MINUTES

St. Louis Site Remediation Task Force Technologies Working Group

October 11, 1995 Meeting

Mallinckrodt Chemical, Inc. Chesterfield, Missouri

Participants Attending

<u>Support</u>

Jim Dwyer, Facilitator Dave Miller, SAIC

Sarah Snyder, FUSRAP

Tom Binz, Laclede Gas Kay Drey, Missouri Coalition for the Environment Robert Geller, MDNR Jim Grant, Mallinckrodt Chemical Laurie Peterfreund, NCEIT Sally Price Mitch Scherzinger, MDNR Clarence Styron, R.M. Wester & Associates Robert Wester, R.M. Wester & Associates

<u>Minutes</u>

Call to Order

Agenda Item

The meeting was called to order at 8:45 a.m. Jim Grant opened the meeting with a summary of the conclusions of the July meeting; he reminded members that they had agreed, based on the research conducted by the Clemson Technical Lab, not to pursue soil washing or chemical extraction as a primary technology for application at the St. Louis Airport Site (SLAPS). However, he said there are other technologies available that ought to be identified and considered and asked Dave Miller to provide an overview of these other technologies.

Mr. Miller discussed various technologies that may have potential application to the St. Louis Site. He said that the Oak Ridge National Laboratory (ORNL) has developed an extensive database of technologies, called the Technology Logic Diagram, to

Determination

Dave Miller will develop a matrix evaluating potential technologies by the November

Discussion of Technologies -----

track various technologies relevant to a particular stage of remediation. For example, he said one section addresses technologies suitable for use in characterization studies. He explained that ORNL considers machines, processes, and new applications of existing techniques to be technologies.

He distributed copies of examples of the information found in the Technology Logic Diagrams, especially from the colume concerning (evaluating) technologies for decontamination and decommissioning. The diagrams provide the following information:

- Overall assessment of the applicability of each technology in question, expressed as E (essential). H (high), M (medium), and L (low)
- Significance of the scale polem to s which the technology is applied on a 1-5 scale, with 5 being highest significance
 - The estimated time required to bring the technology to an acceptable state for application at large scale at the site. This is expressed in number of years and depends on the current state of development of that particular technology
- The estimated cost for bringing the technology from its present state to a level acceptable for commercial or large-scale use. Costs are presented as \$M or \$K, which indicates the number of millions or thousands of dollars, without escalation
- The projected unit processing cost for mature technology (\$ per square foot or other unit, or "N" for no estimate)

An example of the ranking system follows:

H-5-5(\$3.5M;N)

This indicates that this technology has a high overall usefulness; the technology is estimated to take five years before it will be ready for application at the site; an Task Force meeting.

approximate expenditure of \$3.5 million will be required to bring the technology to this state of readiness, and the unit processing cost cannot be projected at the present time.

The Technology Logic Diagrams detail how the formulas are calculated. For example, in determining the status of a technology, the rankings are as follows:

Accepted	5
Demonstration Needed	4
Predemonstration	3
Conceptual	2
Preconceptual	1

Mr. Miller said there are some technologies that might be applicable to the St. Louis Site, especially those which improve characterization of existing conditions. He said that soil washing and in-situ vitrification, which have been discussed by the working group, are only two of the many technologies available for consideration. For example, there may be technologies that can provide more precise answers to these questions:

> What contaminants are present?

He said DOE has a good idea what the contaminants are at the site, but that the more precise the characterization, the more cost-effective the cleanup.

 How concentrated are the contaminants?

> Mr. Miller said DOE does not have as well-developed data for this question.

• Where are the contaminants located?

He said DOE knows the

bounds, but not the distribution of the contaminants within those boundaries.

• How far have the contaminants spread?

Mr. Miller said DOE has fairly comprehensive data about contaminant transport.

 He offered to develop a similar ranking for technologies that might apply at the St.
 Louis Site, using the same format as ORNL does for its Technology Logic Diagrams. The working group asked Mr. Miller to proceed with developing a technology matrix for ditc.
 use as it evaluated potential technologies.

Soil Washing

Kay Drey asked that an article on chelating agents, which are used in some soil washing and/or chemical extraction processes, be distributed to the members of the working group. (ATTACHMENT A)

She said soil washing has not been demonstrated to be a viable option for St. Louis Site soils. Mr. Grant acknowledged that North County soil typically has a high clay content, which makes it unsuitable for soil washing. However, he said soil at the downtown site is mostly fill, which may prove to be more suitable for this type of process.

