

GROUNDWATER REMEDIATION - PASSIVE REACTIVE BARRIER

MOUND SITE PLUME REMEDIATION OF GROUNDWATER CONTAINING CHLORINATED ORGANIC COMPOUNDS, AMERICIUM AND URANIUM AT THE ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE.

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ABSTRACT:

The Mound Site Plume at the Rocky Flats Environmental Technology Site contains chlorinated organic compounds, americium and uranium in excess of action levels established in regulatory documents. The proposed remediation consists of constructing a subsurface groundwater collection system in combination with a passive reactive metals treatment system to treat contaminated groundwater from the Mound Site Plume and seep SW059 to the regulatorily specified surface water action levels.

The project has the following objectives:

- Intercept and treat contaminated groundwater, including seep SW059, at the distal end of the Mound Site Plume.
- Design, install and operate a passive groundwater treatment system that, to the extent practicable, protects surface water and reduces the contaminant mass loading in surface water.
- Develop cost and performance data for design, construction and operation of low cost and effective treatment systems.

This paper provides the status of the project objectives and the background information to describe the project.

I. PURPOSE OF THIS PAPER:

The Mound Site Plume, at the Rocky Flats Environmental Technology Site (RFETS), contains chlorinated organic compounds, americium and uranium in excess of action levels established in the site's regulatorily binding cleanup agreement. A remedial action is underway to cleanup the contaminated groundwater using a passive reactive barrier. The purpose of this paper is to provide a status on the progress of the cleanup in relation to the objectives for the project as defined in the Final Mound Site Plume Decision Document dated September 30, 1997.

II. ACKNOWLEDGEMENT:

Much of the information provided in this paper was taken from a similar paper which was presented at the Spectrum 98 conference and other documents. A listing of the references from which information was taken for this paper is provided at Part V. Information taken from a given

reference is followed by an abbreviated description of the reference placed inside parenthesis.

III. BACKGROUND:

A. General:

The Mound Site Plume is located on the east side of the RFETS Industrial Area, and east of the protected area fence. This plume of primarily volatile organic compound (VOC) contaminated groundwater is believed to originate from the Mound Site, and extend northward to where the plume discharges as seeps (including seep SW059) and subsurface flow into the South Walnut Creek drainage. Additionally, low levels of uranium and metals below background levels have been detected at seep SW059.

Most of the groundwater contamination is believed to be derived from the Mound Site where approximately 1,405 intact drums were stored on the ground surface, covered with soil, between April 1954 and September 1958. The drums contained uranium and beryllium-contaminated lathe coolant (a mixture of approximately 70 percent hydraulic oil and 30 percent carbon tetrachloride). Historical information also indicates that some of the coolant contained low levels of plutonium. In 1970, all drums along with some radiologically-contaminated soil were removed from the Mound Site. Approximately 10 percent of the drums were thought to be leaking at the time of removal. However, there are no records of the volume of contaminants released to the soils at the Mound Site (DOE 1992).

An accelerated removal action was completed in Spring 1997 to excavate the soil contaminated with VOCs above action levels from the Mound Site (DOE 1997a).

The groundwater cleanup action consisted of constructing a subsurface groundwater collection system coupled with a passive reactive metals treatment system to treat contaminated groundwater from the Mound Site Plume and surface water seeps to the surface water action levels specified in the Rocky Flats Cleanup Agreement (RFCA). Please note that funding for this project was provided by DOE EM-50 - Subsurface Contaminant Focus Area, DOE RFETS and the U.S. Environmental Protection Agency through the Superfund Innovative Technology Evaluation Program.

B. Hydrogeologic Setting:

At the source area for the Mound Site Plume, bedrock unconformably underlies approximately 12 feet of surficial deposits and consists of weathered claystone and minor sandstones of the Cretaceous Arapahoe and Laramie Formations (DOE 1995, DOE 1997a). The Arapahoe No. 1 Sandstone subcrops under the northwest corner of the Mound Site, and is truncated to the north by the South Walnut Creek drainage. Groundwater within the Arapahoe No. 1 Sandstone exits into the colluvium, causing a higher water table, and an increase in vegetation (DOE 1995, RMRS 1996a). The Arapahoe No. 1 Sandstone is absent under the eastern portion of the Mound Site.

