at an off-site USACE-approved laboratory. Field duplicates and QA splits were collected with FSS samples and compared to the original samples as a measure of precision. All samples used to close out FSS units were found to meet the required quality standards. USACE, Argonne, and the NYSDEC also performed QA reviews of the sample data and collected field split samples and biased samples as deemed necessary.

SUMMARY OF OPERATION AND MAINTENANCE

The applied remedial alternatives (building demolition and off-site disposal, complete soil excavation above ROD criteria and off-site disposal, and no action for groundwater) do not require operation and maintenance actions at the Linde Site.

SUMMARY OF REMEDIAL COSTS

Table V presents a summary of remediation costs for the Linde Site. There are no operation and maintenance costs. The Contractors for the 1996-1997 and 1998-1999 non-time-critical removal actions and 2000-2010, 2004-2005, and 2010-2013 remedial actions were Bechtel National Incorporated (BNI), Radian International, Incorporated (Radian), IT Corporation (IT) and its successor, Shaw Environmental, Incorporated (Shaw), and Cabrera Services, Incorporated (Cabrera).

TABLE V. Summary of remedial costs

Linde Removal/Remedial Actions	Estimate in Action Memo or ROD	Total Remediation Costs[a]
	(millions of dollars)	
Non-Time-Critical Removal Action (1996-1997) -Demolition of Building 38 (BNI)	$11.3 (EE/CA)[b]	**$25.0[c]**
Non-Time-Critical Removal Action (1998-1999) -Demolition of Building 30 (Radian)	$7.7 (EE/CA)[d]	**$12.4**
Remedial Action (1999-2010) -Soils OU (IT/Shaw)	$27.7 (ROD)[e]	**$246.3**
Remedial Action (2010-2013) -Soils OU (Cabrera)		
Remedial Action (2004-2005) -Building 14 OU (Shaw)	$9.8 (ROD)[f]	**$21.7**
Total	-	**$305.4**

[a] Total Remediation Costs include both contractor and government (DOE and USACE) costs.
[b] Total estimated present value cost for the USDOE selected remedy in 1996 dollars. The Engineering Evaluation/Cost Analysis (EE/CA) [14] underestimated the volume of Building 38 rubble and contaminated soil requiring disposal.
[c] Estimated USDOE costs for the decontamination and demolition of Building 38, excavation and off-site disposal of contaminated soil stored near Bldg 90, and decontamination of Buildings 14 and 31.
[d] Total estimated present value cost for the selected remedy in 1996 dollars. The EE/CA [15] underestimated the volume of Building 30 rubble requiring disposal. The actual disposal volume of 6,778 m^3 (8,865 yd^3) was well in excess of the EE/CA estimate of 3,736 m^3 (4,486 yd^3).
[e] Total estimated present value cost for the selected remedy in 1999 dollars. The FS Addendum [16] underestimated the volume of soil requiring disposal. The actual disposal volume of 146,670 m^3 (191,834 yd^3) was well in excess of the 1999 soil volume estimate of 17,164 m^3 (22,450 yd^3). The ROD [9] did not anticipate the need to excavate soils off the FUSRAP-designated Linde Site (i.e. onto the Mil-Sher, Carrier, and R.P. Adams properties) and around utility tunnels, or demolish Buildings 8 East Annex, 8A, 31, 58, 73A, and 90 to access contaminated soils underneath.

[f] Total estimated present value cost for the selected remedy in 2000 dollars. The Proposed Plan [17] underestimated the volume of Building 14 rubble requiring disposal. The actual disposal volume of 10,858 m^3 (14,202 yd^3) was well in excess of the ROD [11] estimate of 573 m^3 (750 yd^3).

FIVE-YEAR REVIEW REPORT

USACE issued A Five-Year Review Report [13] to determine the effectiveness of the selected remedial actions contained within the ROD [9]. The trigger date for the five-year review was the initiation of soil excavation activities in September 2000. This first and only five-year review was due in September 2005, however, the five-year review report was not issued until August 2010. The report concluded that the excavation and off-site disposal remedy implemented for the soils and structure surfaces OU at the Linde Site was expected to be protective of human health and the environment upon completion. In the interim, exposure pathways that would result in unacceptable risk were being controlled.

