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Analysis of Monolith Cores from an Engineering Scale Demonstration of a Prospective Cast Stone Process

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June 2016

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EXECUTIVE SUMMARY

The primary disposition path of Low Activity Waste (LAW) at the DOE Hanford Site is vitrification. A cementitious waste form is one of the alternatives being considered for the supplemental immobilization of the LAW that will not be treated by the primary vitrification facility. Washington River Protection Solutions (WRPS) has been directed to generate and collect data on cementitious or pozzolanic waste forms such as Cast Stone.

This report documents the coring and leach testing of monolithic samples cored from an engineering-scale demonstration (ES Demo) with non-radioactive simulants. The ES Demo was performed at SRNL in October of 2013 using the Scaled Continuous Processing Facility (SCPF) to fill an 8.5 ft. diameter x 3.25 ft. high container with simulated Cast Stone grout. The Cast Stone formulation was chosen from the previous screening tests. Legacy salt solution from previous Hanford salt waste testing was adjusted to correspond to the average LAW composition generated from the Hanford Tank Waste Operation Simulator (HTWOS). The dry blend materials, ordinary portland cement (OPC), Class F fly ash, and ground granulated blast furnace slag (GGBFS or BFS), were obtained from Lafarge North America in Pasco, WA.

In 2014 core samples originally obtained approximately six months after filling the ES Demo were tested along with bench scale molded samples that were collected during the original pour. A latter set of core samples were obtained in late March of 2015, eighteen months after completion of the original ES Demo. Core samples were obtained using a 2" diameter x 11" long coring bit. The ES Demo was sampled in three different regions consisting of an outer ring, a middle ring and an inner core zone. Cores from these three lateral zones were further segregated into upper, middle and lower vertical segments. Monolithic core samples were tested using the Environmental Protection Agency (EPA) Method 1315 which is designed to provide mass transfer rates (release rates) of inorganic analytes contained in monolithic material under diffusion controlled release conditions as a function of leaching time. Compressive strength measurements and drying tests were also performed on the 2015 samples. Leachability indices reported are based on analyte concentrations determined from dissolution of the dried samples.

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LIST OF ABBREVIATIONS

DOE/ORP	Department of Energy – Office of River Protection
EPA	Environmental Protection Agency
GGBFS or BFS	Ground granulated blast furnace slag
HTWOS	Hanford Tank Waste Operations Simulator
ICP-MS	Inductively Coupled Plasma – Mass spectroscopy
ICP-OES	Inductively Coupled Plasma – Optical Emission spectroscopy
ID	Inner Diameter
L/D	Length to Diameter Ratio
LAW	Low Activity Waste
LI	Leachability Index
OPC	Ordinary portland cement
QAP	Quality Assurance Program
SCPF	Scaled Continuous Processing Facility
SRNL	Savannah River National Laboratory
WRPS	Washington River Protection Solutions

1.0 Introduction

The Department of Energy – Office of River Protection (DOE/ORP) has directed Washington River Protection Solutions (WRPS) to generate and collect data on cementitious or pozzolanic waste forms such as Cast Stone. A cementitious waste form is one of the alternatives being considered for Supplemental Immobilization of Hanford Low Activity Waste (LAW), along with vitrification, bulk vitrification, and fluidized bed steam reforming. The goal of this project for WRPS was to obtain data on the performance of the Cast Stone waste form and process for immobilizing LAW.

A testing program was developed to obtain additional information on the Cast Stone option.¹ Screening tests were conducted in 2013 to examine expected ranges in waste composition, waste concentration, dry materials sources, and free water (in the waste liquid)-to-dry blend mix ratios.²

An engineering scale demonstration with nonradioactive LAW simulants was initiated in October 2013. The primary objectives were to increase the Technology Readiness Level of the Cast Stone process/technology for immobilizing Hanford LAW and to demonstrate equivalent performance between waste forms produced at the laboratory bench and engineering pilot plant scales.³ The Scaled Continuous Processing Facility (SCPF) at Savannah River National Laboratory (SRNL) was used to fill a container with simulated Cast Stone grout to demonstrate the ability to operate a process to immobilize a simulated LAW salt solution in a cementitious waste form. This report describes and summarizes the core sampling and leach testing of monolithic samples that were obtained during April of 2014 and later in March of 2015 from the engineering-scale demonstration Cast Stone monolith.

2.0 Experimental Procedure

Leach testing activities performed as part of the Engineering Scale Demonstration, heretofore referred to as the ES Demo, are described in a Task Technical and Quality Assurance Plan.⁴ This plan identifies the approach for core sampling and leach testing of as-retrieved core samples.

2.1 Coring Samples

The ES Demo large scale monolith that was poured in October of 2013 was core sampled using 2” inner diameter (ID) by 11” tall steel coring bits in April of 2014. A schematic of the eight core locations for the initial 2014 core sampling activities is shown in Figure 2-1. Cores 1, 2, 3 and 7 were obtained from the outer ring, cores 4 and 5 were obtained from the middle ring and cores 6 and 8 were obtained from the inner region of the ES Demo monolith. As shown in the bottom of Figure 2-1 the ES Demo monolith was divided into regions that experienced different cure temperatures due to heat of hydration. The vertical zones shown correspond to the separate lifts poured on three successive days to form the monolith. Cored samples were placed in Ziploc[®] poly bags with a damp cloth containing water for sealed storage until testing. During processing of the ES Demo, grout was collected in cylindrical 2” diameter x 4” tall molds from both the READCO mixer discharge and the hose discharge into the container. These samples were stored in a humid environment either in a closed box proximal to the container or inside the laboratory.³

The ES Demo was again core sampled in March of 2015 and the three additional cores are identified in Figure 2-1. Cores 9, 10 and 11 were obtained from the outer, middle and inner zones of the ES Demo monolith, respectively. These core samples were vacuum-sealed in polybags without any damp cloth containing water until the start of testing. Damp cloths were not added to these cores since the vacuum seal was assumed to be more impervious to air and water vapor transport than the Ziploc[®] seals. A photograph showing the drill, drill extension and core bit as operated by technical personnel for the 2015 core sampling event is shown in Figure 2-2. Photographs of the Cast Stone monoliths as they were extruded from the core bits are shown in Figure 2-3.

Information on the individual core samples obtained from the 2014 ES Demo and the molded grab samples used in leach testing is provided in Table 2-1 and Table 2-2, respectively.

Table 2-1 shows the 77 individual core samples obtained from the eight core sampling positions from the 2014 core sampling event. The general core labeling scheme is Core Number, A-D/ T,M,B, with the core number representing the core locations identified in Figure 2-1, A through D representing continuous depth from top to bottom of each coring position, and T, M, B representing the top, middle and bottom segments or sub-samples within a core sample segment. Core sample segments were labeled 'A, B, C and D' going from the top to the bottom of the ES Demo monolith. Multiple core samples were obtained from most segments and those were identified as top (T), middle (M) and bottom (B) sub-samples within a core sample segment. The total length of these cores ranged from ~ 30.6" (Core 6) to 35.7" (Core 2). The cores identified in Table 2-1 are also pictured in Figure 3-1. Ten of the cores shown in Table 2-2 are highlighted to indicate samples that were leach tested as described in Section 3.3 below. Table 2-2 contains information pertaining to the collection date, sampling location and storage location for the molded samples that were leach tested in this work. These samples were collected in 2" by 4" cylindrical molds and are a subset of the twenty samples that were collected on each of three days of the ES Demo filling.³ All molded samples collected at the time of the ES Demo were stored in sealed Ziploc[®] poly bags with a damp cloth and some were kept in covered/lidded steel boxes (outside) and some were stored inside the laboratory.³

Table 2-3 shows the core identification and location for the nine different segments, i.e., three different core locations (9, 10 and 11) with top, middle and bottom vertical zone segments each, that were sampled from the ES Demo in 2015. Similar to the 2014 sampling event, each zone of each core was ~ 11" corresponding to the 11" core drill bit that was used. Core position 9 produced two cores from the top of the ES Demo monolith from the total ~ 11" core that were stored in bags 1 (upper section) and 2 (lower section). An additional two cores were obtained from the middle zone of the ES Demo monolith from the total ~ 11" core that were stored in bags 3 (upper section) and 4 (lower section). The final core from position 9 at the bottom of the ES Demo monolith was obtained as a single ~ 11" core stored in bag 5. This core was later segmented to produce sample 9-5 (upper section) and sample 9-6 (lower section). Core position 10 produced two cores from the top (bags 7 (upper section) and 8 (lower section)), two cores from the middle (bags 9 (upper section) and 10 (lower section)) and a single (bag 11) from the bottom of the ES Demo monolith. This core was later segmented to produce sample 10-11 (upper section) and sample 10-12 (lower section). Core position 11 produced two cores from the top (bags 13 (upper section) and 14 (lower section)), two cores from the middle (bags 15 (upper section) and 16 (lower section)) and two cores from the bottom (bags 17 (upper section) and 18 (lower section)). As noted in Table 2-3 photographs of these cores as they appear in the vacuum-sealed bags are presented in Figure 3-5. A single core from each bag, including the 2 different cores from bags 5 and 11 were leach tested as described below in Section 3.3.

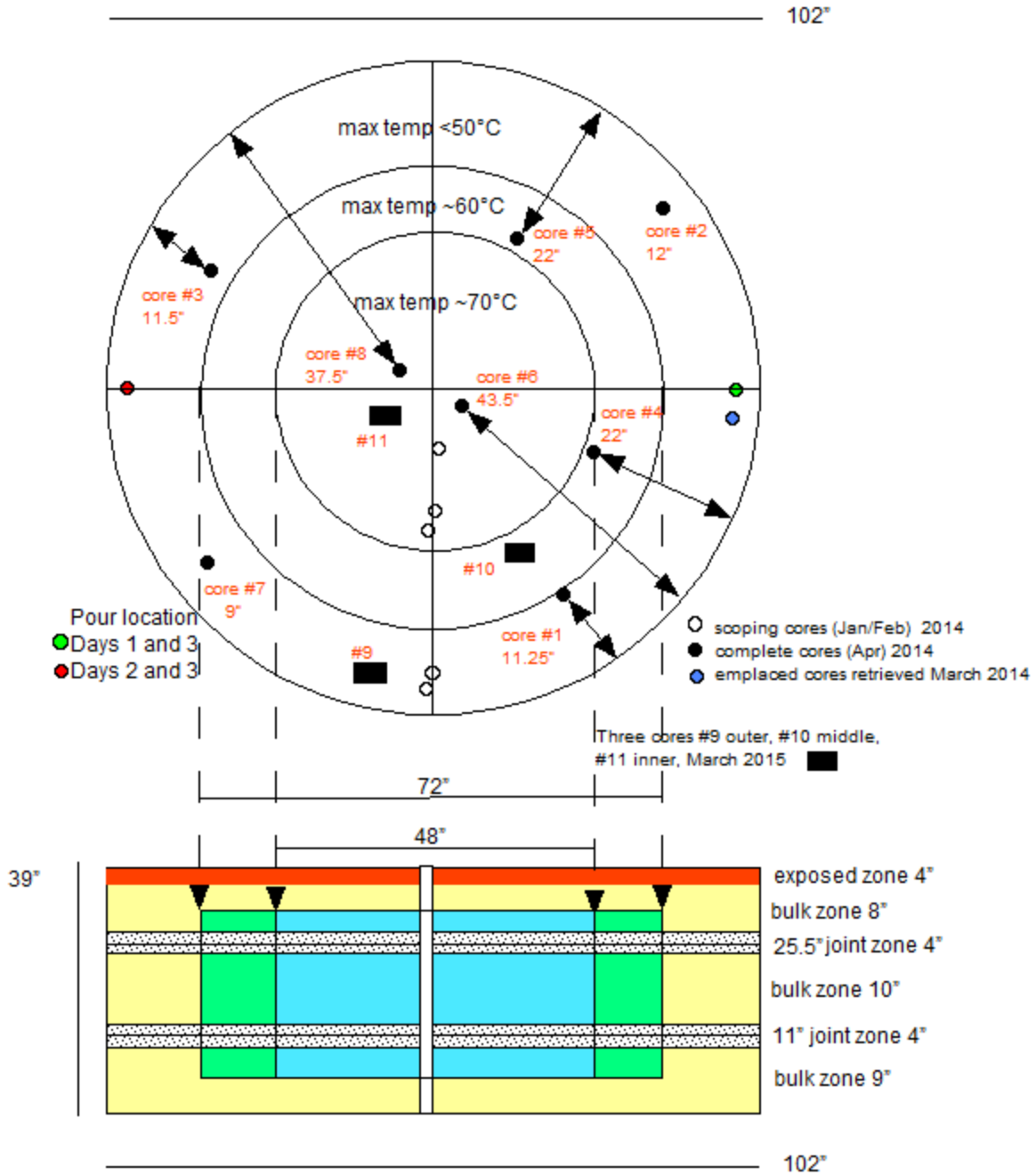


Figure 2-1. Schematic of ES Demo Coring Locations



Figure 2-2. Core Drilling Apparatus

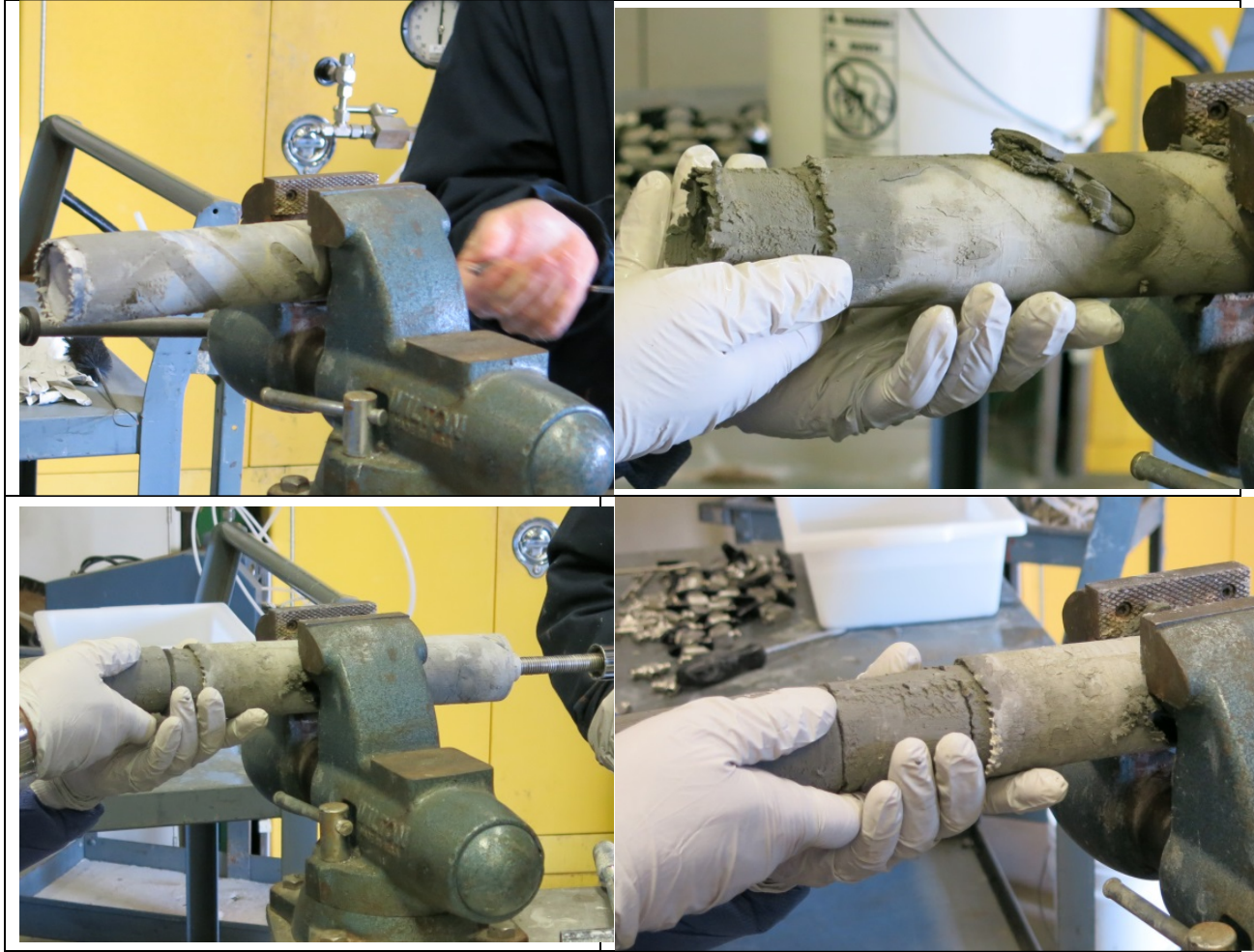


Figure 2-3. Removal of Cores from Core Bit

Table 2-1. Core Samples Obtained from 2014 Core Sampling Event

Outer Ring	Mass	Length	Outer Ring	Mass	Length	Middle Ring	Mass	Length	Inner Zone	Mass	Length
Core*/ Locate**	(g)	(in.)	Core*/ Locate**		(in.)	Core*/ Locate**	(g)	(in.)	Core*/ Locate**	(g)	(in.)
2A/T	184.9	2.1	1A/T	541.8	5.7	5A/T	244.2	2.6	6A/T	317.2	3.3
2A/M	204.2	2.2	1A/B	363.7	3.7	5A/M	290.4	3.0	6A/B	481.9	5.0
2A/B	382.5	4.1	1B/T	88.0	1.2	5A/B	281.7	3.0	6B/T	172.7	2.0
2B/T	357.2	3.7	1B/M	106.5	1.1	5B/T	313.9	3.2	6B/B	442.0	4.7
2B/B	307.3	3.2	1B/M/B	325.1	3.5	5B/B	448.1	4.5	6C/T	257.7	2.7
2C/NA***	566.4	5.9	1B/B	197.1	2.2	5C/T	372.9	4.0	6C/M	223.1	2.2
2D/T	526.3	5.7	1C/T	317.8	3.3	5C/B	401.8	4.1	6C/B	339.4	3.4
2D/B	390.6	3.8	1C/M	428.2	4.4	5D/T	212.5	2.3	6D/T	147.6	1.6
2E/NA***	444.2	5.0	1C/B	166.4	1.8	5D/M	207.8	2.3	6D/B	522.6	5.7
3A/T	360.9	3.6	1D/T	337.1	3.6	5D/B	169.8	1.9	8A/T	262.2	2.7
3A/B	431.5	4.4	1D/B	185.9	1.9	5D/B	233.4	2.5	8A/M	304.1	3.3
3B/T	449.6	4.7	7A/T	360.3	3.9	4A/T	312.5	3.4	8A/B	207.9	2.4
3B/B	246.1	2.5	7A/B	448.8	4.8	4A/B	315.7	3.4	8B/T	220.7	2.4
3C/T	480.8	5.0	7B/T	336.4	3.5	4B/T	449.7	4.6	8B/M	317.5	3.2
3C/B	183.3	1.9	7B/M	291.5	3.0	4B/B	427.7	4.4	8B/B	197.1	2.2
3D/T	224.2	2.4	7B/B	81.3	0.8	4C/T	291.5	2.8	8C/T	280.7	2.9
3D/M	250.4	2.6	7C/T	304.6	3.3	4C/B	432.0	4.4	8C/M	129.5	1.4
3D/B	377.4	3.9	7C/B	479.3	4.7	4D/T	318.7	3.6	8C/B	370.1	3.2
-	-	-	7D/T	469.6	4.7	4D/M	235.2	2.6	8D/NA***	580.5	6.0
-	-	-	7D/B	323.6	3.3	4D/B	174.1	1.9	-	-	-

*A, B, C and D represent sequential core samples from top (A) through bottom (D) of the monolith

** T=Top, M=Middle, B=Bottom represent relative location within an individual core sample segment

*** NA = these cores were singular continuous cores with no Top/Middle/Bottom sub-core segments

Note: 1) these cores are shown below in Figure 3-1; 2) the shaded cores were used in leach testing.