Near the distal end of the plume, clay-rich colluvium partially derived from the Rocky Flats

Alluvium unconformably overlies Laramie Formation claystone (DOE 1995, EG&G 1995a, EG&G 1995b, RMRS 1996c, and RMRS 1996a). The elevation to bedrock is variable as this area has been extensively disturbed by landslides and/or slumps. Aerial photographs showed that the area was extensively regraded in 1962. The bedrock surface forms a shallow trough plunging to the north, which probably directs groundwater flow. Depth to the bedrock surface varies from 5 to 15 feet over much of the area. At the eastern extent, bedrock is 25 feet below ground surface due to fill material brought in for the eastern perimeter road.

The groundwater occurs in the alluvium, colluvium, in the weathered bedrock, and in the underlying Arapahoe No. 1 Sandstone. Groundwater flow is primarily to the north and follows the bedrock surface. Recharge occurs primarily through local infiltration of precipitation or local runoff. Geometric mean hydraulic conductivities are 6×10^{-04} cm/sec for the Rocky Flats Alluvium and 8×10^{-08} cm/sec for the weathered claystone (DOE 1995). Geometric mean hydraulic conductivity for the colluvium is 9×10^{-05} cm/sec (EG&G 1995b).

The groundwater discharges through subsurface seeps from the bedrock into the colluvium along the hillside, seeps on the south bank of South Walnut Creek, and through evapotranspiration. Infiltration into the underlying unweathered claystone is limited (DOE 1995, EG&G 1995b). Depending on the season, unsaturated areas may occur within the plume (DOE 1996b, EG&G 1995b, RMRS 1996a). At seep SW059, groundwater containing low levels of VOCs with trace amounts of radionuclides discharges at a rate averaging less than 0.5 gallons per minute. The seep water is currently collected, transported and treated onsite (DOE 1995, RMRS 1996b).

Based on historical flow rates from seep SW059, available hydrogeologic data, and typical rates for other groundwater drains at the Site, the groundwater flow for the Mound Site Plume was calculated to be 0.1 to 2 gallon per minute.

C. Mound Site Plume Contamination Data Summary:

Tetrachloroethene is the predominant contaminant found in soil and groundwater at the Mound Site, with the highest historic groundwater concentration of 528,000 ug/l in Well 0174. Concentrations decrease towards South Walnut Creek, which supports the Mound Site as the source area for the contaminants seen in this plume.

From the source area to the distal end of the groundwater plume, the most commonly detected groundwater contaminants in the Mound Site Plume are tetrachloroethene and trichloroethene. Carbon tetrachloride is detected only on the western side of the plume; at seep SW059 and at location 10397. This may indicate that there is a separate source of contamination in the road fill. Both dichloroethene and vinyl chloride are present in the distal portion of the plume, and are degradation products of trichloroethene and tetrachloroethene (RMRS 1996a, DOE 1995, DOE 1996b).

Soil and groundwater samples were collected near the distal end of the plume during Spring 1997 to support the design of the collection and treatment system. The analyses indicate

that the highest groundwater concentrations in the distal end of the plume are trichloroethene (TCE) at 844 ug/l, tetrachloroethene (PCE) at 260 ug/l, and cis-1,2 dichloroethene at 808 ug/l seen at location 10797, directly downgradient of the Mound Site source area. Table 1 summarizes the groundwater results of this investigation.

Table 1. Groundwater Contaminants of Concern from Recent Investigation Results (in ug/l)

Compound	Minimum	Maximum	Average	Number of	Tier I¹	Tier II¹
Vinyl Chloride	nd	55.0	13.0	5	200	2
1,1 Dichloroethene	nd	94.2	18.0	8	700	7
cis 1,2 Dichloroethene	nd	808.0	169.0	9	7000	70
Carbon Tetrachloride	nd	6.6	0.8	1	500	5
Chloroform	nd	177	17	6	10000	100
Trichloroethene	nd	844	195	9	500	5
Tetrachloroethene	nd	261	66	8	500	5
Methylene Chloride	nd	18	4	3	500	5
Americium 241*	0.25	0.25	0.25	1	15	0.15
Gross Beta*	3.1	28	8	14		19**
Uranium 234*	3.4	3.4	3.4	1	298	3

* Insufficient water to obtain radiological analyses, data is from seep SW059

** Surface water action level for Walnut Creek

¹ - Soil action levels at RFETS are identified as either Tier I or Tier II. Tier I action levels, when exceeded, trigger an evaluation, remedial action and/or management action given the presence of institutional controls. Tier II action levels, when not exceeded, do not require remedial action and/or institutional controls. Soil concentrations which fall between the Tier I and Tier II action levels are left to negotiation amongst the parties to the Rocky Flats Cleanup Agreement.