Two issues were identified during the five-year review. However, neither issue impacted the level of protectiveness of the soils and structure surfaces OU remedial action. The first issue related to the need for improved outside project communication. The second issue was stakeholder concern that cleanup criteria identified in the ROD [9] would allow FUSRAP-eligible contamination to remain at levels that would preclude unrestricted use of the land. However, this is no longer an issue since FUSRAP-eligible residuals at the Linde site are at levels that allow for UU/UE. No additional five-year reviews are required.

FIVE-YEAR REVIEW REQUIREMENTS

The implemented remedy resulted in no FUSRAP-eligible COCs remaining in soil at the Linde Site above average background. Since FUSRAP-eligible residuals at the site are at levels that allow for UU/UE, five-year reviews are not required pursuant to Section 121(c) of CERCLA and Part 300.430(f)(4)(ii) of the NCP and the site is suitable for use without restrictions.

The ROD for the groundwater OU [12] (indicated that no CERCLA action was warranted for groundwater at the Linde Site since there were no exposure pathways to human or environmental receptors. This No Action remedy also allowed for UU/UE conditions since the naturally occurring concentrations of constituents in groundwater at the Linde Site precluded its use without treatment, and the treatment to remove the naturally occurring constituents would also remove any of the FUSRAP-eligible constituents that may be present.

CONCLUSIONS

The remedies implemented at the Linde FUSRAP Site achieved the degree of cleanup and protection specified in the RODs [9] [11] [12] for all pathways of exposure. No further response is needed to protect human health and the environment from the FUSRAP-eligible COCs. All ROD remedial action goals have been achieved, and all ARARs have been met for the site. Residual concentrations have been found to be suitable for unrestricted use of the site. Per a Memorandum of Understanding between USDOE and USACE regarding program administration and execution of FUSRAP [18], the Linde FUSRAP Site will be officially transferred from USACE to USDOE ’s Office of Legacy Management for long-term stewardship. This site transfer will occur two years after the Site Closeout Report for the Linde FUSRAP Site is signed Army final, which is anticipated to be in fiscal year (FY) 2017 (i.e. between October 2016 and September 2017).

REFERENCES

1. (USACE) U.S, Army Corps of Engineers, *Environmental Quality - Formerly Utilized Sites Remedial Action Program, Engineer Regulation 200-1-4 (*2014).
2. (USDOE) U.S. Department of Energy, *Remedial Investigation Report for the Tonawanda Site, DOE/OR-21949*-300 (1993).
3. United States of America, *Comprehensive Environmental Response, Compensation, and Liability Act, Title 42 of United States Code Section 9601et seq. [42 USC 9601 et seq.*].
4. United States of America, *National Oil and Hazardous Substances Pollution Contingency Plan, Title 40 Code of Federal Regulations Part 300 [40 CFR 300]*.
5. USDOE, *Tonawanda Site – Approval Memorandum for Praxair Interim Actions* (1996).
6. USDOE, *Order 5400.5, Radiation Protection of the Public and Environment, Washington, D.C.* (1990).
7. (AEC) Atomic Energy Commission, *Regulatory 1.86, Termination of Operating Licenses for Nuclear Reactors* (1974).
8. USACE, *Action Memorandum for the Demolition of Building 30 at the Linde Site (1998).*
9. USACE, *Record of Decision for the Linde Site* (2000).
10. USDOE, *Remedial Investigation Report for the Tonawanda Site, DOE/OR-21949-300* (1993).
11. USACE, *Record of Decision for the Building 14 Operable Unit, Linde Site, Tonawanda, New York* (2003).
12. USACE, *Record of Decision for the Groundwater Operable Unit, Linde Site, Tonawanda, New York* (2006).
13. USACE, *Five-Year Review Report for the Linde FUSRAP Site, Town of Tonawanda, Erie County, New York* (2010).
14. USDOE, *Engineering Evaluation/Cost Analysis (EE/CA) for Praxair Interim* Actions (1996).
15. USDOE, *Engineering Evaluation/Cost Analysis (EE/CA) for Building 30 at Praxair (*1996).
16. USACE, *Addendum to the Feasibility Study for the Linde Site, Tonawanda, New York (*1999).
17. USACE, *Proposed Plan for the Building 14 Operable Unit, Linde Site, Tonawanda, New York* (2002).
18. USACE and USDOE, *Memorandum of Understanding between the U.S. Department of Energy and the U.S. Army Corps of Engineers Regarding Program Administration and Execution of the Formerly Utilized Sites Remedial Action Program (FUSRAP)* (1999).