Table 2-2. Molded Samples Collected During ES Demo Filling Used in Leach Testing

2" x 4" Container	Collection Date	Collection Site	Storage
15	10-7-2013	Mixer	Inside
16	10-7-2013	ES Demo Container	Inside
21	10-8-2013	Mixer	Outside
26	10-8-2013	ES Demo Container	Outside

Table 2-3. Core Identification and Location for 2015 Samples*

Vertical Zone	Core #9 (Outer ring)	Core #10 (Middle ring)	Core #11 (Center Zone)
Top	Bags 1 & 2	Bags 7 & 8	Bags 13 & 14
Middle	Bags 3 & 4	Bags 9 & 10	Bags 15 & 16
Bottom	Bag 5**	Bag 11**	Bags 17 & 18
Thermal History	<50 °C	50-60 °C	60-70 °C

*See Figure 3-5 for photographs of these cores that were vacuum-sealed in polybags

** These cores were extruded such that they were stored in a single bag. They were later segmented to provide two different samples for leach testing. See text.

2.2 Leach Testing, Compression Testing and Moisture Analysis

Monolith subsamples of the core samples were subjected to the United States EPA Manual SW-846 Method 1315 leach test.⁵ Leachability indices (LI) were calculated based on the observed diffusivity equation presented in Section 12.2.5 of Reference 5. Leach indices for 2014 samples were determined for aluminum, calcium, chromium, sodium, nitrate and nitrite. Leach indices for the 2015 samples were determined for chromium, sulfur, sodium, nitrate and nitrite. The 2014 samples were tested as ten single samples from the various core regions. Four sets of duplicate 2"x4" samples that had been collected in molds during the ES Demo were also tested. Leach tests were started 28 days after core sample collection. Leach testing of the 2015 samples used two replicate samples from each core height (top, middle and bottom) resulting in eighteen tests. These leach tests were started on the day following sample core collection. The leachates were analyzed via Inductively Coupled Plasma – Optical Emission spectroscopy (ICP-OES) for aluminum, calcium, sulfur, sodium and chromium—an ultrasonic nebulizer was also used in the chromium analysis. For the leachates from 2015 testing that showed less than detectable 0.01 mg/L chromium values, these leachates were further analyzed via Inductively Coupled Plasma – Mass spectroscopy (ICP-MS) with a nominal detection limit of 0.001 mg/L. Ion Chromatography was used to analyze for nitrate and nitrite anions. Diffusivities were calculated based on the calculated as-batched analyte concentrations in the Cast Stone.³ The Al, Ca, nitrate and nitrite components derive from the simulant solution, whereas the Cr, Na and S components are present in both the simulant solution and the dry blend. Diffusivities were also calculated using the measured

composition from chemical analysis of the 2015 core samples. The Lithium Tetraborate Fusion method used in dissolution for cations analysis and the Potassium Hydroxide Fusion method used in dissolution for anions analysis have been previously described.²

Compressive strength testing was performed on the 2015 core sub-samples via the techniques presented in previous testing using a Humboldt compression machine model HCM-1000.⁶ Samples had aged for eight months after core sampling before the compression tests were performed. All sub-cores were prepared to have 90-degree right angles on tops and bottoms. The diameter and height of each sample was determined by averaging three separate measurements of each dimension. Moisture content analysis was performed on 15 – 30 gram samples in a convection oven at 110 °C.

2.3 Quality Assurance

The SRNL work scope was performed in accordance with a Quality Assurance Program (QAP) that meets the Quality Assurance criteria specified in DOE Order 414.1D, Quality Assurance; 10 CFR 830, “Nuclear Safety Management,” Subpart A, “Quality Assurance Requirements,” paragraph 830.122; and also meets the requirements of ASME NQA-1-2004, Quality Assurance Requirements for Nuclear Facility Applications, including NQA-1a-2005 and NQA-1b-2007 Addenda, or later version. The SRNL work scope was performed in accordance with Savannah River Site Manual 1Q, QAP 2-3 (Control of Research and Development Activities). Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

3.0 Results and Discussion

3.1 Core Samples

Photographs of the cored samples from the 2014 ES Demo sampling event are shown in Figure 3-1. These samples are shown as stored in the Ziploc[®] plastic bags with the water-dampened cloth. The samples are superimposed over the color-coded background that corresponds to the lower portion of Figure 2-1 which shows the different temperatures measured for the outer (yellow), middle (green) and the inner (blue) zones of the ES Demo monolith. Photographs of the core samples from the 2015 ES Demo sampling event are shown in Figure 3-2, Figure 3-3 and Figure 3-4 for the outer (top, middle, bottom), middle (top, middle, bottom) and inner (top, middle, bottom) core samples, respectively. These photographs show that each core up to eleven inches in height was not extruded from the sampling bit as a single, continuous monolithic core sample. Each core sample is comprised of several sub-samples or fragments. The figure captions to Figure 3-2 through Figure 3-4 indicate the vacuum-sealed bags that the core fragments were stored in that are shown in Figure 3-5. Figure 3-5 shows the 2015 core samples as they appeared after vacuum-sealing.



Figure 3-1. 2014 ES Demo Core Samples. From left to right, Core positions 7, 1, 3, 2, 4, 5, 8 and 6.

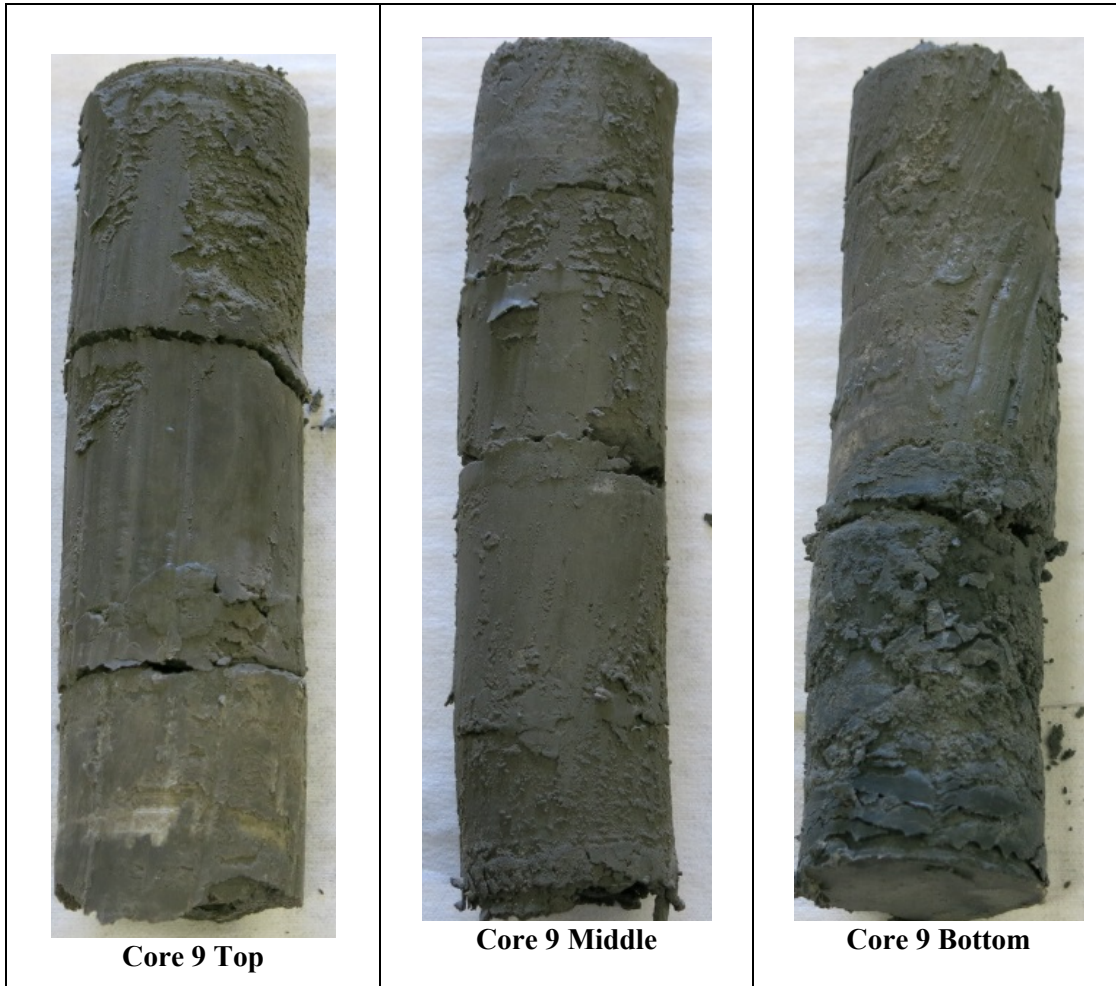


Figure 3-2. Pictured from left to right, 2015 Core 9 (Top, stored in bags 1 (upper section of core) and 2 (lower section of core)), Core 9 (Middle, stored in bags 3 (upper section of core) and 4 (lower section of core)) and Core 9 (Bottom, stored in bag 5). The core in bag 5 was later segmented into samples 9-5 (upper section) and sample 9-6 (lower section).

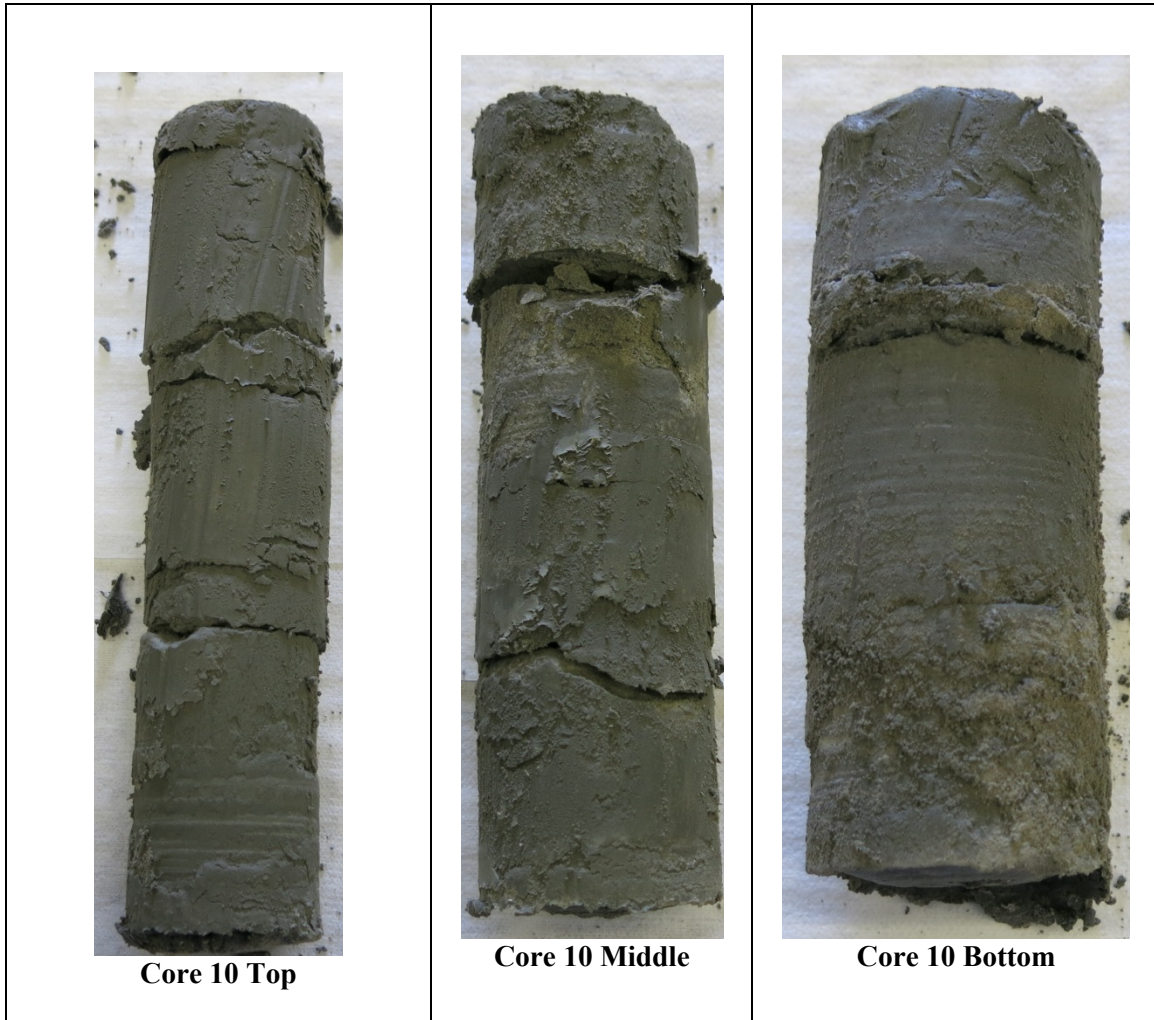


Figure 3-3. Pictured from left to right, 2015 Core 10 (Top, stored in bags 7 (upper section of core) and 8 (lower section of core), Core 10 (Middle, stored in bags 9 (upper section of core) and 10 (lower section of core) and Core 10 (Bottom, stored in bag 11). The core in bag 11 was later segmented into samples 10-11 (upper section) and sample 10-12 (lower section).

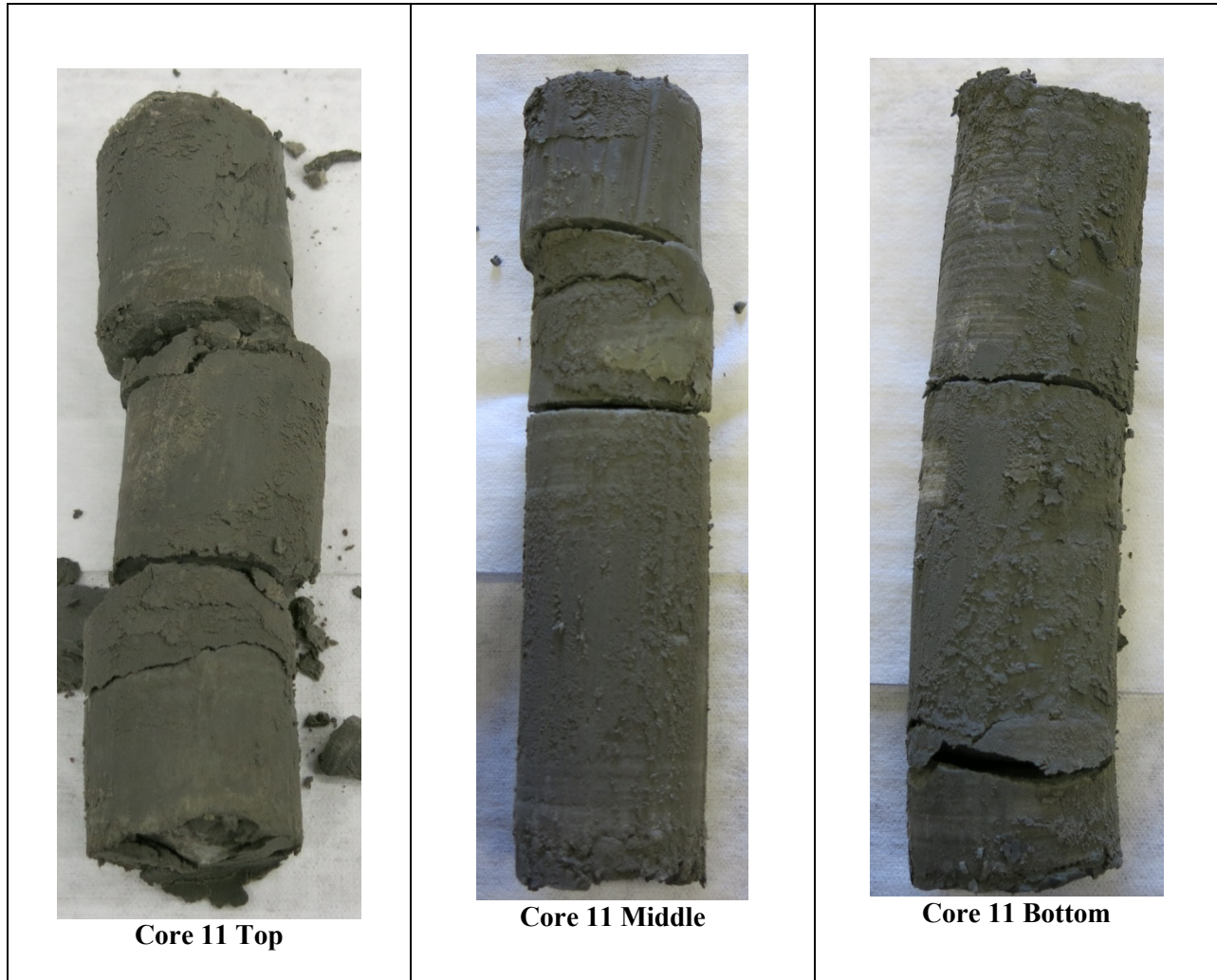


Figure 3-4. Pictured from left to right, 2015 Core 11 (Top, stored in bags 13 (upper section of core) and 14 (lower section of core)), Core 11 (Middle, stored in bags 15 (upper section of core) and 16 (lower section of core)) and Core 11 (Bottom, stored in bags 17 (upper section of core) and 18 (lower section of core))



Figure 3-5. 2015 Cores 9, 10 and 11 After Vacuum-Sealing

3.2 Compression Testing, Moisture Content and Chemical Composition of Non Leached Samples

Compression test results for the 2015 core samples that had been cured for eight months after coring are shown in Table 3-1. Samples used for the compression testing were obtained by sorting through the core samples and sub-samples remaining after earlier samples had been removed for leach testing. Sub-core samples were prepared to have right-angle tops and bottoms. All upper, middle and lower zones from the three cores are represented, except for the lower zone from outer core 9 which did not have a representative segment for testing. The length to diameter (L/D) values of the measured cores were all below the nominal or typical target for compression testing of L/D = 2 for bench scale molded monoliths.⁶ The compressive strengths ranged from 569 to 2150 psi with an average of 1059 psi. Compressive strengths for the top samples from each core ranged from 1307 psi to 2150 psi. This range is above the average value of 1059 psi which indicates the cores obtained from the upper exposed region of the ES Demo monolith had higher strength than the middle or lower regions of the monolith.