IV. PROJECT APPROACH:

A. General:

A down gradient capture system was designed and installed in 1998 near South Walnut Creek to intercept contaminated groundwater and to minimize impacts to surface water. A subsurface groundwater collection system coupled with a passive reactive metals treatment system to treat contaminated groundwater from the Mound Site Plume to the appropriate surface water action levels is currently in operation. The downgradient capture system was chosen as the best remediation method following an evaluation of other more traditional options. The passive treatment system was chosen as it effectively treats VOCs and radionuclides to below action levels at a lower operations and maintenance cost than other treatment options. The treated water is being discharged to surface water.

A funnel (impermeable barrier groundwater collection system) and gate (treatment system) was keyed into the underlying claystone for flow cut-off and treatment of the collected groundwater. In order to capture the contaminant plume, a groundwater collection system was installed which extends from the western road approximately 250 feet to the east.

The variable elevation of the bedrock surface and the similarity between the clay-rich colluvium and bedrock makes it difficult to install a collection system keyed a certain depth into bedrock. Therefore, the collection system was installed at a variable depth of approximately 8 to 15 feet across the site, at least 6 inches, but up to several feet, into claystone, without regard to whether this is colluvium or bedrock. The contaminated groundwater is being treated in a series of cells containing reactive iron filings to remove VOCs and radionuclides. Under normal operations, the treated water is discharged to groundwater using an infiltration gallery located adjacent to South Walnut Creek. However, the system is designed to allow discharge directly to surface water in South Walnut Creek.

B. Project Objectives: The following three (3) project objectives are taken from the Final Mound Site Plume Decision Document dated September 30, 1998:

1. **Intercept and treat contaminated groundwater**, including seep SW059, at the distal end of the Mound Site Plume;
 2. **Design, install and operate a passive groundwater treatment system** that, to the extent practicable, protects surface water and reduces the contaminant mass loading in surface water;
 3. **Develop cost and performance data for design, construction and operation** of low cost and effective treatment systems.
- A status will be provided on each of these project objectives.

C. Status of progress toward objectives:

1. Intercept and treat contaminated groundwater:

Conventional excavation/trenching techniques were used to install the funnel and gate system. Silt fences were installed down gradient of the excavation to control release of sediment. During trench construction, the material removed from the trench was stockpiled adjacent to the trench. A horizontal groundwater-collection line was installed on the up gradient side of the impermeable barrier. Filter pack or pea gravel was installed from the top of the claystone to the level of the horizontal collection line. The trench was then backfilled and excess fill was spread over the top of the collection system. The construction of the system to intercept and treat contaminated groundwater was complete in July 1998.

2. Design, install and operate a passive groundwater treatment system:

A reactive metals treatment system is being used to degrade dissolved VOCs and remove radionuclides from groundwater. The reactive metal media works by inducing conditions that cause substitution of hydrogen for chlorine in the chlorinated VOCs. The end-products of the process are completely dehalogenated hydrocarbons and non-toxic salts. Examples of end-products of chlorinated VOCs degraded by this process are ethene, ethane, and chloride ions. Radionuclides are removed by undergoing a reduction and/or absorption process.

The treatment system was designed based on the results of laboratory treatability studies conducted by Envirometal Technologies, Inc. (ETI), the patent holder for the reactive iron filings technology, and by Sandia National Laboratories (Sandia) for radionuclide removal. ETI's and Sandia's recommendations on the volume of reactive media and retention times required to meet the surface water action levels were incorporated into the final design of the treatment system.

Sandia tested the ability of media to remove the metals and radionuclides found in Mound Site seep water by performing column test using a surrogate water sample. Their results show removal of metals and radionuclides in approximately 12 minutes.

For their laboratory treatability study, ETI used uncontaminated groundwater from RFETS and spiked it to the maximum contaminants levels expected for the three RFETS VOC plumes.¹ Initial concentrations used in the column testing and concentrations in the treated effluent are shown in Table 2.

All VOCs, with the exception of methylene chloride (dichloromethane) were removed to below surface water action levels. The concentrations of methylene chloride in the Mound Site Plume (Table 2) are already not detectable or low level, and surface water action levels would be met.