Mr. Miller said he would try to distinguish between North County and downtown soils in the matrix.

The next meeting of the Technologies Working Group is scheduled for 1 p.m. on November 14, 1995 at the World Trade Center in Clayton. The meeting adjourned at 10:40 a.m.

Approved November 14, 1995

cies of higher molecular weight (15).

We extracted the middle GFC fraction, which contained the largest radionuclide concentrations, with chloroform to remove compounds that would interfere in the subsequent analysis. All the radionuclide remained in the aqueous phase after the chloroform extraction. The aqueous layers were then evaporated to dryness and methylated to facilitate gas chromatography-mass spectrometry (GC-MS) analysis (16).

The GC profile for the methylated fraction is illustrated in Fig. 3. We used MS to demonstrate that the dominant peak represents the tetramethyl ester of EDTA, an extremely strong chelate commonly used in decontamination operations at nuclear facilities (17). Through use of an internal CDTA standard, the EDTA concentration of this sample has been calculated to be approximately $3.4 \times 10^{-7}M$; EDTA has also been detected in samples RS3 obtained near pit 4 and RS9 near trench 5 (18).

Other constituents detected in trench leachates include palmitic acid. phthalic acid (19), and other mono- and dicarboxylic acids, which are much weaker complexing agents than EDTA. The concentrations of strong chelates similar to EDTA, such as nitrilotriacetic acid (NTA) and DTPA, are below the detection limit of this analysis, which is approximately $5.0 \times 10^{-9}M$. Because NTA is biodegradable, it would not be expected in significant concentrations in the groundwater even if it had been originally present in the waste (20). Both DTPA and other multidentate chelates were used only sparingly in decontamination at ORNL during the 1,950's and 1960's and consequently do not appear to be significant in the radionuclide mobilization at this site.

We thus reasoned that EDTA is the dominant mobilizing agent in samples RS7, RS3, and RS9. A minor portion of the migrating ⁶⁰Co and U is associated with natural organics. Ligands such as phthalic, palmitic, and other carboxylic acids may also be contributing to ⁶⁰Co and U mobilization to a small extent.

The identification of EDTA as a radionuclide mobilizer in the ORNL disposal area raises a question about the suitability of this chelate in decontamination operations. Although EDTA is used in decontamination because of its powerful metal-binding properties, this same characteristic also leads to radionuclide mobilization. The radionuclide mobilization caused by EDTA in the ORNL burial grounds probably does not at present impose a health hazard. However, its con-



Fig. 2. The GFC elution profiles of groundwater from RS7. a small seep east of trench 7 [fro (13)]. [Courtesy of Limnology and Oceanography, Seattle]



Fig. 3. The GC profile of GFC-purified and methylated groundwater sample RS7.

1479

tinued use in decontamination operations around the country, and therefore its presence in low- and intermediatelevel waste, constitutes a potential for the release of undesirable amounts of radionuclides. Because EDTA is resistant to decomposition by radiation (21), thermally very stable (22), and only slowly biodegradable (23), it is extremely persistent in the natural environment. Indeed, the presence of significant concentrations of EDTA in waste 12 to 15 years old attests to its persistence. Therefore, wherever EDTA and similar compounds have been introduced into, terrestrial disposal sites, the aqueous transport of transition metals, rare earths, and transuranics, which characteristically form the most stable complexes with chelates. may be augmented.

There can be no question about the strong complexing capaçity of EDTA and similar chelates for certain radionuclides including the rare earths and actinides. For example, all of the trivalent rare earths along with Am³⁺, Cm³⁺, Pu³⁺, Pu⁴⁺, Pu⁶⁺, and Th⁴⁺ possess at least as high or higher complexity constants, K., for EDTA as Co²⁺ (24). Both EDTA and DTPA are used in the therapeutic removal of transuranics ingested by humans because of the strong complexes formed with these elements (25). Our evidence suggests but does not prove that EDTA is also contributing to the migration of trace levels of Pu, Am, Cm, Th, and Ra, which have been detected in the soil from seep RS7 approximately 100 yards (90 m) east of trench 7. For example, actinides were found in concentrations of $43 \pm 8 \text{ dpm/g of } {}^{238}\text{Pu}, 110 \pm 7 \text{ dpm/g of }$ 241 Am, and 495 ± 20 dpm/g of 244 Cm in a weathered shale sample collected /at a depth of 71 cm in well T7-12, which is adjacent to well RS7 (4, 5). In addition, chelates increase the uptake of numerous trace elements by plants. Consequently, the ecological recycling rates of certain radionuclides such as 239Pu and ²⁴¹Am, and therefore the possibility of their entering human food chains, increases in the presence of complexing agents (26).