The average compressive strength for the ES Demo cores of 1059 psi is similar to the average compressive strength of two sets of bench scale samples that were made with a similar composition recipe as that of the ES Demo monolith.² The two sets of samples are identified as Mix # 3, Random Run Order 3 and Mix # 22, Random Run Order 19 in Table 2-1 of reference 2. The composition of these samples used 'Average' 7.8 sodium molarity, Type I/II portland cement, NW High Ca fly ash, SE blast furnace slag and a water-to-dry blend solids ratio of 0.6.² Table D-3 of reference 2 shows the compressive strengths from the triplicate samples from these two sets as Test/Mix # 27 (3a) = 1329, 1363 and 1380 psi, and Test/Mix 36 (22a) = 1382, 1381 and 1366 psi. Thus these six bench scale samples with L/D ratios of 2 had average compressive strengths of 1369 ± 20 psi. The latter value is quite similar to the average compressive strength of 28-day cured Mix #54 bench scale samples having the same formulation as the ES Demo at 1443 psi.⁶ It would also be informative to compare the compressive strengths of the ES Demo samples to those of the molded samples collected during the original pour, which have not been measured at this time. Calculated bulk densities shown in Table 3-1 were obtained by dividing the measured mass by the calculated volume. These densities with an average of 1.72 ± 0.04 g/cm³ are similar to those measured using an ASTM procedure for bench scale molded 2"x 4" samples collected at the time of the ES Demo with an average of 1.73 ± 0.06 g/cm³.³

Table 3-1. 2015 Compressive Strength Data

Core ID*	Diameter (cm)	Height (cm)	Vol. (cm ³)	Mass (g)	Bulk Density (g/cm ³)	L/D	Compressive Strength (psi)
9-1	5.0	5.8	112.5	197.1	1.75	1.16	1307
9-3	5.0	5.8	114.0	195.9	1.72	1.15	569
9-4	5.0	6.9	136.4	232.9	1.71	1.38	1066
10-7	5.0	4.9	93.8	165.4	1.76	0.98	2150
10-8	5.1	5.6	112.4	190.1	1.69	1.11	826
10-10	5.0	5.7	110.2	184.8	1.68	1.14	734
11-13	4.9	3.9	75.9	126.5	1.67	0.80	1531
11-15	5.0	6.6	128.5	223.7	1.74	1.32	637
11-17	4.9	7.0	134.6	238.6	1.77	1.43	712

*See Table 2-3 for location of these cores.

Moisture analysis was determined from select sub-core samples. Table 3-2 moisture analysis data shows these samples contained between 23 to 29% water with an average of 25.7% for all samples with nominal

relative standard deviation (RSD) of ~ 5% for 1, 2, and 5 days of drying. Standard deviation (St.Dev.) values shown for any data in this report are calculated from an Excel[®] spreadsheet function and the RSD is calculated as the (St.Dev./Avg.) x 100%. These data show that the moisture loss was not significant after the initial 24 hrs of drying. The mass loss observed for these ES Demo core samples is in the same range as that observed for a set of twenty-six bench-scale samples (analyzed in triplicate) with average moisture loss of 24.4% ± 3.5%.² The dried product sub-core samples from moisture testing were dissolved and analyzed for chemical composition. Elemental chemical compositions of these samples are shown in Table 3-3. These data are the reported elemental concentrations that were adjusted for the moisture content. Thus the data shown in Table 3-3 are in units of mg of species per kg of moist solid. Measured elemental compositions from the dried solids were adjusted by multiplying by (1-(%moisture content/100)).

Table 3-2. 2015 Percent Moisture Analysis Data

Core ID	Mass Loss		
	(24hr)	(48hr)	(120hr)
9-1	25.6%	25.6%	25.3%
9-2	24.6%	24.6%	24.6%
9-3	29.3%	29.4%	29.2%
9-4	26.3%	26.3%	26.1%
9-5	27.0%	27.4%	27.3%
10-7	23.7%	23.7%	23.4%
10-8	25.6%	25.8%	25.7%
10-10	26.0%	25.9%	25.6%
11-13	24.3%	24.3%	24.1%
11-14	26.0%	26.0%	25.7%
11-15	26.4%	26.4%	26.1%
11-16	25.1%	25.9%	25.7%
11-17	25.6%	25.6%	25.3%
11-18	23.3%	25.4%	25.3%
Avg.	25.6%	25.9%	25.7%
St.Dev.	1.5%	1.4%	1.4%
%RSD	5.8	5.3	5.3

Table 3-3. Chemical Composition for ES Demo Cores

Core ID	(mg/kg)*														
	Al	Ba	Ca	Cr	Cu	Fe	K	Mg	Na	P	S	Si	Sr	Ti	Zn
9-1	33467	969	138372	531	149	14016	6237	6649	66892	679	4193	81219	1122	1385	260
9-2	39515	906	114496	514	113	10351	7235	10899	69682	653	4741	86931	968	1546	102
9-3	31567	910	127937	489	149	12736	5329	6093	61653	651	3521	75247	1088	1292	236
9-4	34604	906	128567	638	100	13022	6321	7847	68303	624	3878	81554	1058	1359	192
9-5	28688	634	142775	522	105	10628	5586	6453	69580	512	4716	67300	851	1107	227
10-7	38782	817	120623	460	<73	9778	6989	11177	67469	613	4741	84702	871	1505	99
10-8	32472	921	132365	562	104	13327	6496	6306	71117	674	3864	77510	1089	1317	242
10-10	34706	850	121273	501	89	11781	6232	8156	72630	599	4115	78920	1006	1344	181
11-13	41564	900	116430	510	106	10476	6865	11601	69221	630	4404	89913	942	1535	101
11-14	35067	811	117344	506	89	11199	6178	8460	70936	604	4023	78930	982	1295	151
11-15	33197	910	134111	548	163	14312	5658	6469	67522	665	3760	78886	1128	1299	246
11-16	32458	848	122062	504	108	12236	5765	6988	67357	590	3672	75594	1017	1261	258
11-17	35338	694	130742	631	<74	13373	4395	7882	72207	464	3073	84049	906	1032	154
11-18	23042	195	158489	466	97	6611	4570	6648	69800	313	5109	51427	477	766	208
Avg.	33890	805	128970	527	114	11703	5990	7973	68884	591	4129	78013	965	1289	190

* mg of species per kg of moist solid – see text

3.3 Leach Testing

Leachate concentrations from leach testing are shown in Appendix A for both the 2014 and the 2015 sample sets. Diffusivities were calculated from the measured metal species and the as-batched nitrate and nitrite species and these are also tabulated in Appendix A.

Plots of various analyte diffusivities are shown in Figure 3-6 - Figure 3-11 for the 2014 samples. Similar diffusivity plots are shown in Figure 3-12 - Figure 3-17 for the 2015 samples. These plots show the change in calculated diffusivities over the various time intervals. For instance, the Cr diffusivities for the molded monoliths are shown to be lower in Figure 3-7 (bottom) vs. the Cr diffusivities for the 2014 ES Demo core samples shown in Figure 3-6 and Figure 3-7 (top). In general, for all the plots, the first several diffusivities are typically higher than the remaining diffusivities of the latter time intervals.

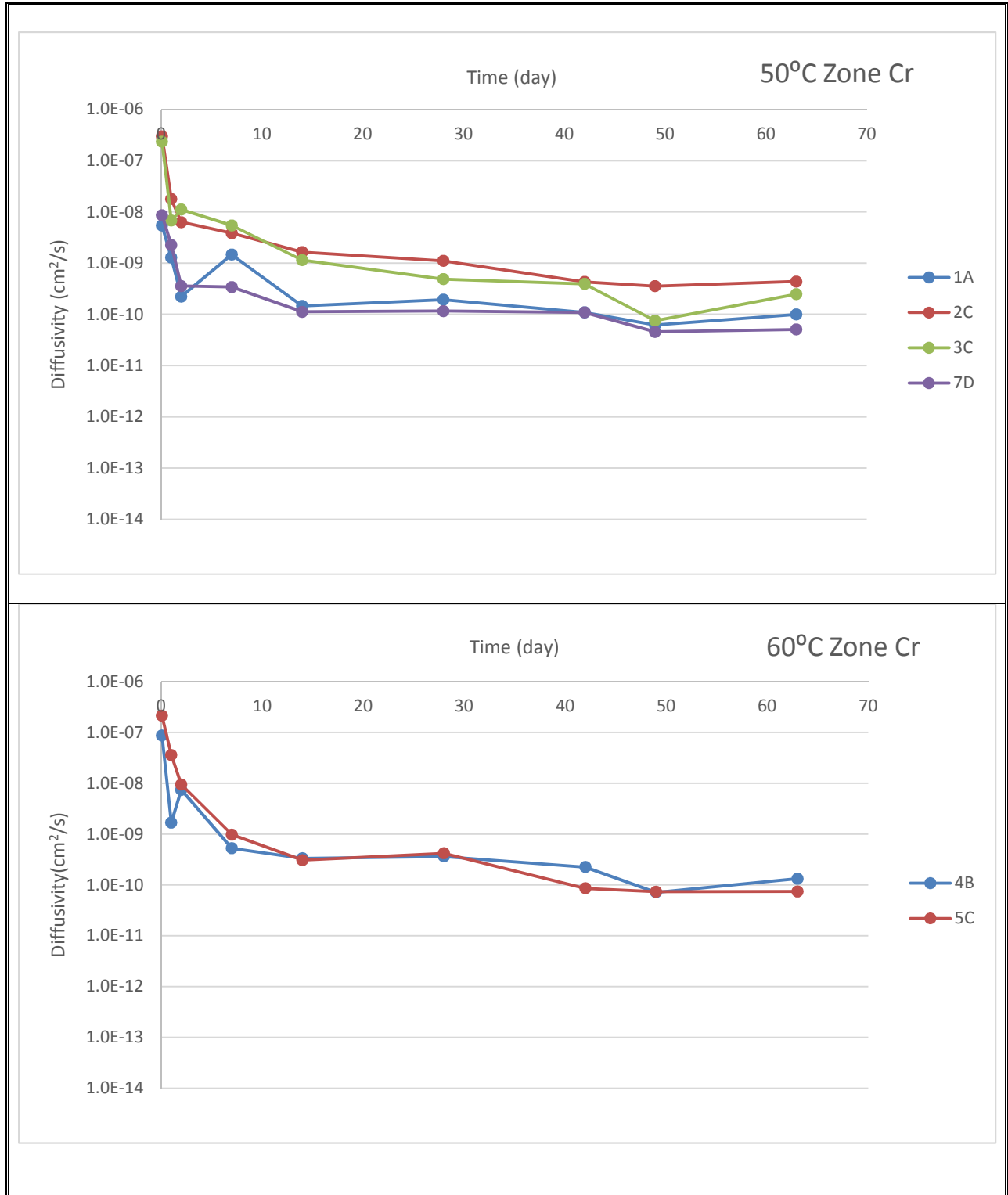


Figure 3-6. Cr Diffusivity for 2014 Cores for 50°C (top plot) and 60°C (bottom plot)

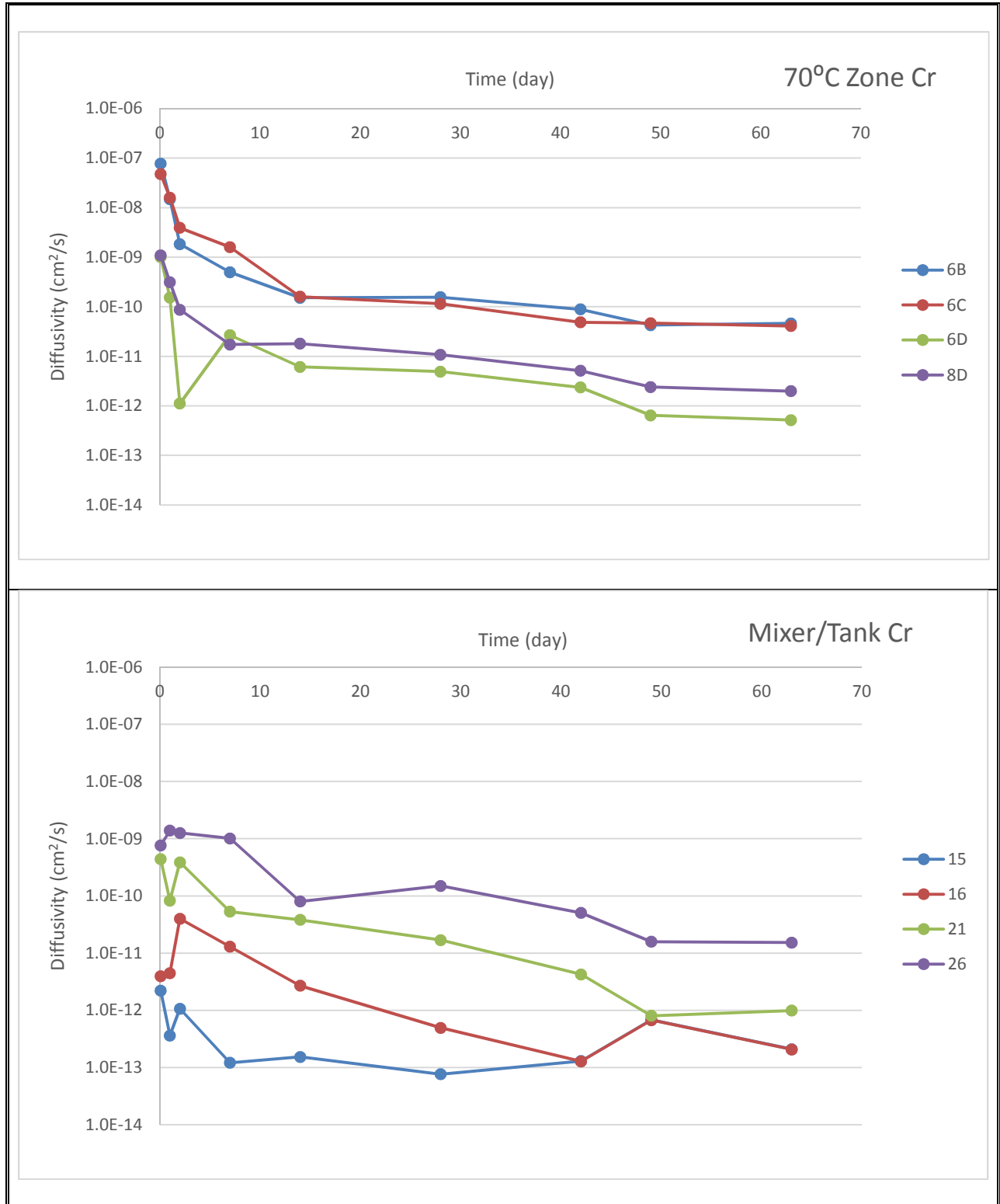


Figure 3-7. Cr Diffusivity for 2014 Cores for 70°C (top plot) and Molded Cores (bottom plot)

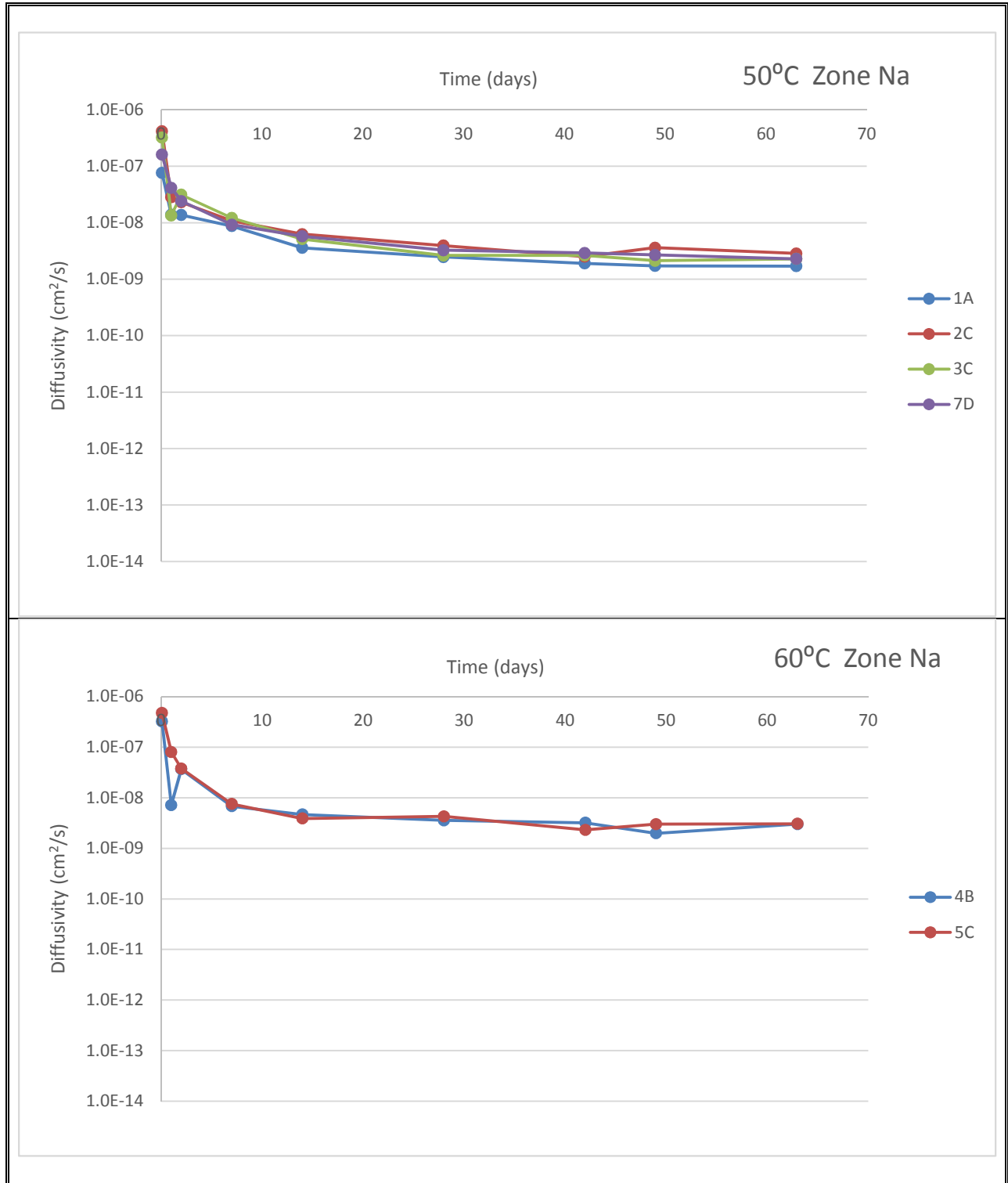


Figure 3-8. Na Diffusivity for 2014 Cores for 50°C (top plot) and 60°C (bottom plot)