Table 2. Results of ETI Bench Scale Testing - Connelly Iron

Compound	Influent Conc. (ug/L)	Effluent Conc. (ug/L)	Surface Water Action Level (ug/L)
Carbon Tetrachloride	1,004	nd	5
Trichloromethane	110	nd	8
Dichloromethane	111	105	5
Tetrachloroethene	5,496	nd	5
Trichloroethene	5,250	nd	5
Cis-1,2-dichloroethene	64	nd	70
1,1-Dichloroethene	318	nd	7
Vinyl Chloride	102	nd	2
1,1,1-Trichloroethane	37	nd	200

nd = non detect

¹ Please note that RFETS has three VOC contaminated groundwater plumes.

3. Develop cost and performance data for design, construction and operation:

i. Design - Treatability studies have shown that reactive (zero valent) iron will treat contaminated groundwater in the three RFETS VOC plumes to regulatory action levels. The EPA's Superfund Innovative Technology Evaluation Program will monitor the Mound Site Plume's containment and treatment system for up to one year to obtain operating data. The operating data will be used in designing similar containment and treatment systems for other VOC plumes at RFETS.

a. Valves and Piping -

Extra valves were required to allow flow through the system to be configured in multiple paths.

Lesson Learned - Each treatment cell should be designed so it is able to be isolated from the flow path. Flow should be able to be routed to any of the cells, either separately, in series, or in parallel.

ii. Construction -

a. Trench Stability

The originally planned, nearly vertical trench walls stayed open for about a week. The uphill side of the trench moved horizontally into the trench and re-excavation was required several times to maintain trench depth. There was no immediate danger to worker health and safety, due to slope failure, however workers were not allowed to work on uphill side of trench. A manlift was used to provide access to that side. The sides of trench were laid back to mitigate slope problems. This required additional materials for the collection system. Slope movement increased during hot dry weather. After the trench was closed, uphill slope movement stopped. Lessons learned -- Keep the trench sections open as short of a time as possible.

Close trench sections as soon as possible if slope failure occurs.

b. Valves and Piping

The specified valves leaked or broke and were replaced after installation. Valves and piping were damaged, probably during backfill operations. Two connections where lines enter the treatment cells broke and were redone. Several leaks occurred where lines entered the treatment cells.

Lessons learned -- Appropriate valves and piping are required.
Backfill operations as per specifications so as not to damage components
Connections must be leak tight.

c. Flow Meter

Specifications call for a battery powered flow meter. A solar panel with a back-up rechargeable battery or similar system is suggested to reduce long-term maintenance.

d. Utilities

While the excavation specialists cleared the area, and concurrence was obtained that no utilities existed in the area, a utility was encountered. Careful excavation by the heavy equipment operator prevented cutting the utility.

Lessons learned -- Anticipate that utilities may be present

e. General Equipment

Poor equipment performance caused delays. Undersized equipment had to be replaced. The manlift was slow and required multiple repairs.

Lessons learned -- Equipment selected must be efficient and effective for the task.

f. Records and Documentation

Documentation was difficult to obtain after work was completed.

Lesson learned -- Records and documents must be submitted weekly.

g. Piezometers, clean-outs and collection sump

Piezometers and trench clean-outs were braced during initial backfill operations. However, continued backfill pushed these off vertical. This impacts the ease and accuracy of the required water level measurements, and creates the potential for problems when the clean-outs are used. A hole was drilled in the collection sump cover, and a threaded cap was inserted. This allows for monitoring what is in the sump and obtaining water level measurements without removing the cover.

Lessons learned -- Provide support for clean-outs and piezometers throughout backfill operations.

iii. Operation -

The U.S. EPA Superfund Innovative Technology Evaluation (SITE) program is evaluating the performance of the reactive barrier for treatment of the Mound Site Plume. The goal of the SITE program is to collect well-documented data that are of known and reproducible quality, and are defensible. The samples to be collected are the influent water and treated water that has passed through 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 feet of zero-valent iron. Analysis of each sample collected will depend on the water flow rate through the system which is being recorded from the flow totalizer. The sample analysis parameters being collected are VOCs, Uranium, Cations, Anions, Dissolved Gases, Temperature, pH, Eh, Dissolved Oxygen and Electrical Conductivity. The VOC measurements are carbon tetrachloride, trichloromethane, dichloromethane, tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, 1,1-dichloroethene, 1,1,1-trichloroethane and vinyl chloride. Sample collection and analysis for the SITE program is expected to begin in the Winter of 1998 - 1999.