In the United States, there are six commercial and five Energy Research and Development Administration terrestrial radioactive waste burial sites which have in the past received or are currently receiving low- and intermediate-level radioactive wastes (27). Varying levels of radionuclide migration from original disposal sites have been observed at four of these waste burial sites other than ORNL, including the Savannah River Laboratory, South Carolina (28); the Hanford, Washington, facilities (29): West Valley, New York (30, 3. 1997) Maxey Flats. Kentucky (31). The CHORE River facility in Canada has expenses similar migration problems (32) - migration of Pu, the presence of Pu in the dissolved fraction of leachates, and the existence of mobile Pu-contaminate leachates in waste pits have been fur the ed at the Hanford. West Valley Maxey Flats facilities, respectively 27-31). Complexing agents are either ent or suspected to be present in ways of Chalk River, West Valley, and March Flats (31. 32).

The use of EDTA and similar more pounds in decontamination operaand therefore their presence in low- and intermediate-level waste in the United States and the rest of the world, is widespread (21). Throughout the world, leveand intermediate-level radioactive wasa: is being buried along with chemicals traare likely to cause the migration of hazardous isotopes such as Pu over the long term. Indeed, trace levels of the dionuclides are being released by groundwater transport at many radioactive waste disposal sites in this country, and migration of radioactive transition metals, rare earths, and transuranic? is probably being aided by chelates such as EDTA. Consequently, if the use otEDTA and similar compounds is to continue, waste solutions should be treated for the removal or destruction of the chelates prior to final disposal in the ground. Another alternative would be to use suitable substitutes, compounds that are effective in decontamination but do not facilitate radionuclide_mobilization.

One such useful substitute may be NTA, which is a potential replacement for phosphates in detergents. This compound is rapidly biodegradable (20) and is a strong ligand, although slightly weaker in complexing capacity than EDTA.

The biodegradability of other chelates such as triethylenetetraaminehexaacetic acid (TTHA), hydroxyethylenediaminetriacetic acid (HEDTA), N-(2-hydroxyethyl)-ethylenediaminetriacetic acid (HEEDTA), ethylenediamine di-(O-hydroxvphenylacetate) (EDDHA), and DTPA is apparently not well known. Some of these compounds are stronger ligands than EDTA and therefore would be more effective in decontamination. However, the use of such compounds, if nonbiodegradable, could lead to even more migration from disposal sites than that caused by EDTA.

Numerous other alternatives to the use of EDTA and related compounds are available. Hat with success equipment, ins address over their decontaminated minimum af a life interview reagents r oxidizand the second tere halburnt . relatively hild cd ein mittale tartrate. met la guerate des conchate bisulfate. and the second second second state to ra-Rother to the second fronment to a much lesses el tent than EDTA.

Escution of the Courters & decontem soften existens and seat sques are assistance all show there reagents used experiences in a number of in successive meatitents have been shown the there are a free of the strees to SIDTAL

JEFFELL L MEANS DANCE CRERAR

1482 mento de le Revele

Principal in Terms 3548

Server 1 COGULD

Tarren (Contrate (Contrate)

Assects of Section.

Barecher, water call again

Columbus. Ohio 43201

References and Notes

Autoria ORNI - 100 Current Durent Durent Калария Маран Марана, Кар.
 Калария К. К. Е.
 Калария К. К. Е.