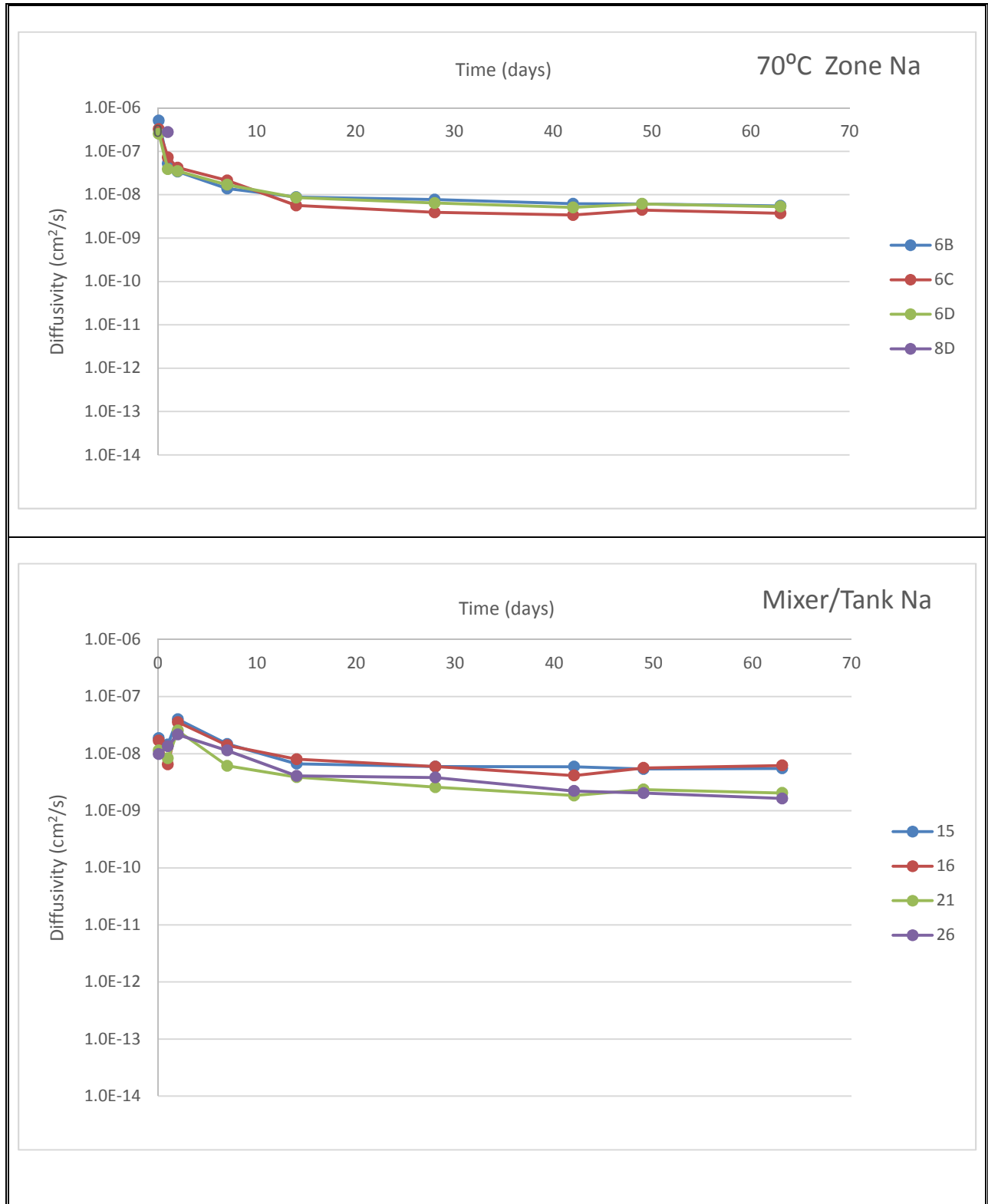


Figure 3-9. Na Diffusivity for 2014 Cores for 70°C (top plot) and Molded Cores (bottom plot)

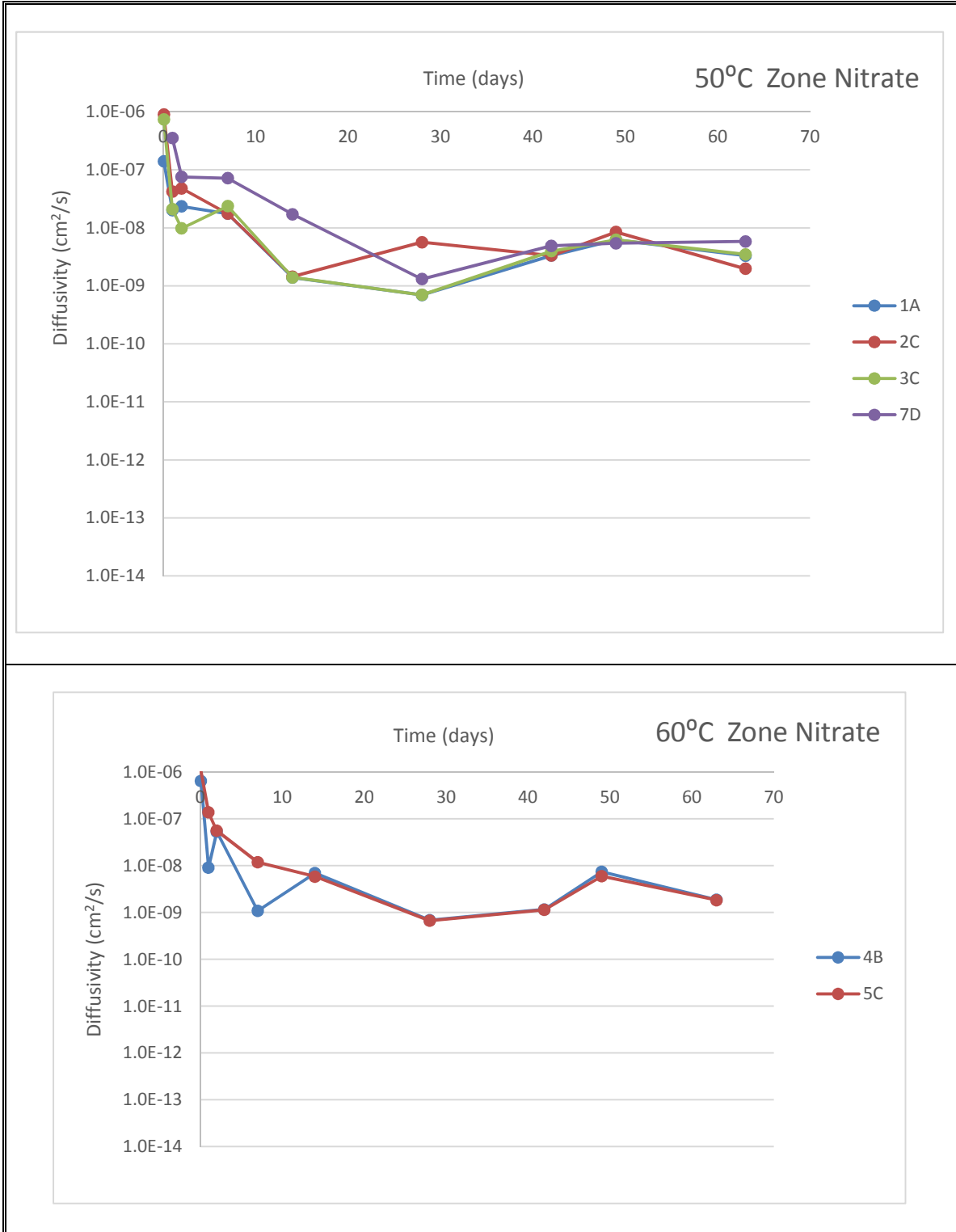


Figure 3-10. Nitrate Diffusivity for 2014 Cores for 50°C (top plot) and 60°C (bottom plot)

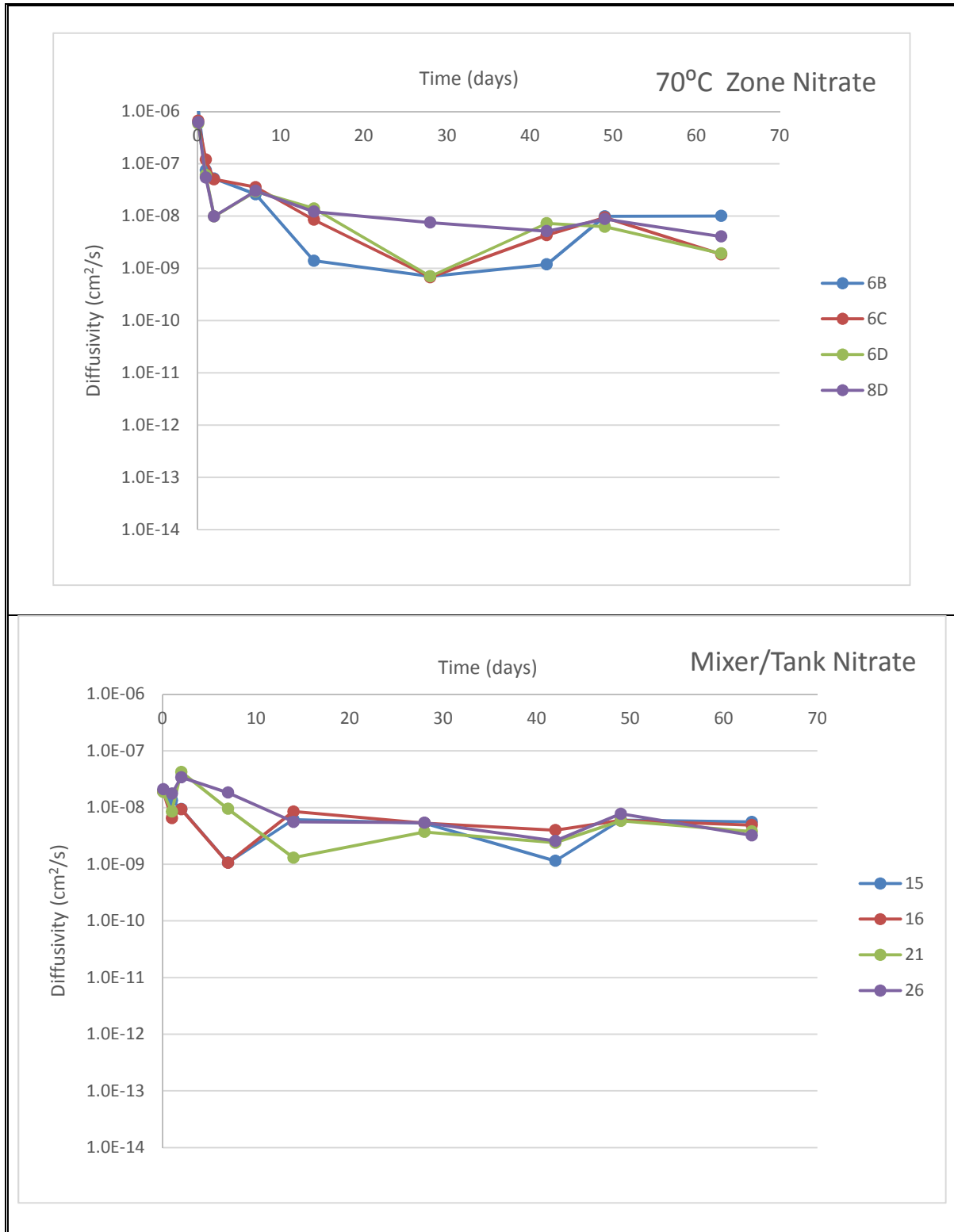


Figure 3-11. Nitrate Diffusivity for 2014 Cores for 70°C (top plot) and Molded Cores (bottom plot)

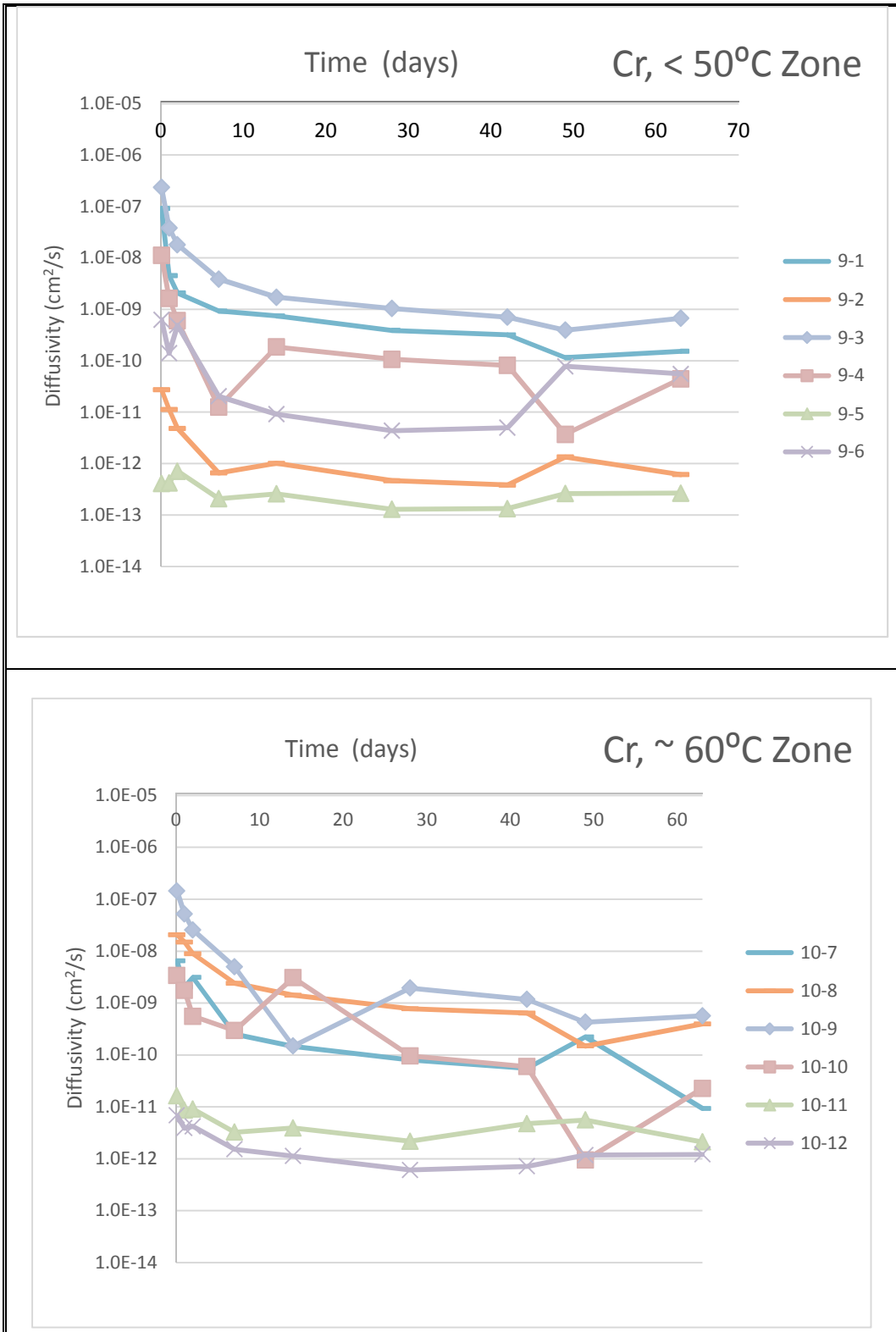


Figure 3-12. Cr Diffusivity for 2015 Cores for 50°C (top plot) and 60°C (bottom plot)