A cost analysis will be completed as part of the evaluation of this reactive barrier. The cost analysis will include a tabulation of the installation costs including the cost of the iron. Total installation, operation and maintenance, site investigation, design feasibility tests, general contracting and post-installation monitoring costs will be presented and potentially compared to a traditional pump-and-treat system costs.

Preliminary results of sampling and analysis for VOC content of the influent and effluent indicate that the system is successfully removing the VOC contaminants of concern. The results following treatment (Table 3 - shown in the column titled Effluent 11/04/98) are all non-detects (ND) except for acetone, methylene chloride, and 2-Butanone (MEK).

Table 3:

Mound Plume Treatment System Analytical Results (Preliminary) in ug/l

Location/Date	Collection Sump 11/04/98 (influent)		Top of Reactor 1 (influent) 11/04/98		Effluent 11/04/98	
Parameter	Result	Detection Limit	Result	Detection Limit	Result	Detection Limit
Acetone	ND	25.0	ND	25.0	180	83.0
Benzene	ND	2.5	ND	2.5	ND	8.3
Bromodichloromethane	ND	10.0	ND	10.0	ND	17.0
Bromoform	ND	2.5	ND	2.5	ND	8.3
Bromomethane	ND	5.0	ND	5.0	ND	17.0
Carbon disulfide	ND	2.5	ND	2.5	ND	8.3
Carbon tetrachloride	57.0	2.5	52.0	2.5	ND	8.3
Chlorobenzene	ND	2.5	ND	2.5	ND	8.3
Dibromochloromethane	ND	2.5	ND	2.5	ND	8.3
Chloroethane	ND	5.0	ND	5.0	ND	17.0
Chloroform	23.0	2.5	21.0	2.5	ND	8.3
Chloromethane	ND	5.0	ND	5.0	ND	17.0
1,1-Dichloroethane	1.6J	2.5	1.3J	2.5	ND	8.3
1,2-Dichloroethane	0.55J	2.5	0.53J	2.5	ND	8.3
1,1-Dichloroethane	4.0	2.5	3.8	2.5	ND	8.3
cis-1,2-Dichloroethene	30.0	1.2	27.0	1.2	ND	4.2
1,2-Dichloroethane (total)	26.0	2.5	23.0	2.5	ND	8.3
1,2-Dichloropropane	ND	2.5	ND	2.5	ND	8.3
cis-1,3-Dichloropropene	ND	2.5	ND	2.5	ND	8.3
trans-1,3-Dichloropropene	ND	2.5	ND	2.5	ND	8.3
Ethylbenzene	ND	2.5	ND	2.5	ND	8.3
2-Hexanone	ND	12.0	ND	12.0	ND	42.0
Methylene chloride	0.75J	2.5	0.97J	2.5	2.6J	8.3
4-Methyl-2-pentanone	ND	12.0	ND	12.0	ND	42.0
Styrene	ND	2.5	ND	2.5	ND	8.3
1,1,2,2-Tetrachloroethane	ND	2.5	ND	2.5	ND	8.3
Tetrachloroethane	35.0	2.5	31.0	2.5	ND	8.3
Toluene	ND	2.5	ND	2.5	ND	8.3
1,1,1-Trichloroethane	4.6	2.5	4.2	2.5	ND	8.3
1,1,2-Trichloroethane	ND	2.5	ND	2.5	ND	8.3
Trichloroethane	64.0	2.5	59.0	2.5	ND	8.3
Vinyl chloride	1.0J	5.0	0.83J	5.0	ND	17.0
Xylenes (total)	ND	2.5	ND	2.5	ND	8.3
2-Butanone (MEK)	ND	12.0	ND	12.0	29J	42.0

Though detected in the effluent, acetone has not been encountered anywhere else in the system and cannot be a treatment reaction product. The same is true of 2-Butanone (MEK). It is assumed that the detection of both of these is a product of contamination within the testing lab. Methylene chloride is found in the influent, but at a lower amount than within the effluent. Again, this could be a product of lab contamination, but also might be due to a reaction within the treatment system. Regardless of the origin, the concentration is below action levels. Further sampling and analysis will clarify if and how each of these three contaminants is being detected within the effluent. That none of the other organic contaminants were present is preliminary confirmation of the effectiveness of the treatment system.

V. REFERENCES

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