2. D. A. Webster, U.T. Geol. Surv. Open File Re

- D. A. A Coster, S. C. Georgen, Opportune Rep. 76-727 (1976).
 T. F. C. C. entuls in all a Phys. Rep. 4 (1553); matches & D. D. 1995 (2010). Structures in a 13, 897 (1967). Annual Separation and I. Tamura, *ibid.* 18, 467 (1970). In F. Somerrage and D. G. Gudi-ner, *iaid*, 41, 362 (1955); T. F. Longerung, and T. ner, 1010 (11, 90) (200); 5 St. Lumerick and T. Tamura, 500 Sec. Suc. Am. Proc. 29, 383 (1965); P. H. Carrigan (1, 1, 5 Geol Surv. Proj. Pap. 433-G (1968); R. J. Pickering, U.S. Cool, Surv. Proj. Proc. 423 (1, 1997); J. Con. 423 Prof. 200, 413 4 (200, 11) Constant of the Arthough Andrew Series and Antonia and Antonia and Antonia and Antonia Surface Water Unter-tational Atomic Energy Astronomy Waster Inter-national Atomic Energy Astronomy Decision Io Seas, Ocions into Surface Walers (International Atomic Energy Agency, Vienna, 1960), pp. 57-88; J. O. Duguid, Oak Ridge Nati Lab. Rep. ORNL-5017 (1975); Oak Ridge Nati, Lab. Rep. ORNL-5141 (1976); Oak Ridge Nati, Lab. Rep. ORNL-5141 (1976); S. J. L. Means, D. A. Crerar, J. O. Duguid, Oal Ridge Nati, Lab. Jer. SRA LIM-5,148 (1976); S. J. L. Means, D. S. Strange, M. P. Seresik, J. S.

- J. L. Meals . Duguid, optimizer to the composition S. Wahiberg, Trans. Am
- 6. Et A. Jenne and S. S. Wahlberg, Trans. An Geophys. Union +6, 170 (1965). 7. $K_d = [^{40}Co., dpm.n]$ is sediment] = $[^{40}Co.(dp.n., m)$ in 0.22-µm filtered acueous phase]⁻¹ Labor phone K. union of the sediment] = $[^{40}Co.(dp.n., m)]$ ratory K_a values were determined by the "batch" process. Untreased soil and weathered shale samples were shaken with solutions of appropriate chemical composition until equilibrium between absorbed and dissolved "Co has been reached.
- 8. We calculated the actual K_4 values from environmental soil and associated interstitial water samples, using the same definition as in (7)
- G. de Marsily, E. Ledoux, A. Barbreau, J. Mar-gat, Science 197, 519 (1977).
- 10. Groundwater samples were collected in polyethylene bottles and then immediately filtered through ashless Whatman filter paper of moder-ate retention and then through 0.22-um Millipore memoranes.
- 11. In the ion-exchange analyses we sluted seven In the on-exchance analysis we related bever hundred millitlier: if the desired sample through a column 2 million file to 25 cm with Resyn 101, Nat-Gom Lucen-exchange resin, at a flow rate of approximately 5 ml/min.
 The general GPC processor is described area where (3), in the net end approximation of anon-

137652

re chelating agents

Reports

Migration of Radioactive Wastes: Radionuclide Mobilization by Complexing Agents

Abstract. Ion exchange, gel filtration chromatography, and gas chromatographymass spectrometry analyses have demonstrated that ethylenediaminetetraacetic acid (EDTA), an extremely strong complexing agent commonly used in decontamination operations at nuclear facilities, is causing the low-level migration of cobalt-50 from intermediate-level liquid waste disposal pits and trenches in the Oak Ridge National Laboratory burial grounds. Because it forms extremely strong complexes with rare earths and actinides, EDTA or similar chelates may also be contributing to the mobilization of these radionuclides from various terrestrial radioactive waste burial sites around the country.

From 1951 through 1965, intermediatelevel radioactive liquid waste at Oak Ridge National Laboratory (ORNL) in Oak Ridge. Tennessee, was disposed of in seven different seepage pits and trenches (1). Since 1944, solid waste at ORNL has routinely been buried in shallow trenches in six different burial grounds (2). Ground burial of radioactive waste is an effective means of disposal if the radionuclide can be confined to the geologic column through geochemical processes. Although the Conasauga shale, the predominant bedrock of the ORNL burial grounds, has an extremely high adsorption capacity for most fission by-products, trace quantities of certain radionuclides are migrating from both solid and liquid waste disposal sites (3).

Several factors have contributed to the radionuclide mobilization. One is that the annual precipitation at ORNL, over 127 cm, is greater than at any other radioactive waste burial site in the country (2). As a result, water infiltrates into trenches at a faster rate than it can be dissipated and mixes with the waste. In addition, groundwater levels are comparatively shallow and a high-density surface drainage network is present. There is also an abundance of fractures in the underlying rock, which diminishes the rock's sorptive capacity because the exchange sites adjacent to the fissures are saturated with the exchangeable ions in the waste (2). Finally, the presence in the waste of complexing agents such as organic chelates used in decontamination operations and natural organic acids from the soil promotes the formation of strong complexes with certain radionuclides that reduce the adsorption capacity of the shale and soil for the radionuclide.