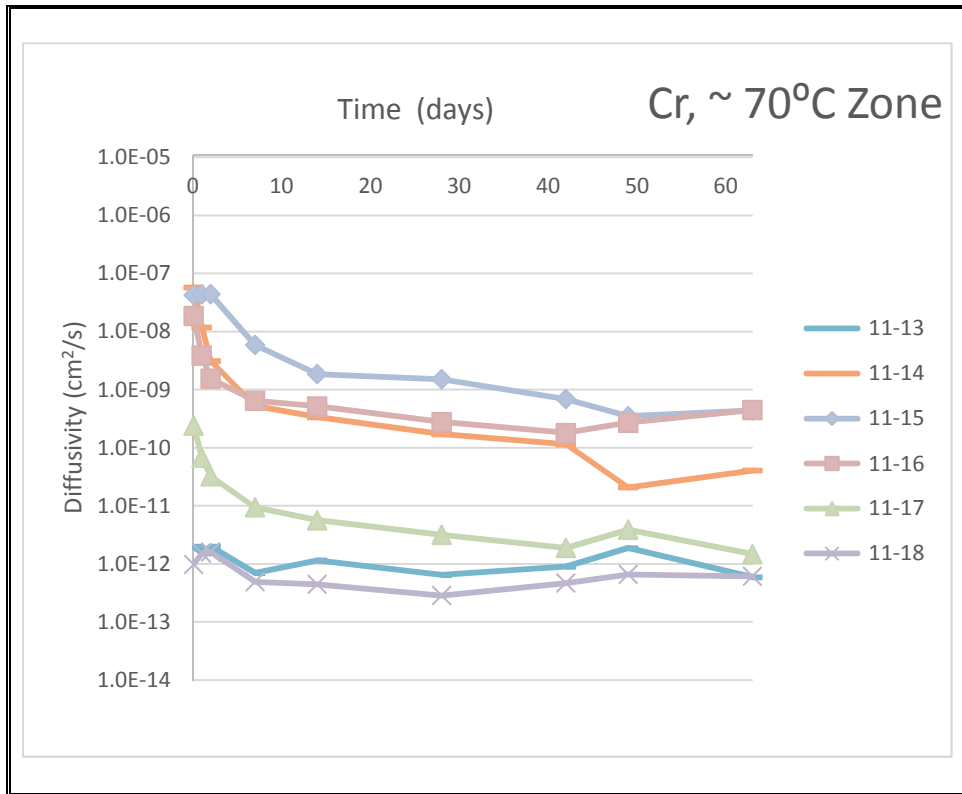


Figure 3-13. Cr Diffusivity for 2015 Cores for 70°C

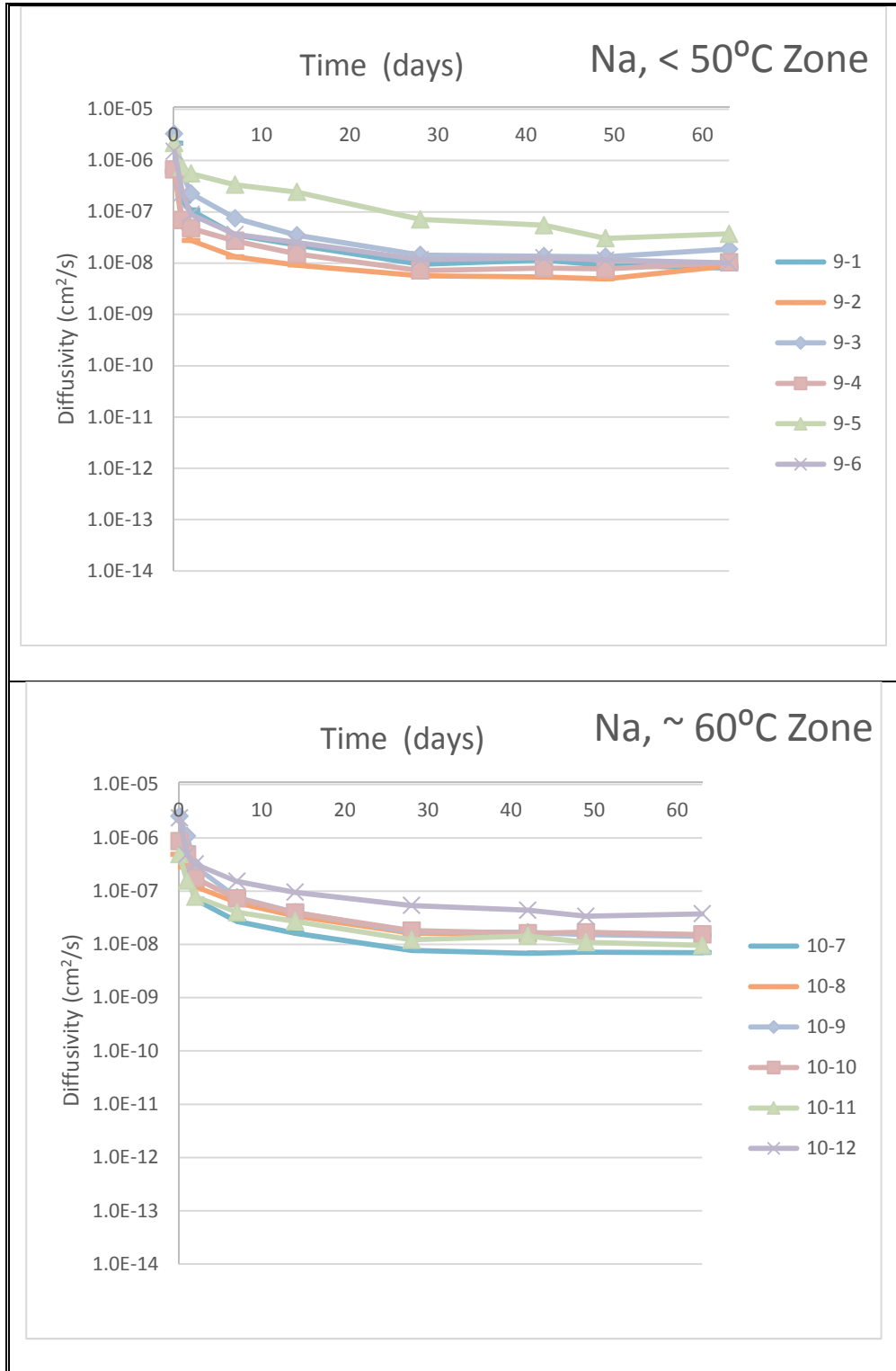


Figure 3-14. Sodium Diffusivity for 2015 Cores for 50°C (top plot) and 60°C (bottom plot)

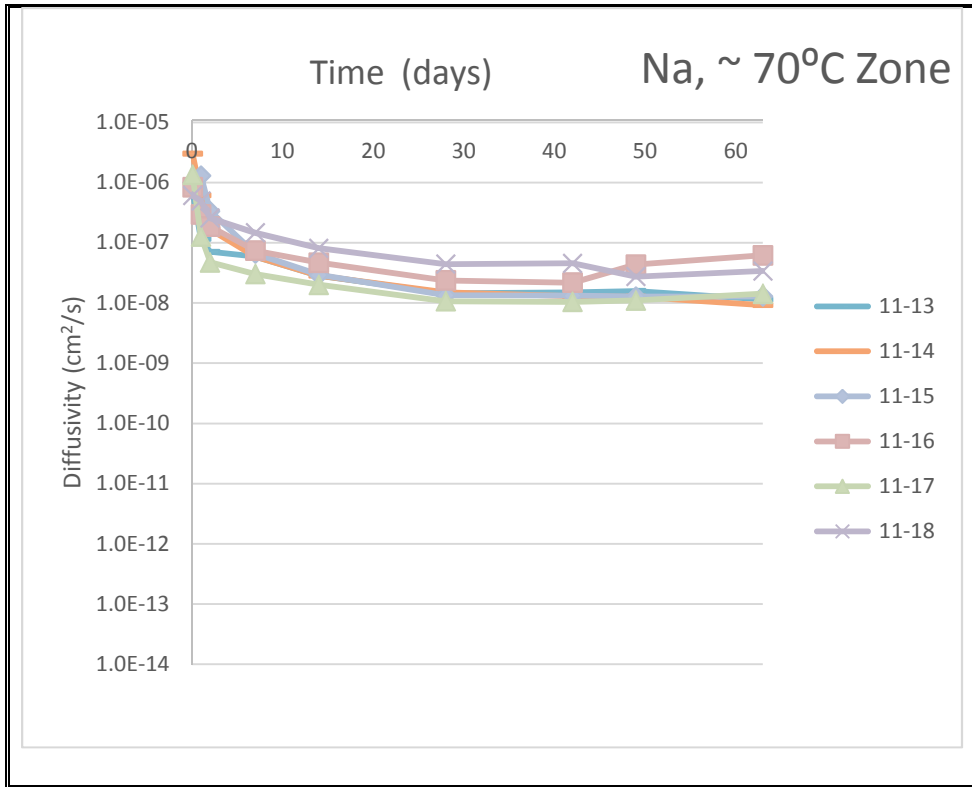


Figure 3-15. Sodium Diffusivity for 2015 Cores for 70°C

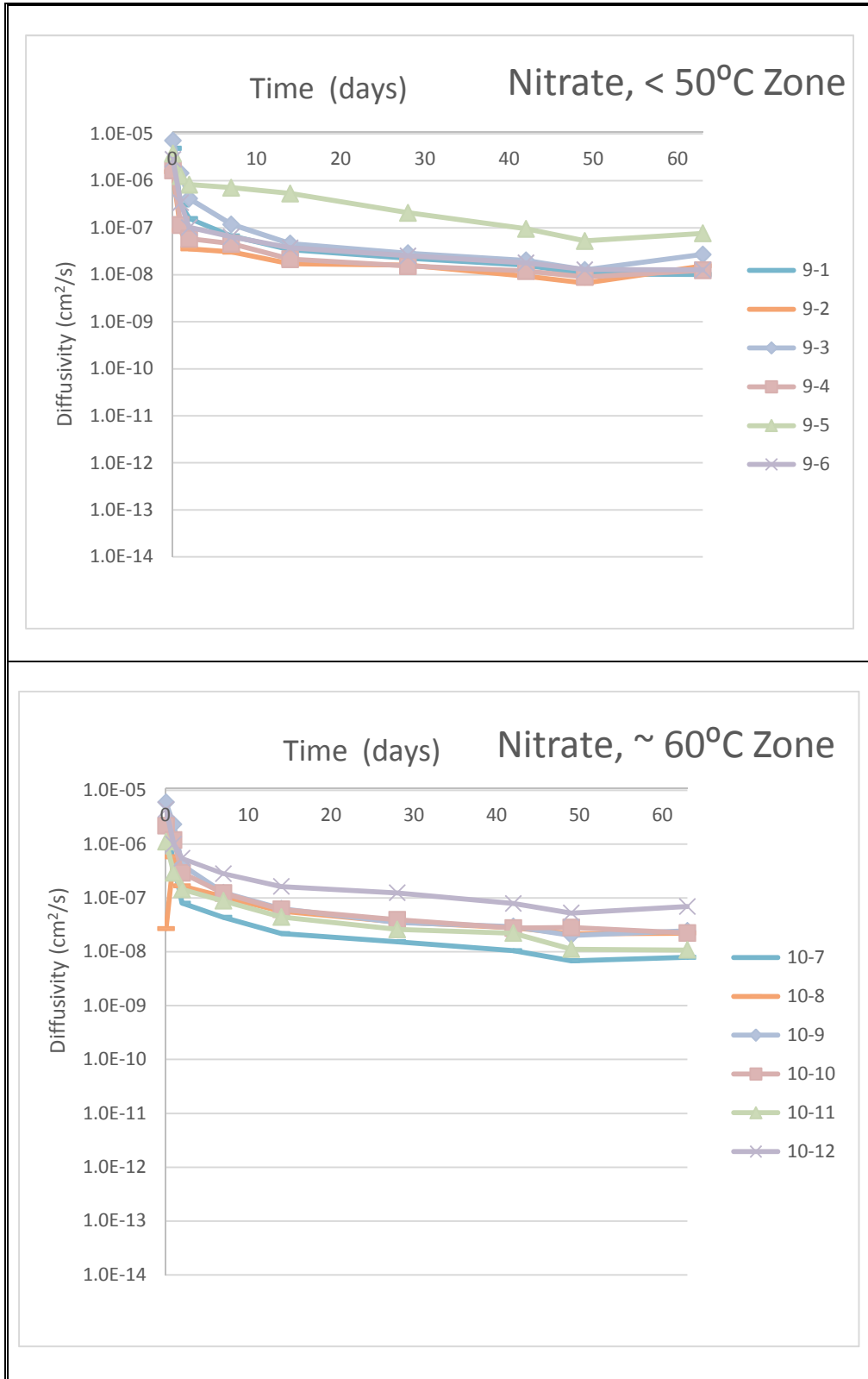


Figure 3-16. Nitrate Diffusivity for 2015 Cores for 50°C (top plot) and 60°C (bottom plot)

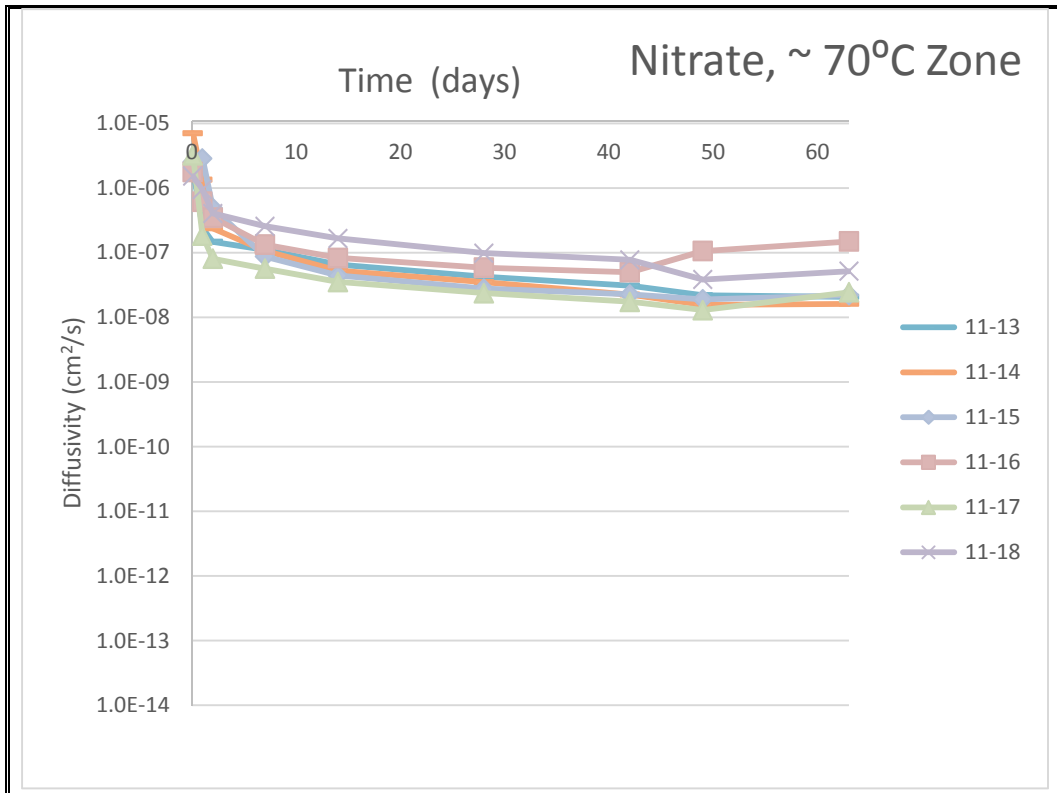


Figure 3-17. Nitrate Diffusivity for 2015 Cores for 70°C

Leachates were measured for pH and conductivity after each leach interval. Plots of the leachate pH and conductivity are shown in Figure 3-18 through Figure 3-21 for the 2014 and the 2015 samples. These plots show the individual interval values and lines connecting the data across the sample intervals up to 63 days. The vertical scale is similar in both sets of figures to aid in comparison of the data sets. The overall pH range and conductivity range were lower for the 2014 samples (average pH = 11.2 +/- 0.5 and average conductivity = 1.8 +/- 0.9 mS/cm) vs. the 2015 samples (average pH = 12.2 +/- 0.2 and average conductivity = 4.8 +/- 2.9 mS/cm). These data are tabulated in Appendix B. The pH plots for the leachates from the molded samples indicate that the pHs were very similar for the two sets of pairs. Samples 15 and 16 were collected on the same day and stored inside. Samples 21 and 28 were collected on the same day and stored outside. For each of these pairs one was collected at the mixer (sample 15 and 21) and one was collected at the ES Demo (sample 16 and 26). Since the pH is a measure of hydroxide ion in the leachate solutions and the conductivity is a measure of total ionic conductivity in the leachate solutions, these data suggest that the 2015 leachates contained higher levels of leached species (hydroxide and various ionic species) in the analyzed leachates compared to the earlier 2014 core leachates.

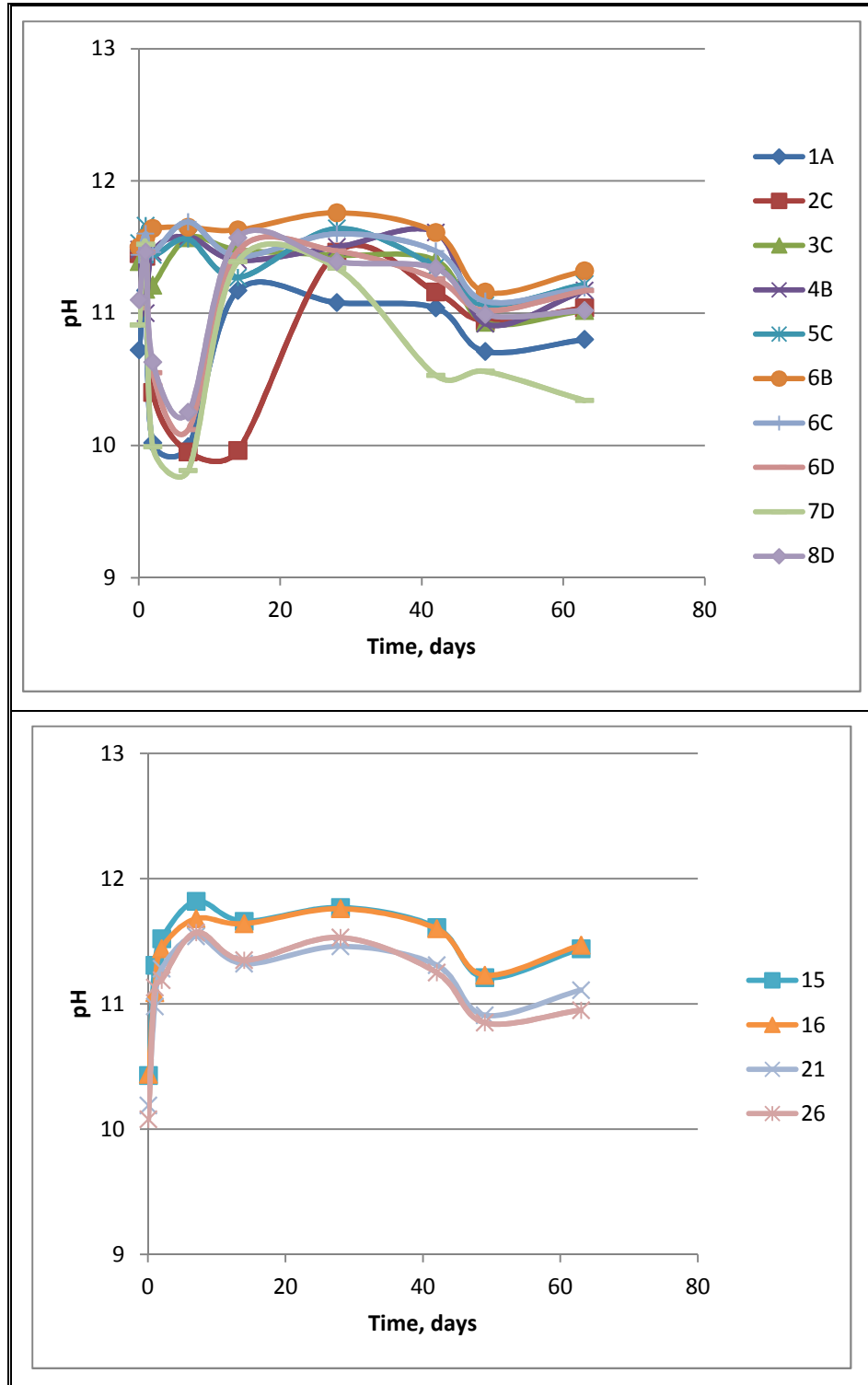


Figure 3-18. pH Plots for 2014 Samples. ES Demo (top plot) and Samples Collected in Molds (bottom plot).