It is this last factor that is of principal concern in this report. The isotope 60Co has been found in concentrations up to 10⁵ dpm/g in the soil and up to 10³ dpm/ ml (450 pCi/ml) in the water in areas adjacent to seepage trench 7 and in lesser concentrations in the vicinity of trench 5 and pit 4 (Fig. 1). Traces of various alpha-emitters such as isotopes of U, Pu. Cm. Th, and Ra have also been detected in water or soil from the area around trench 7 (2-4). We show here that 50 Co is transported in the groundwater from the trenches and pits as organic complexes. A portion of the migrating 60Co is adsorbed by oxides of Mn in the shale and soil (4-6). Additional evidence suggests that some U is migrating by the same mechanism.

The following experimentally measured distribution coefficients (K_d) illustrate the pronounced effects that organic ligands have on the adsorption capacity of sediment for trace metals. We determined that the K_d values for ⁶⁰Co in weathered Conasauga shale at pH 6.7 and 12.0 were approximately 7.0×10^4 and 0.12×10^4 , respectively. In the presence of $10^{-3}M$ ethylenediaminetetraacetic acid (EDTA) the K_d values were reduced to 2.9 and 0.8 (7).

The actual K_d values calculated from ⁶⁰Co concentrations in soil and water from various wells in the ORNL burial grounds are similar (8). The K_d values for ⁵⁰Co from wells in the vicinity of trench 7 range from approximately 7 to 70, averaging about 35 (see Table 1). The pH of well water ranges from 6.0 to 8.5 (4), and the EDTA concentrations are approximately $3.4 \times 10^{-7}M$ (this study). Actual $K_{\rm u}$ values for ⁶⁰Co in burial ground waters are therefore significantly lower than the theoretical value for neutral systems containing no EDTA and are somewhat greater than the experimental value for neutral systems containing $10^{-3}M$ EDTA.

The importance of sediment sorption capacity (or K_1) on radionuclide migration rates within geologic substrates has been modeled by Marsily et al. (9). Using variables such as K_{d} , rock permeability, and hydraulic gradient, they calculated the migration rates of 239Pu buried at the bottom of geologic formations 500 m thick. The results show that ²³⁹Pu with a K_d of 2 × 10⁹, typical of a chemical setting devoid of complexing agents, rock fractures, and similar factors tending to reduce sediment adsorption, will not migrate to ground level until more than 106 years after burial, the migration rates being slowest in those geologic formations with lowest permeability. With a half-life of 24,400 years, Pu would essentially be completely decayed by the time of contact with the surface environment. At the other extreme, in a chemical setting characterized by no sorption $(K_d = 0)$, Pu would reach the environment in 6 to 14,500 years, depending on the permeability of the geologic formation (9). That is, in the most confining formation Pu would have decayed about only one-half of one halflife before it reached the surface. In formations of low to moderate permeability, migration of Pu over 500 m would have occurred in only tens to several hundreds of years, the movement being four to five orders of magnitude more rapid than in the situation $K_d = 2 \times 10^3$.

In the Oak Ridge setting, the adsorption capacity of the Conasauga shale for inorganic forms of Co is very high. Hence, mobilization of this radionuclide in the absence of strong complexing agents. rock fractures. and other factors tending to reduce sorption would be negligible. However, in the presence of strong chelates. rock fractures, and other factors tending to decrease sorption. the K_d is drastically reduced and mobilization rates may be accelerated by several orders of magnitude.

A compilation of selected radionuclide analyses for filtered water, weathered Conasauga shale, and soil samples collected between June 1974 and June 1975 from wells in seeps adjacent to pit 4, trench 5, and trench 7 is given in Table 1 (10). Locations of pits, trenches, and sampling sites are shown in Fig. 1.