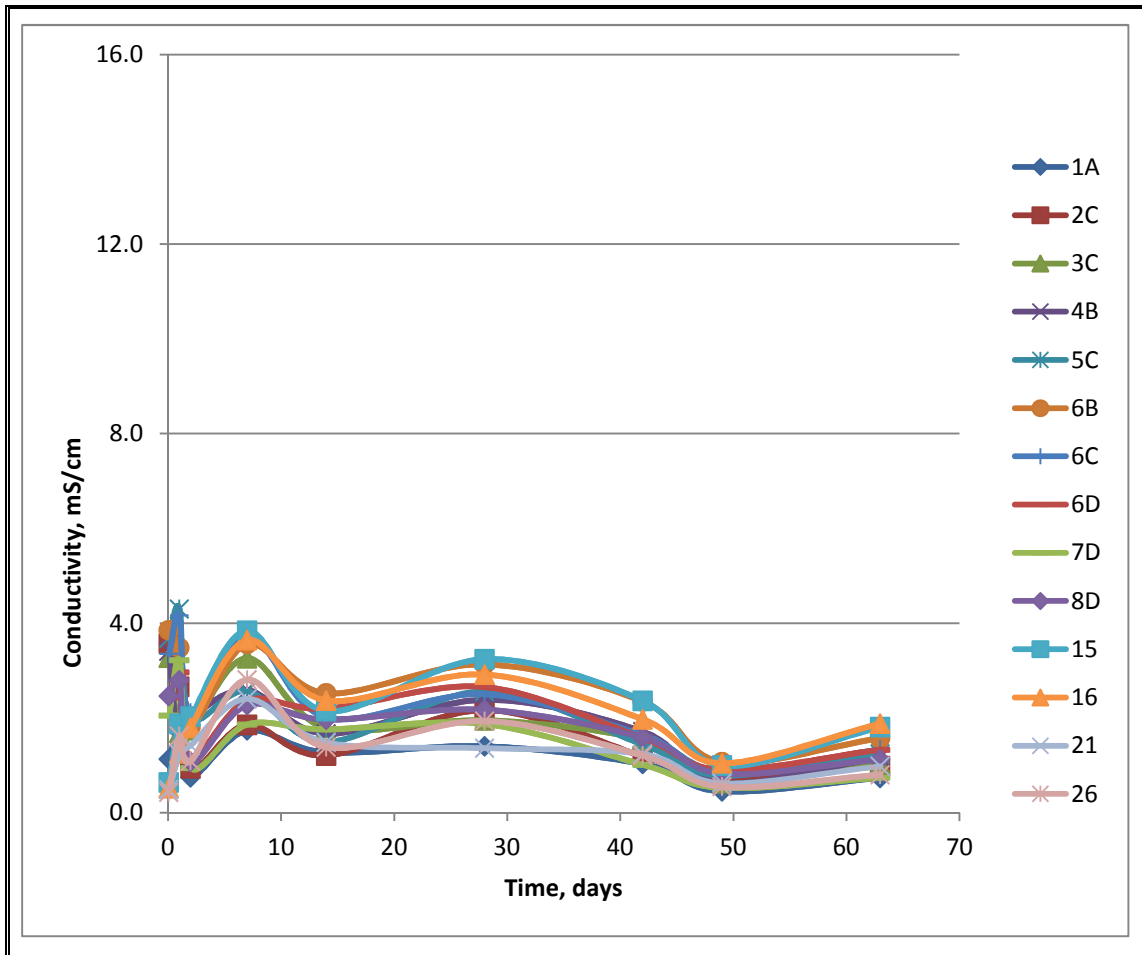


Figure 3-19. Conductivity Plot for 2014 Samples

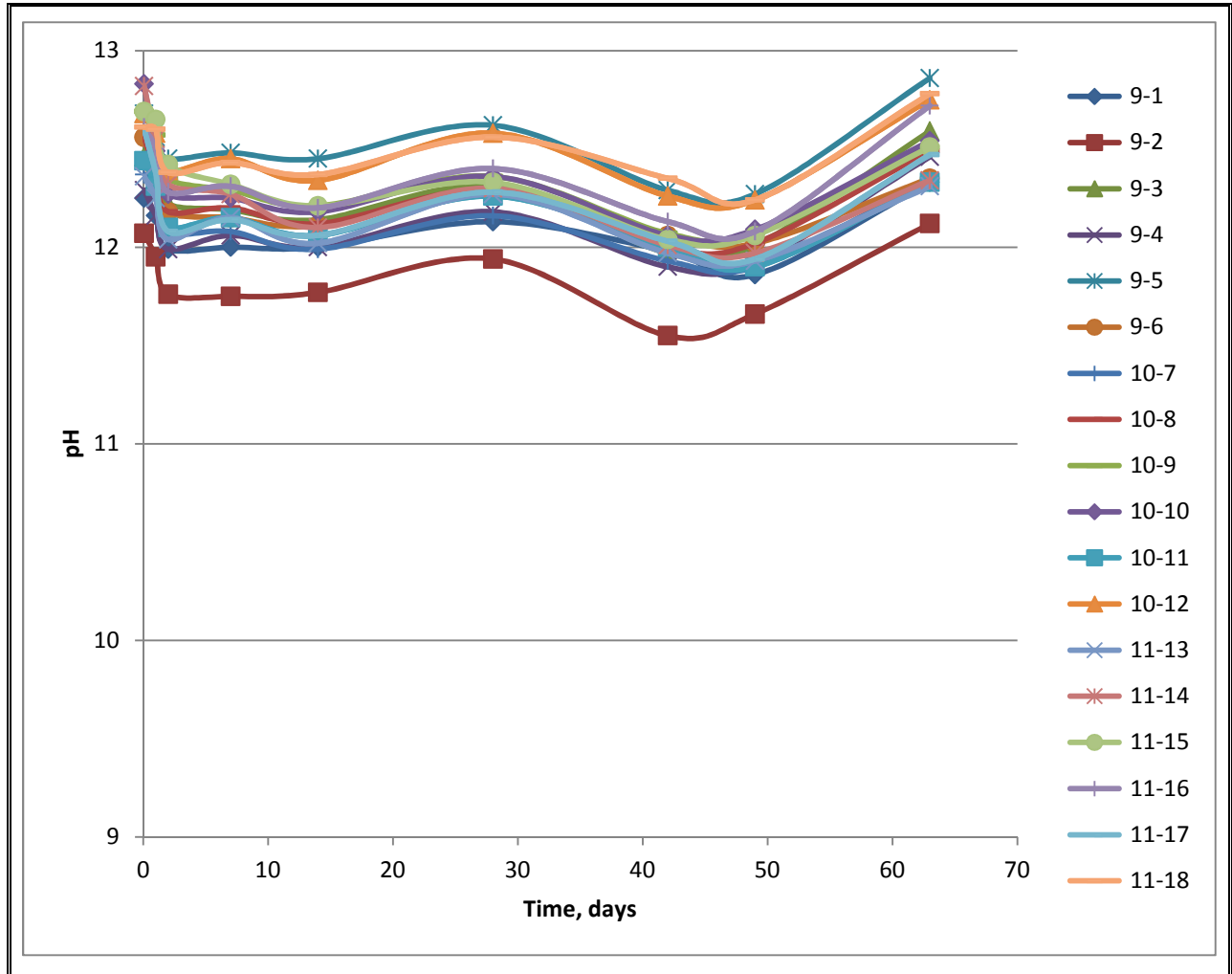


Figure 3-20. pH Plot for 2015 Samples

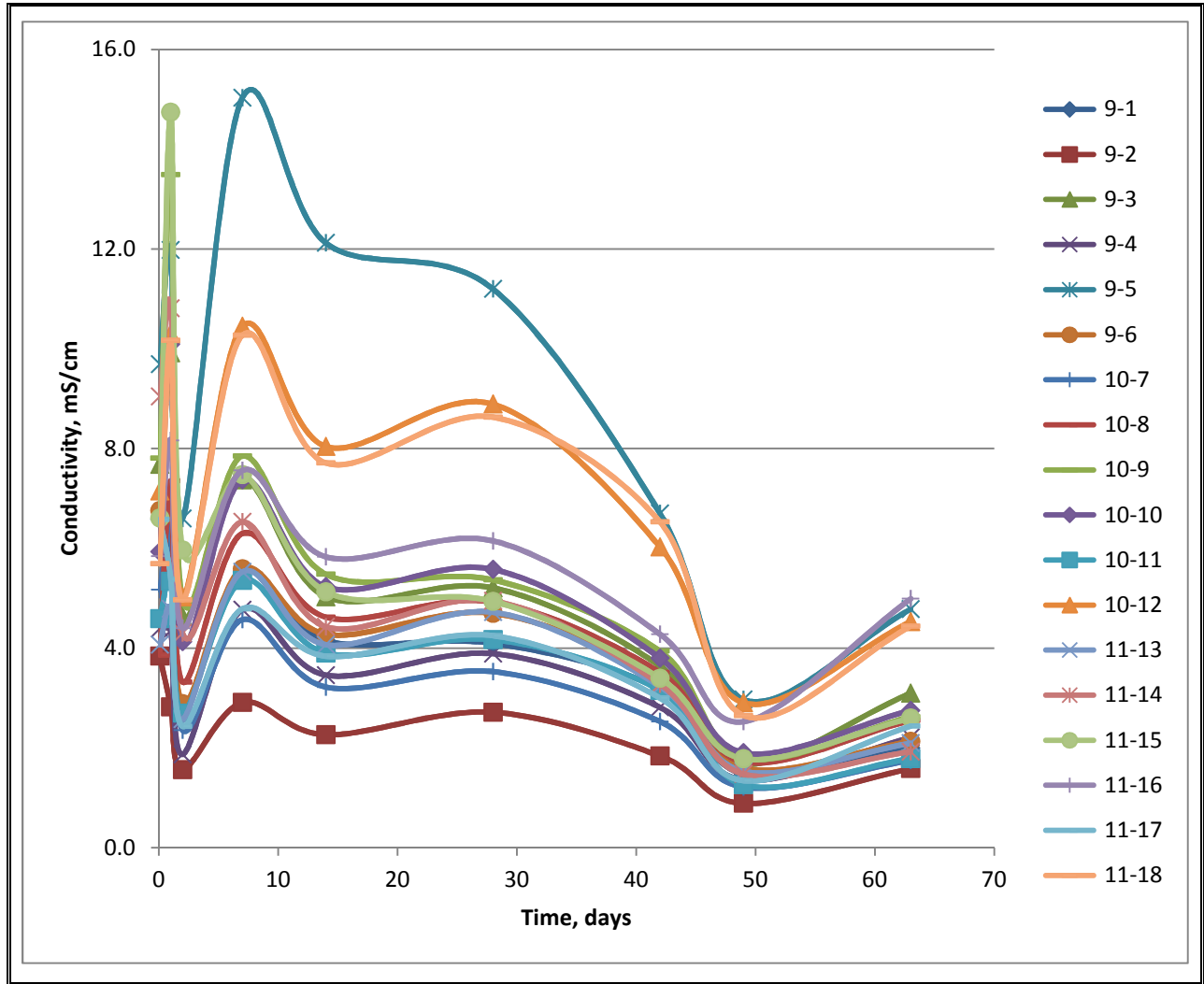


Figure 3-21. Conductivity Plot for 2015 Samples

Leachability indices (LI) were determined for Al, Ca, Cr, Na, nitrite and nitrate for the 2014 ES Demo core samples and the four samples collected in molds at the time of the ES Demo pouring. These data are shown in Table 3-4 for all the samples as the average LI for all sample intervals. Table 3-5 averages the LI for samples from the outer, middle and inner core zones, as well as the molded samples. Leachability indices (LI) were determined for Cr, S, Na, nitrite and nitrate for the 2015 ES Demo core samples. These data are shown in Table 3-6 for all the samples as the average LI for all sample intervals. Table 3-7 averages the LI for samples from the outer, middle and inner core zones as well as the average LI(Cr) values for the top, middle and bottom vertical zones. The average LI values shown include averages from all nine time intervals. Average LI values for subsets of the data can also be computed as was performed for the last four time intervals of the data presented in the previous cast stone screening tests by Westsik et al.²

The LI values presented here show that the average LI(Cr) is about 0.5 unit higher for the latter 2015 ES Demo core sample data set (average LI(Cr) = 10.2) vs. the 2014 ES Demo core sample data set (average LI(Cr) = 9.5) for the redox-sensitive Cr.⁷ The Cr present in the ES Demo cast stone matrix would have started out as the chromate anion (Cr(VI)O_4^{2-}) in the caustic simulant used to make the cast stone. However it could be reduced to Cr(III) in the final cast stone matrix by the cast stone additives such as blast furnace slag. The higher average LI(Cr) values for the 2015 ES Demo samples could be due to the more sensitive lower detection capability from the ICP-MS analysis used in the latter testing and could also reflect the 12 month longer curing time for the 2015 ES Demo samples. The average LI(Cr) values from the original four molded samples (average LI(Cr) 11.1 ± 11 %RSD) is higher than either overall average LI(Cr) sampling from the ES Demo (ES Demo 2015 average LI(Cr) values range from 8.4 to 12.6 and ES Demo 2014 average LI(Cr) values range from 8.5 to 11.1). Of all of the analytes measured, Cr showed the greatest variability in average LI values across individual core samples. In both the 2014 and 2015 core sample data sets the highest average LI(Cr) values were seen for samples obtained from the bottom section of the ES Demo monolith as shown by the data at the bottom of Table 3-4 and Table 3-6. For the 2015 ES Demo samples, two notable exceptions are the average LI(Cr) for both the top layer samples 9-2 and 11-13 with respective average LI(Cr) values of 11.8 and 11.9. The exceptions can also be seen from the diffusivity plots for sample 9-2 shown in the top plot of Figure 3-12 and for sample 11-13 shown in Figure 3-13. Both of the average LI(Cr) values are above the overall average LI(Cr) value for the six bottom samples of 11.5. While this simplified comparison of the overall average LI values from the various zones suggest that the diffusivity of Cr for the ES Demo might be dependent on the vertical zones, whereas the other species diffusivities appear not to be dependent on depth, a more rigorous statistical analysis of all the individual samples, which is beyond the scope of the current task, would be required to further investigate the dependency of the various LI values on vertical zones for all species. A possible explanation for these observations is the overall exposure of the ES Demo to general weathering stored above-ground outside vs. the more controlled storage of the molded samples out of the weather (sealed bags with damp cloth inside covered/lidded steel box). It is known that the ES Demo monolith had been covered for the first four months with a rigid cover but after that initial time period was only covered with a tarp that did not thoroughly exclude exposure to the elements such as moisture or rainwater.³

The average LI values for the major Cast Stone analytes (Na, nitrite and nitrate) can be compared to show that both ES Demo samplings were similar, with the 2014 LI values in the range of 7.8 to 8.2 and the 2015 LI values in the range of 6.9 to 7.3. Comparative LI values from the molded samples are in the range of 8.2 to 8.5. Previous leach testing of bench-scale Cast Stone samples also reported LI(Na) values in the range of 8.0 to 8.5.⁶

Table 3-4. Average EPA Leachability Indices (LI) for the 2014 ES Demo Samples and Comparison of Average LI Values by Vertical Zones

Sample	Al	Ca	Cr	Na	NO ₂	NO ₃
1A	11.1	12.8	9.5	8.2	8.4	8.1
2C	10.9	12.7	8.5	8.0	8.1	7.9
3C	11.2	11.5	8.7	8.1	8.3	8.1
4B	11.2	12.1	9.1	8.1	8.2	8.2
5C	11.0	12.1	8.9	7.9	7.9	7.9
6B	10.7	11.8	9.3	7.7	7.8	7.9
6C	10.9	12.3	9.2	7.8	7.9	7.8
6D	10.8	13.0	11.1	7.8	7.8	7.9
7D	11.0	13.1	9.6	8.0	8.1	7.9
8D	10.8	12.8	10.6	7.9	7.9	7.8
15	11.4	12.4	12.5	8.0	8.5	8.3
16	11.5	12.3	11.7	8.0	8.3	8.2
21	11.5	12.7	10.6	8.3	8.5	8.2
26	11.4	12.8	9.7	8.3	8.4	8.0
Comparison of Vertical Zones						
Avg. Middle & Top	11.0	12.2	9.0	8.0	8.1	8.0
St. Dev.	0.2	0.5	0.3	0.2	0.2	0.1
%RSD	1.7	3.8	3.9	2.3	2.8	1.8
Avg. Bottom	10.9	13.0	10.4	7.9	7.9	7.9
St. Dev.	0.1	0.2	0.8	0.1	0.2	0.1
%RSD	1.1	1.2	7.3	1.3	1.9	0.7
Middle & Top / Bottom	1.01	0.94	0.87	1.01	1.02	1.02

**Table 3-5 Average EPA Leachability Indices (LI) for the 2014 ES Demo Samples
Averaged by Lateral Zone**

Sample	Analyte	Avg. LI
1A, 2C, 3C, 7D Outer Ring	Al	11.0
	Ca	12.5
	Cr	9.1
	Na	8.1
	NO ₂	8.2
	NO ₃	8.0
4B, 5C Middle Ring	Al	11.1
	Ca	12.1
	Cr	9.0
	Na	8.0
	NO ₂	8.1
	NO ₃	8.1
6B, 6C, 6D, 8D Inner Core	Al	10.8
	Ca	12.5
	Cr	10.1
	Na	7.8
	NO ₂	7.8
	NO ₃	7.8
15, 16, 21, 26 Molded Samples	Al	11.4
	Ca	12.6
	Cr	11.2
	Na	8.2
	NO ₂	8.5
	NO ₃	8.2

Table 3-6 Average EPA Leachability Indices (LI) for the 2015 ES Demo Samples and Comparison of Average LI Values by Vertical Zones

Sample	Cr	S	Na	NO ₂	NO ₃
9-1	9.0	7.4	7.4	7.3	7.2
9-2	11.8	7.6	7.8	7.7	7.5
9-3	8.4	7.2	7.1	7.1	6.9
9-4	9.8	7.7	7.6	7.5	7.4
9-5	12.6	6.8	6.7	6.7	6.4
9-6	10.3	7.4	7.4	7.4	7.2
10-7	9.5	7.5	7.5	7.5	7.4
10-8	8.7	7.3	7.3	7.4	7.2
10-9	8.5	7.1	7.1	7.0	6.8
10-10	9.7	7.2	7.2	7.1	6.9
10-11	11.3	7.5	7.4	7.3	7.2
11-12	11.8	6.8	6.9	6.9	6.6
11-13	11.9	7.1	7.4	7.3	7.1
11-14	9.2	7.2	7.2	7.2	7.0
11-15	8.4	7.1	7.2	7.2	6.9
11-16	9.1	7.1	7.1	6.9	6.7
11-17	11.0	7.5	7.5	7.3	7.2
11-18	12.2	6.9	7.0	7.0	6.7
Comparison of Vertical Zones					
Top: Average	10.0	7.4	7.4	7.4	7.2
St. Dev.	1.4	0.2	0.2	0.2	0.2
%RSD	14.4	2.5	2.8	2.4	2.6
Middle: Average	9.0	7.2	7.2	7.1	6.9
St. Dev.	0.6	0.2	0.2	0.2	0.2
%RSD	7.2	3.2	2.7	2.9	3.5
Bottom: Average	11.5	7.2	7.2	7.1	6.9
St. Dev.	0.8	0.4	0.3	0.3	0.4
%RSD	7.3	4.9	4.6	3.9	5.2
Ratio: top/bot	0.87	1.03	1.04	1.04	1.05
Ratio: mid/bot	0.78	1.01	1.01	1.00	1.01

Table 3-7 EPA Leachability Indices (LI) for the 2015 ES Demo Samples Averaged by Lateral Zone

Sample	Analyte	Avg.
Core 9, 1-6 Outer Ring	Cr	10.3
	S	7.4
	Na	7.3
	NO ₂	7.3
	NO ₃	7.1
Core 10, 7-12 Middle Ring	Cr	9.9
	S	7.2
	Na	7.2
	NO ₂	7.2
	NO ₃	7.0
Core 11, 13-18 Inner Core	Cr	10.3
	S	7.2
	Na	7.2
	NO ₂	7.1
	NO ₃	6.9

4.0 Conclusions and Recommendations

The SRNL ES Demo was successfully sampled by two successive core-drilling campaigns completed six months and eighteen months after filling. Conclusions from the core analyses presented in this report are as follows:

- The average values from compression testing on the 2015 ES Demo cores are comparable to average compressive strengths obtained for the bench scale samples collected at the time of ES Demo filling. All measured values were above the 500 psi minimum considered for shallow land burial.
- Moisture analysis and calculated bulk density of the ES Demo cores are similar to bench scale monolith data.
- The LI(Cr) data indicate that lower detection limits attained by ICP-MS and longer curing time likely contribute to observed higher LI(Cr) values for the 2015 vs. the 2014 ES Demo samples. Future leaching studies of Cast Stone that involve Cr should use this analytical method to most accurately obtain the LI measurements. Diffusivity values for Cr in this study show the highest variability relative to the other species measured (Na, Al, S, nitrate and nitrite). Average LI(Cr) values from the bottom core segments are higher than the average LI(Cr) determined for the middle and top segments for both the 2014 and 2015 ES Demo cores.
- The LI(Cr) values for the redox-sensitive Cr are higher for the molded samples collected during the ES Demo than for the ES Demo samples. This may be due to better storage against general weather elements as these samples were stored in sealed poly bags inside a covered/lidded steel box and were not exposed to the weather as much as the ES Demo monolith.
- The average LI values for Na, nitrite and nitrate were all within the range of 6.9 to 8.5 for the two different ES Demo core samplings and the molded samples, which suggests similar diffusive leach behavior between these varied Cast Stone monolithic samples.
- The overall pH range and conductivity range were lower for the 2014 samples (average pH = 11.2 +/- 0.5 and average conductivity = 1.8 +/- 0.9 mS/cm) vs. the 2015 samples (average pH = 12.2 +/- 0.2 and average conductivity = 4.8 +/- 2.9 mS/cm). Since the pH is a measure of hydroxide ion in the leachate solutions and the conductivity is a measure of total ionic conductivity in the leachate solutions, these data suggest that the 2015 leachates contained higher levels of leached species (hydroxide and various ionic species) in the analyzed leachates compared to the earlier 2014 core leachates.