A surprising initial observation. first

SCIENCE, VOL. 100. 30 JUNE 1978

made by E. A. Bondietti, was that "Co in groundwater did not readily exchange with cation-exchange resins (Rexyn 101, Na⁺-form). Data from several samples show that only about 5 to 10 percent of the "Co could be adsorbed by the resin, the other 90 to 95 percent being retained in solution as a tightly bonded complex. It seemed apparent that whatever agent was responsible for this effect was also preventing complete adsorption of certain radionuclides by the Conasauga shale and soil.

Subsequent ion-exchange analyses that we carried out demonstrated that the strength of ⁶⁰Co complexes with possible inorganic groundwater components such as sulfate, nitrate, bicarbonate, carbonate, chloride, orthophosphate, and even stronger ligands such as pyrophosphate and metaphosphate was insufficient to produce the ion-exchange elution behavior of "Co observed in the samples (11). However, in the presence of very low concentrations (1078M and less) of multidentate chelating agents such as diethylenetriaminepentaacetic acid (DTPA), cyclohexanediaminetetraacetic acid (CDTA). EDTA, and also natural organics such as humic and fulvic acids. ⁶⁰Co resisted adsorption by the resin.

Table 1. Selected radionuclide analyses of weathered Conasauga shale and soil and filtered water samples $(0.22 \,\mu\text{m})$ and corresponding K_{d} values from wells in the vicinity of pit 4, trench 5, and trench 7.

Well code	Date	Aqueous ³ H (dpm/ml)	Aqueous ™Co (dpm/ml)	Adsorbed *"Co (dpm/ml)	<i>K</i> _d ([™] Co)*
RS3	24 June 1975	1280	90.0	NAt	
RS5	25 June 1975	1290	39.0	NAt	
RS7	26 June 1974	3050	669.0‡	43,700	65.3
T7-118	31 July 1974	3930	518.0	16,900	32.6
T7-12	31 July 1974	3450	547.0	28.600	52.3
T7-13	8 August 1974	3740	816.0	24,500	30.0
T7-14	31 July 1974	1900	227.0	6.600	29.1
T7-15	31 July 1974	2090	153.0	1.060	6.9
RS9	24 June 1975	3130	80.9	NA†	





Fig. 1. Location of small seeps associated with pits 1, 2, 3, and 4 and trenches 5, 6, and 7. Contours are in feet (from (4)). [Courtesy of Oak Ridge National Laboratory, Oak Ridge, Tennessee]

In order to differentiate between the radionuclide-mobilizing effects of synthetic chelates of low molecular weigh: and those of humic substances of higher molecular weight, we fraction groundwater samples, using gel filt chromatography (GFC), a process which separates solutes according to size (12). Since most weak inorganic, metallic complexes are sorbed during the GFC process, the presence of trace metals in a given fraction of an elution profile demonstrates an association between the trace metal and a ligand in that fraction (13, 14).

Elution profiles of a concentrated groundwater sample from location RS⁻ near trench 7 for Sephadex gels G-10, G-15, and G-25 are illustrated in Fig. 2. Each of these elution profiles contains three fractions decreasing in molecular weight to the right. The blue dextrar, peak coincides with the fraction of the sample having molecular weights above 700. Between 90 and 95 percent of the "Co and 70 percent of the U present in the sample are correlated with the middle fraction, which represents : group of organics with molecular weight: less than 700 plus the Na⁺-salts of several polyvalent anions. Between 5 and 10 percent of the ⁶⁰Co and 30 percent of the U are associated with the fraction hay molecular weights above 700, and ⁶⁰Co or U are observed with the smallest molecular weight peak, which through infrared spectrophotometry was determined to be comprised principally of NaNO₃ and NaCl. Reliable Pu analyses of the GFC fractions could not be obtained.

Infrared spectrophotometric data indicate that the large molecular weight fractions associated with minor ⁶⁰Co and U transport are humic substances. Because groundwater in and very close to the trenches is typically low in humic content, we believe that humics are not major contributors to radionuclide transport from the trenches. On the contrary, we believe that humics become associated with radionuclides some distance from the trenches, particularly in the seeps, where groundwater humic concentrations are the greatest.

After we had completed the GFC fractionations, the identities of complexing agents in the major radionuclide-bearing fractions were still unknown. We suspected that these materials were synthetic chelates, but humic substances lower molecular weight could not completely ruled out, particularly view of their greater acidity and metacomplexing capacity relative to the spe

00-1774

Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for the St. Louis Site, Missouri



U.S. Department of Energy

Property of ST LOUIS FUSRAP LIBRARY