Recommendations based on the data from this report include:

- Compressive strength measurements on the molded samples that were collected during pouring of the ES Demo for comparison to the measured compressive strengths of the ES Demo cores.
- A statistical analysis of the individual diffusivities and leach index values for all cores and all species could identify within statistical significance if any of the species mobilities are dependent on either lateral or depth profiles within the ES Demo.

- To further understand the mobility of redox-sensitive Cr in the cast stone matrix, studies such as those performed by Langton⁷ on non-Cr containing Hanford Low Activity Waste simulants spiked with technetium (NH₄TcO₄) could be performed on Cr-containing samples to investigate redox-sensitive Cr oxidation rate via the depth-discrete sampling and leaching method approach.

5.0 References

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- ² J.H. Westsik, Piepel, G.F., Lindberg, M.J., Heasler, P.G., Mercier, T.M., Russell, R.L., Cozzi, A.D., Daniel, W.E., Eibling, R.E., Hansen, E.K., Reigel, M.M., and Swanberg, D.J,” Supplemental Immobilization of Hanford Low-Activity Waste: Cast Stone Screening Tests,” PNNL-22747:SRNL-STI-2013-00465, September, 2013.
- ³ A.D. Cozzi et al., “Engineering Scale Demonstration of a Prospective Cast Stone Process,” SRNL-STI-2014-00428, September, 2014.
- ⁴ C.L. Crawford, “Task Technical and Quality Assurance Plan for Core Drilling, Exposure and Analysis of Cores from the Cast Stone Engineering Scale Demonstration,” SRNL-RP-2015-00163, March, 2015.
- ⁵ EPA. 2012. *Mass Transfer Rates of Constituents in Monolith or Compacted Granular Materials Using a Semi-Dynamic Tank Leaching Test*. EPA Manual SW-846, Method 1315, U.S. Environmental Protection Agency, Washington, D.C.
- ⁶ A.D. Cozzi et al., “Supplemental Immobilization of Hanford Low-Activity Waste: Cast Stone Augmented Formulation Matrix Tests,” SRNL-STI-2014-00619, July, 2015.
- ⁷ C.A. Langton, “Tc Oxidation in Slag-Based Sodium Salt Waste Forms Exposed to Water and Moist Hanford Soil,” C, August, 2014.

Appendix A. Leachate Concentrations and Calculated Diffusivities

Table A-1. Leachate Concentrations (mg/L) for 2014 Samples

Interval ID	Sample ID	Al	Ca	Cr	Na	NO ₂	NO ₃
T-1	1A	0.85	1.75	0.491	241	47.6	265
T-1	2C	1.58	1.84	3.573	551	122	658
T-1	3C	1.28	1.95	3.220	492	117	606
T-1	4B	1.67	1.62	1.966	496	111	571
T-1	5C	1.46	2.17	3.114	606	142	728
T-1	6B	2.25	1.60	1.848	619	145	754
T-1	6C	1.44	2.21	1.475	501	114	584
T-1	6D	1.11	1.00	0.210	434	99.6	539
T-1	7D	0.97	1.10	0.635	359	83.9	433
T-1	8D	1.25	1.06	0.218	453	110	554
T-1	15	1.25	1.06	0.010	120	12.4	<100
T-1	16	0.67	1.18	0.014	115	12.5	100
T-1	21	0.49	0.81	0.144	96	12.7	100
T-1	26	0.46	0.83	0.179	84	12.1	100
T-2	1A	2.66	1.55	0.586	252	41	247
T-2	2C	3.62	2.86	2.152	354	63.8	351
T-2	3C	1.82	1.94	1.344	248	43.5	251
T-2	4B	1.67	2.18	0.674	182	26	167
T-2	5C	4.75	3.52	3.155	615	126	658
T-2	6B	5.92	1.52	1.992	487	93.1	477
T-2	6C	5.98	2.34	2.099	585	118	614
T-2	6D	5.08	1.57	0.201	417	80.3	427
T-2	7D	4.07	3.16	0.802	449	92.1	493
T-2	8D	4.68	1.83	0.287	389	73.9	403
T-2	15	1.97	1.65	<0.010	261	33.1	204
T-2	16	1.33	2.19	0.035	176	20.7	143
T-2	21	0.93	1.06	0.153	201	26.9	166
T-2	26	1.28	1.16	0.594	242	40.9	225
T-3	1A	2.11	<1.0	0.142	146	21.9	155
T-3	2C	2.81	<1.0	0.743	186	30.3	218
T-3	3C	2.91	21.0	1.004	220	46.32	<100
T-3	4B	3.62	<1.0	0.826	240	37.96	235
T-3	5C	3.23	14.3	0.942	246	44.59	244
T-3	6B	4.10	10.4	0.408	230	38.57	231
T-3	6C	4.27	12.0	0.606	259	35.2	231
T-3	6D	3.96	<1.0	0.010	232	45.82	<100
T-3	7D	3.04	<1.0	0.185	200	48.64	280
T-3	8D	3.50	<1.0	0.088	209	41.46	<100
T-3	15	1.78	6.9	<0.010	253	38.38	<100
T-3	16	1.53	6.3	0.061	240	35.63	<100
T-3	21	1.89	3.7	0.194	205	25.83	216
T-3	26	1.58	1.7	0.330	179	28.46	183

Table A-1. Leachate Concentrations (mg/L) for 2014 Samples, continued

Interval ID	Sample ID	Al	Ca	Cr	Na	NO₂	NO₃
T-4	1A	6.09	1.0	1.087	347	62.88	400
T-4	2C	6.26	1.0	1.729	378	73.67	393
T-4	3C	5.53	18.7	2.084	408	87.5	462
T-4	4B	3.65	3.8	0.653	307	64.28	100
T-4	5C	4.01	1.2	0.899	327	58.29	334
T-4	6B	8.34	14.2	0.631	435	85.65	486
T-4	6C	8.26	1.0	1.151	549	107	578
T-4	6D	8.41	1.0	0.146	480	95.3	515
T-4	7D	6.88	1.0	0.540	367	73.6	406
T-4	8D	8.87	1.0	0.117	455	97.2	521
T-4	15	3.02	2.1	0.010	457	63.2	100
T-4	16	2.75	2.2	0.104	447	72.7	100
T-4	21	3.30	1.4	0.213	299	48.2	303
T-4	26	4.61	1.0	0.878	385	73.7	398
T-5	1A	4.60	1.0	0.304	198	28.9	100
T-5	2C	4.95	1.0	1.004	256	40.1	100
T-5	3C	3.71	10.4	0.852	236	34.5	100
T-5	4B	3.39	9.5	0.463	226	29.3	225
T-5	5C	3.54	3.7	0.449	209	27.2	209
T-5	6B	6.80	11.9	0.310	308	58.8	100
T-5	6C	4.36	5.1	0.323	251	40.9	251
T-5	6D	6.64	2.1	0.062	303	49.6	315
T-5	7D	5.80	2.4	0.275	257	43.1	100
T-5	8D	5.87	3.2	0.106	269	45.8	293
T-5	15	2.18	1.3	0.010	273	30.3	213
T-5	16	2.41	1.7	0.042	301	38.7	253
T-5	21	2.90	1.5	0.161	212	36.2	100
T-5	26	2.89	1.5	0.220	205	27.5	195
T-6	1A	5.61	1.00	0.496	232	39.85	100
T-6	2C	6.89	4.04	1.168	287	54.23	280
T-6	3C	3.74	8.31	0.784	239	10	100
T-6	4B	4.18	5.54	0.682	280	46.34	100
T-6	5C	5.42	3.10	0.743	310	71.53	100
T-6	6B	9.12	0.87	0.445	408	127	100
T-6	6C	5.15	2.15	0.388	296	54.85	100
T-6	6D	7.26	0.13	0.079	371	68.97	100
T-6	7D	6.35	1.00	0.395	274	47.12	273
T-6	8D	6.28	1.00	0.116	309	56.25	326
T-6	15	3.45	1.44	0.010	365	10.51	280
T-6	16	3.64	1.00	0.026	367	46.02	283
T-6	21	3.71	1.00	0.151	245	30.74	239
T-6	26	4.49	1.00	0.425	281	41.82	272

Table A-1. Leachate Concentrations (mg/L) for 2014 Samples, continued

Interval ID	Sample ID	Al	Ca	Cr	Na	NO ₂	NO ₃
T-7	1A	4.45	1.00	0.286	156	20.32	168
T-7	2C	3.87	1.00	0.558	176	10	165
T-7	3C	3.60	5.90	0.542	183	26.1	183
T-7	4B	3.99	5.41	0.413	204	27.9	100
T-7	5C	3.59	2.25	0.257	175	48.7	100
T-7	6B	6.61	9.20	0.257	280	28.8	100
T-7	6C	3.98	1.11	0.194	211	37.4	194
T-7	6D	5.86	1.00	0.042	253	29.6	247
T-7	7D	3.96	1.00	0.294	199	10	221
T-7	8D	5.02	1.00	0.061	232	38.2	207
T-7	15	2.88	3.44	0.010	279	24	100
T-7	16	2.82	3.36	0.010	235	20.9	188
T-7	21	3.18	1.37	0.058	159	21.7	147
T-7	26	3.78	1.00	0.189	164	22.7	144
T-8	1A	2.68	7.96	0.094	64.9	10	100
T-8	2C	2.95	10.36	0.222	92.2	11.64	115
T-8	3C	2.34	12.75	0.103	71.7	10	100
T-8	4B	1.96	9.60	0.102	69.9	10	110
T-8	5C	2.57	11.90	0.104	87.0	10.7	100
T-8	6B	3.81	14.70	0.078	121.8	17	126
T-8	6C	2.81	8.01	0.083	105.6	13.7	125
T-8	6D	3.73	7.06	0.010	121.7	18.1	100
T-8	7D	3.16	2.06	0.083	83.5	11.8	100
T-8	8D	3.43	9.97	0.018	103.8	14.1	118
T-8	15	1.57	8.33	0.010	116.4	17.9	100
T-8	16	1.98	11.13	0.010	119.6	24.9	100
T-8	21	1.98	8.36	0.011	78.3	10.6	100
T-8	26	2.01	8.70	0.046	68.6	10	109
T-9	1A	3.99	5.37	0.216	116.5	14.6	132
T-9	2C	4.35	1.74	0.444	147.9	29.2	100.0
T-9	3C	3.69	9.60	0.339	134.5	16.9	135
T-9	4B	4.25	8.58	0.249	155.2	20	100.0
T-9	5C	4.94	8.62	0.189	158.5	27.8	100.0
T-9	6B	5.53	8.73	0.146	208.7	31.6	229
T-9	6C	4.45	6.21	0.140	174.1	25.2	100.0
T-9	6D	5.58	4.17	0.015	204.5	61.7	100.0
T-9	7D	5.81	0.58	0.158	138.9	24.2	100.0
T-9	8D	4.95	3.24	0.030	169.2	26.64	145
T-9	15	3.17	8.96	0.010	212.7	20.72	174
T-9	16	5.52	9.07	0.010	226.9	29.5	164
T-9	21	3.41	5.69	0.022	131.9	19.21	146
T-9	26	4.79	3.80	0.082	111.2	14.12	127

Table A-2. Leachate Concentrations (mg/L) for 2015 Samples – Outer Cores 9-1 through 9- 6

Interval ID	Sample ID	Cr	S	Na	NO ₂	NO ₃
T-1	9-1	2.063	87.6	1311	339	1610
T-2	9-1	1.130	53.8	884	191	992
T-3	9-1	0.445	23.8	420	76	412
T-4	9-1	0.884	43.4	714	150	799
T-5	9-1	0.706	27.0	509	95	508
T-6	9-1	0.720	28.0	466	111	582
T-7	9-1	0.501	23.1	393	69	379
T-8	9-1	0.131	8.0	152	24	133
T-9	9-1	0.274	14.3	259	41	237
T-1	9-2	0.032	57.8	633	152	822
T-2	9-2	0.051	40.3	455	84	481
T-3	9-2	0.019	14.8	192	32	179
T-4	9-2	0.021	30.3	396	90	491
T-5	9-2	0.024	20.4	293	60	328
T-6	9-2	0.023	25.7	326	82	447
T-7	9-2	0.016	18.8	245	47	263
T-8	9-2	0.013	5.7	102	17	97
T-9	9-2	0.016	18.2	247	55	265
T-1	9-3	3.296	103.8	1617	379	1930
T-2	9-3	3.273	105.7	1626	354	2140
T-3	9-3	1.311	38.7	606	123	671
T-4	9-3	1.806	57.1	1037	200	1060
T-5	9-3	1.069	26.8	629	108	589
T-6	9-3	1.177	28.6	573	124	658
T-7	9-3	0.742	24.8	427	85	423
T-8	9-3	0.242	9.6	184	28	146
T-9	9-3	0.571	21.7	395	68	386
T-1	9-4	0.738	46.2	742	165	952
T-2	9-4	0.693	29.3	587	118	618
T-3	9-4	0.246	15.1	286	49	257
T-4	9-4	0.105	31.6	639	131	675
T-5	9-4	0.359	17.8	423	79	412
T-6	9-4	0.386	20.6	414	95	492
T-7	9-4	0.259	18.3	335	63	334
T-8	9-4	0.024	6.6	144	24	126
T-9	9-4	0.151	14.9	300	58	268
T-1	9-5	0.004	80.8	1256	232	1340
T-2	9-5	0.010	109.2	1801	332	1900
T-3	9-5	0.008	50.9	908	154	899
T-4	9-5	0.013	128.6	2099	429	2480
T-5	9-5	0.013	81.1	1585	318	1920
T-6	9-5	0.013	53.7	1210	270	1690
T-7	9-5	0.010	43.1	818	132	875
T-8	9-5	0.006	12.3	266	38	284
T-9	9-5	0.011	23.7	531	70	618
T-1	9-6	0.165	62.6	1055	231	1180
T-2	9-6	0.192	63.0	1020	180	1010
T-3	9-6	0.209	21.5	367	57	320
T-4	9-6	0.126	43.8	697	143	756
T-5	9-6	0.076	25.4	517	95	514
T-6	9-6	0.074	26.3	499	110	596
T-7	9-6	0.060	24.7	399	71	385
T-8	9-6	0.104	8.9	166	26	143
T-9	9-6	0.159	15.7	280	45	256

Table A-3. Leachate Concentrations (mg/L) for 2015 Samples – Middle Cores 10-7 through 10-12

Interval ID	Sample ID	Cr	S	Na	NO ₂	NO ₃
T-1	10-7	0.513	58.4	810	202	1050
T-2	10-7	0.711	68.9	938	198	1090
T-3	10-7	0.510	21.7	317	50	275
T-4	10-7	0.432	37.5	585	114	604
T-5	10-7	0.292	21.1	402	70	380
T-6	10-7	0.307	22.2	392	84	452
T-7	10-7	0.195	18.9	284	51	286
T-8	10-7	0.171	6.2	127	18	101
T-9	10-7	0.063	12.7	227	40	196
T-1	10-8	0.922	34.4	587	21	112
T-2	10-8	1.928	70.4	1095	240	1280
T-3	10-8	0.867	25.1	419	73	400
T-4	10-8	1.340	47.0	879	177	941
T-5	10-8	0.915	28.3	589	113	618
T-6	10-8	0.958	30.2	572	128	695
T-7	10-8	0.669	28.4	436	84	469
T-8	10-8	0.140	9.8	194	31	181
T-9	10-8	0.414	20.0	332	64	330
T-1	10-9	2.634	83.9	1444	352	1800
T-2	10-9	3.885	146.6	2311	512	2770
T-3	10-9	1.591	40.3	698	117	675
T-4	10-9	2.086	60.8	1064	204	1110
T-5	10-9	0.320	34.0	687	129	702
T-6	10-9	1.639	32.7	634	136	741
T-7	10-9	0.979	36.9	484	92	521
T-8	10-9	0.258	10.2	201	32	188
T-9	10-9	0.536	20.0	349	70	374
T-1	10-10	0.403	49.9	843	214	1090
T-2	10-10	0.714	102.3	1555	369	1980
T-3	10-10	0.234	36.2	543	112	571
T-4	10-10	0.508	65.9	1039	206	1100
T-5	10-10	1.456	35.7	681	128	692
T-6	10-10	0.365	35.9	655	146	784
T-7	10-10	0.221	31.7	475	91	505
T-8	10-10	0.012	12.9	211	33	223
T-9	10-10	0.107	24.5	364	60	357
T-1	10-11	0.025	36.0	571	133	696
T-2	10-11	0.045	48.5	795	169	879
T-3	10-11	0.027	21.8	327	68	360
T-4	10-11	0.048	47.2	694	163	837
T-5	10-11	0.047	26.6	509	101	528
T-6	10-11	0.049	26.1	481	110	572
T-7	10-11	0.056	24.5	402	80	405
T-8	10-11	0.026	7.0	153	25	126
T-9	10-11	0.029	11.0	259	41	223
T-1	10-12	0.018	92.2	1368	274	1520
T-2	10-12	0.033	102.2	1528	308	1780
T-3	10-12	0.020	49.7	724	128	764
T-4	10-12	0.036	97.3	1482	285	1640
T-5	10-12	0.027	52.4	1040	191	1110
T-6	10-12	0.029	62.2	1105	231	1370
T-7	10-12	0.024	74.0	766	136	836
T-8	10-12	0.013	14.6	293	46	299
T-9	10-12	0.024	31.7	558	98	618

Table A-4. Leachate Concentrations (mg/L) for 2015 Samples – Inner Cores 11-13 through 11-18

Interval ID	Sample ID	Cr	S	Na	NO ₂	NO ₃
T-1	11-13	0.010	65.9	761	185	1030
T-2	11-13	0.021	61.0	750	156	886
T-3	11-13	0.014	26.8	340	69	401
T-4	11-13	0.024	67.3	928	189	1030
T-5	11-13	0.028	40.5	572	124	708
T-6	11-13	0.030	43.4	575	140	804
T-7	11-13	0.027	42.8	450	88	527
T-8	11-13	0.017	14.6	202	31	194
T-9	11-13	0.017	24.5	310	54	340
T-1	11-14	1.673	100.7	1580	378	1970
T-2	11-14	1.873	122.0	1761	368	2130
T-3	11-14	0.561	37.2	534	88	520
T-4	11-14	0.682	61.9	948	192	1040
T-5	11-14	0.486	33.3	584	118	649
T-6	11-14	0.490	34.2	601	137	749
T-7	11-14	0.307	30.1	427	82	460
T-8	11-14	0.057	10.4	185	30	167
T-9	11-14	0.144	17.7	285	49	307
T-1	11-15	1.480	53.5	935	231	1210
T-2	11-15	3.697	174.8	2625	580	3190
T-3	11-15	2.158	57.0	777	127	768
T-4	11-15	2.338	67.4	1027	168	962
T-5	11-15	1.169	33.9	607	106	609
T-6	11-15	1.495	29.1	581	120	683
T-7	11-15	0.775	37.0	443	80	473
T-8	11-15	0.240	11.1	190	27	189
T-9	11-15	0.487	20.1	344	59	368
T-1	11-16	0.956	48.6	838	193	996
T-2	11-16	1.072	72.3	1223	281	1440
T-3	11-16	0.395	36.7	566	118	632
T-4	11-16	0.760	54.4	1061	225	1160
T-5	11-16	0.605	35.0	750	156	816
T-6	11-16	0.626	37.3	755	184	969
T-7	11-16	0.388	44.9	556	114	688
T-8	11-16	0.207	25.6	342	75	437
T-9	11-16	0.481	57.6	738	162	935
T-1	11-17	0.104	69.0	1020	249	1290
T-2	11-17	0.136	46.5	771	141	758
T-3	11-17	0.055	16.3	275	53	293
T-4	11-17	0.088	35.3	653	144	729
T-5	11-17	0.061	23.3	474	100	512
T-6	11-17	0.065	25.4	489	116	594
T-7	11-17	0.038	25.7	370	74	390
T-8	11-17	0.024	8.2	167	28	147
T-9	11-17	0.027	20.2	341	69	364
T-1	11-18	0.007	43.4	697	138	902
T-2	11-18	0.021	108.2	1550	298	1750
T-3	11-18	0.012	40.6	651	112	666
T-4	11-18	0.021	83.8	1461	274	1580
T-5	11-18	0.017	51.5	968	192	1130
T-6	11-18	0.020	47.5	1010	202	1230
T-7	11-18	0.019	117.1	786	135	837
T-8	11-18	0.010	12.9	267	40	257
T-9	11-18	0.017	36.4	537	88	540

Table A-5. EPA Diffusivities (cm²/s) for 2014 Samples, Cores 1A, 2C, 3C, 4B and 5C

Core	Species	D(i)T1	D(i)T2	D(i)T3	D(i)T4	D(i)T5	D(i)T6	D(i)T7	D(i)T8	D(i)T9
1A	Al	3.98E-12	6.40E-12	1.19E-11	1.12E-11	8.06E-12	5.99E-12	6.41E-12	1.21E-11	8.28E-12
1A	Ca	1.16E-12	1.51E-13	1.84E-13	2.08E-14	2.63E-14	1.31E-14	2.23E-14	7.42E-12	1.03E-12
1A	Cr	5.46E-09	1.28E-09	2.23E-10	1.47E-09	1.46E-10	1.93E-10	1.09E-10	6.19E-11	9.98E-11
1A	Na	7.69E-08	1.38E-08	1.37E-08	8.77E-09	3.60E-09	2.48E-09	1.91E-09	1.73E-09	1.71E-09
1A	NO ₂	9.08E-08	1.11E-08	9.34E-09	8.71E-09	2.32E-09	2.21E-09	9.75E-10	1.24E-09	8.11E-10
1A	NO ₃	1.41E-07	2.01E-08	2.34E-08	1.76E-08	1.39E-09	6.95E-10	3.33E-09	6.19E-09	3.31E-09
2C	Al	1.42E-11	1.22E-11	2.18E-11	1.22E-11	9.66E-12	9.34E-12	5.02E-12	1.52E-11	1.02E-11
2C	Ca	1.33E-12	5.27E-13	1.90E-13	2.15E-14	2.72E-14	2.22E-13	2.31E-14	1.30E-11	1.12E-13
2C	Cr	2.99E-07	1.79E-08	6.29E-09	3.85E-09	1.64E-09	1.11E-09	4.30E-10	3.56E-10	4.38E-10
2C	Na	4.17E-07	2.84E-08	2.32E-08	1.08E-08	6.27E-09	3.94E-09	2.52E-09	3.61E-09	2.85E-09
2C	NO ₂	6.18E-07	2.78E-08	1.85E-08	1.24E-08	4.63E-09	4.24E-09	2.45E-10	1.74E-09	3.36E-09
2C	NO ₃	8.98E-07	4.21E-08	4.79E-08	1.76E-08	1.44E-09	5.64E-09	3.33E-09	8.48E-09	1.97E-09
3C	Al	9.02E-12	2.99E-12	2.27E-11	9.25E-12	5.26E-12	2.67E-12	4.21E-12	9.34E-12	7.10E-12
3C	Ca	1.45E-12	2.37E-13	8.14E-11	7.28E-12	2.88E-12	9.13E-13	7.82E-13	1.91E-11	3.33E-12
3C	Cr	2.36E-07	6.78E-09	1.11E-08	5.43E-09	1.15E-09	4.86E-10	3.94E-10	7.54E-11	2.48E-10
3C	Na	3.22E-07	1.35E-08	3.13E-08	1.22E-08	5.15E-09	2.63E-09	2.65E-09	2.12E-09	2.29E-09
3C	NO ₂	5.52E-07	1.26E-08	4.20E-08	1.69E-08	3.33E-09	1.40E-10	1.62E-09	1.25E-09	1.09E-09
3C	NO ₃	7.39E-07	2.09E-08	9.78E-09	2.36E-08	1.40E-09	6.98E-10	3.97E-09	6.22E-09	3.48E-09
4B	Al	1.51E-11	2.48E-12	3.45E-11	3.96E-12	4.33E-12	3.28E-12	5.08E-12	6.45E-12	9.28E-12
4B	Ca	9.87E-13	2.94E-13	1.82E-13	3.01E-13	2.36E-12	3.98E-13	6.46E-13	1.07E-11	2.61E-12
4B	Cr	8.66E-08	1.68E-09	7.42E-09	5.25E-10	3.33E-10	3.61E-10	2.25E-10	7.14E-11	1.32E-10
4B	Na	3.23E-07	7.15E-09	3.68E-08	6.78E-09	4.65E-09	3.56E-09	3.20E-09	1.98E-09	3.00E-09
4B	NO ₂	4.88E-07	4.41E-09	2.77E-08	8.99E-09	2.36E-09	2.95E-09	1.82E-09	1.22E-09	1.50E-09
4B	NO ₃	6.45E-07	9.09E-09	5.31E-08	1.09E-09	6.95E-09	6.87E-10	1.17E-09	7.40E-09	1.88E-09
5C	Al	1.13E-11	1.97E-11	2.68E-11	4.68E-12	4.61E-12	5.41E-12	4.03E-12	1.08E-11	1.23E-11
5C	Ca	1.73E-12	7.47E-13	3.63E-11	2.71E-14	3.48E-13	1.22E-13	1.09E-13	1.60E-11	2.58E-12
5C	Cr	2.12E-07	3.59E-08	9.44E-09	9.73E-10	3.07E-10	4.19E-10	8.54E-11	7.34E-11	7.44E-11
5C	Na	4.72E-07	8.01E-08	3.78E-08	7.53E-09	3.89E-09	4.28E-09	2.32E-09	3.00E-09	3.06E-09
5C	NO ₂	7.81E-07	1.01E-07	3.74E-08	7.23E-09	1.99E-09	6.88E-09	5.41E-09	1.37E-09	2.84E-09
5C	NO ₃	1.03E-06	1.38E-07	5.60E-08	1.19E-08	5.87E-09	6.72E-10	1.14E-09	5.98E-09	1.84E-09

Table A-6. EPA Diffusivities (cm²/s) for 2014 Samples, Cores 6B, 6C, 6D, 7D and 8D

Core	Species	D(i)T1	D(i)T2	D(i)T3	D(i)T4	D(i)T5	D(i)T6	D(i)T7	D(i)T8	D(i)T9
6B	Al	2.80E-11	3.19E-11	4.51E-11	2.11E-11	1.77E-11	1.59E-11	1.42E-11	2.47E-11	1.60E-11
6B	Ca	9.77E-13	1.45E-13	2.00E-11	4.22E-12	3.72E-12	1.00E-14	1.90E-12	2.54E-11	2.75E-12
6B	Cr	7.78E-08	1.49E-08	1.84E-09	4.98E-10	1.52E-10	1.56E-10	8.88E-11	4.27E-11	4.63E-11
6B	Na	5.12E-07	5.22E-08	3.42E-08	1.39E-08	8.77E-09	7.72E-09	6.18E-09	6.12E-09	5.52E-09
6B	NO ₂	8.48E-07	5.76E-08	2.91E-08	1.62E-08	9.67E-09	2.26E-08	1.97E-09	3.60E-09	3.82E-09
6B	NO ₃	1.15E-06	7.55E-08	5.22E-08	2.61E-08	1.40E-09	6.99E-10	1.19E-09	9.88E-09	1.00E-08
6C	Al	1.11E-11	3.14E-11	4.71E-11	2.00E-11	7.03E-12	4.90E-12	4.98E-12	1.30E-11	1.00E-11
6C	Ca	1.79E-12	3.32E-13	2.56E-11	2.02E-14	6.62E-13	5.90E-14	2.68E-14	7.30E-12	1.34E-12
6C	Cr	4.79E-08	1.60E-08	3.93E-09	1.60E-09	1.60E-10	1.15E-10	4.87E-11	4.67E-11	4.10E-11
6C	Na	3.24E-07	7.27E-08	4.21E-08	2.14E-08	5.63E-09	3.92E-09	3.39E-09	4.44E-09	3.71E-09
6C	NO ₂	5.06E-07	8.93E-08	2.34E-08	2.45E-08	4.52E-09	4.06E-09	3.21E-09	2.26E-09	2.35E-09
6C	NO ₃	6.64E-07	1.21E-07	5.04E-08	3.57E-08	8.51E-09	6.75E-10	4.31E-09	9.40E-09	1.85E-09
6D	Al	6.86E-12	2.36E-11	4.22E-11	2.16E-11	1.70E-11	1.01E-11	1.12E-11	2.38E-11	1.64E-11
6D	Ca	3.85E-13	1.56E-13	1.86E-13	2.11E-14	1.19E-13	2.11E-16	2.26E-14	5.90E-12	6.31E-13
6D	Cr	1.01E-09	1.53E-10	1.11E-12	2.69E-11	6.12E-12	4.91E-12	2.36E-12	6.41E-13	5.18E-13
6D	Na	2.53E-07	3.85E-08	3.50E-08	1.70E-08	8.56E-09	6.41E-09	5.08E-09	6.15E-09	5.33E-09
6D	NO ₂	4.02E-07	4.31E-08	4.14E-08	2.02E-08	6.92E-09	6.69E-09	2.09E-09	4.11E-09	1.46E-08
6D	NO ₃	5.89E-07	6.08E-08	9.84E-09	2.95E-08	1.40E-08	7.03E-10	7.28E-09	6.26E-09	1.92E-09
7D	Al	4.87E-12	1.41E-11	2.31E-11	1.34E-11	1.21E-11	7.23E-12	4.77E-12	1.59E-11	1.66E-11
7D	Ca	4.30E-13	5.89E-13	1.73E-13	1.96E-14	1.47E-13	1.24E-14	2.10E-14	4.68E-13	1.13E-14
7D	Cr	8.62E-09	2.26E-09	3.57E-10	3.41E-10	1.12E-10	1.16E-10	1.09E-10	4.55E-11	5.06E-11
7D	Na	1.61E-07	4.15E-08	2.42E-08	9.26E-09	5.74E-09	3.27E-09	2.92E-09	2.69E-09	2.29E-09
7D	NO ₂	2.66E-07	5.28E-08	4.34E-08	1.12E-08	4.87E-09	2.91E-09	2.23E-10	1.63E-09	2.10E-09
7D	NO ₃	3.54E-07	7.56E-08	7.19E-08	1.71E-08	1.31E-09	4.88E-09	5.43E-09	5.83E-09	1.79E-09
8D	Al	8.69E-12	2.01E-11	3.32E-11	2.41E-11	1.33E-11	7.64E-12	8.30E-12	2.03E-11	1.30E-11
8D	Ca	4.36E-13	2.12E-13	1.87E-13	2.12E-14	2.70E-13	1.34E-14	2.27E-14	1.18E-11	3.84E-13
8D	Cr	1.10E-09	3.13E-10	8.72E-11	1.73E-11	1.80E-11	1.07E-11	5.13E-12	2.40E-12	1.98E-12
8D	Na	2.77E-07	3.36E-08	2.86E-08	1.54E-08	6.77E-09	4.49E-09	4.29E-09	4.50E-09	3.67E-09
8D	NO ₂	4.93E-07	3.67E-08	3.40E-08	2.12E-08	5.93E-09	4.48E-09	3.51E-09	2.51E-09	2.74E-09
8D	NO ₃	6.25E-07	5.45E-08	9.89E-09	3.04E-08	1.21E-08	7.51E-09	5.14E-09	8.77E-09	4.06E-09

Table A-7. EPA Diffusivities (cm²/s) for 2014 Samples, Molded Cores 15, 16, 21 and 26

Core	Species	D(i)T1	D(i)T2	D(i)T3	D(i)T4	D(i)T5	D(i)T6	D(i)T7	D(i)T8	D(i)T9
15	Al	8.30E-12	3.41E-12	8.18E-12	2.68E-12	1.75E-12	2.20E-12	2.61E-12	4.07E-12	5.07E-12
15	Ca	4.16E-13	1.66E-13	8.47E-12	8.82E-14	4.40E-14	2.66E-14	2.56E-13	7.90E-12	2.80E-12
15	Cr	2.20E-12	3.63E-13	1.07E-12	1.21E-13	1.53E-13	7.64E-14	1.30E-13	6.81E-13	2.09E-13
15	Na	1.87E-08	1.45E-08	4.02E-08	1.48E-08	6.68E-09	5.96E-09	5.92E-09	5.40E-09	5.54E-09
15	NO ₂	5.99E-09	7.03E-09	2.79E-08	8.55E-09	2.48E-09	1.49E-10	1.32E-09	3.86E-09	1.59E-09
15	NO ₃	1.95E-08	1.33E-08	9.46E-09	1.07E-09	6.13E-09	5.30E-09	1.15E-09	6.02E-09	5.59E-09
16	Al	2.34E-12	1.52E-12	5.96E-12	2.18E-12	2.12E-12	2.41E-12	2.47E-12	6.39E-12	1.52E-11
16	Ca	5.02E-13	2.88E-13	7.03E-12	1.01E-13	7.00E-14	1.26E-14	2.42E-13	1.39E-11	2.84E-12
16	Cr	3.96E-12	4.47E-12	3.99E-11	1.30E-11	2.70E-12	4.94E-13	1.28E-13	6.72E-13	2.06E-13
16	Na	1.70E-08	6.49E-09	3.58E-08	1.40E-08	8.00E-09	5.96E-09	4.14E-09	5.64E-09	6.22E-09
16	NO ₂	6.01E-09	2.72E-09	2.37E-08	1.12E-08	4.00E-09	2.83E-09	9.90E-10	7.37E-09	3.18E-09
16	NO ₃	1.92E-08	6.48E-09	9.34E-09	1.06E-09	8.54E-09	5.34E-09	4.00E-09	5.94E-09	4.91E-09
21	Al	1.26E-12	7.26E-13	8.91E-12	3.07E-12	3.00E-12	2.46E-12	3.06E-12	6.25E-12	5.66E-12
21	Ca	2.32E-13	6.60E-14	2.41E-12	3.87E-14	5.49E-14	1.23E-14	3.90E-14	7.68E-12	1.09E-12
21	Cr	4.40E-10	8.25E-11	3.88E-10	5.32E-11	3.81E-11	1.69E-11	4.24E-12	8.02E-13	9.88E-13
21	Na	1.15E-08	8.32E-09	2.55E-08	6.12E-09	3.89E-09	2.59E-09	1.85E-09	2.36E-09	2.06E-09
21	NO ₂	6.07E-09	4.48E-09	1.22E-08	4.80E-09	3.42E-09	1.23E-09	1.04E-09	1.31E-09	1.32E-09
21	NO ₃	1.88E-08	8.53E-09	4.26E-08	9.48E-09	1.30E-09	3.73E-09	2.39E-09	5.81E-09	3.80E-09
26	Al	1.20E-12	1.57E-12	7.02E-12	6.76E-12	3.35E-12	4.05E-12	4.88E-12	7.19E-12	1.26E-11
26	Ca	2.77E-13	8.91E-14	5.49E-13	2.19E-14	6.04E-14	1.39E-14	2.35E-14	9.35E-12	5.47E-13
26	Cr	7.65E-10	1.39E-09	1.26E-09	1.01E-09	7.99E-11	1.49E-10	5.04E-11	1.58E-11	1.53E-11
26	Na	9.84E-09	1.36E-08	2.17E-08	1.14E-08	4.09E-09	3.82E-09	2.22E-09	2.04E-09	1.64E-09
26	NO ₂	6.19E-09	1.16E-08	1.66E-08	1.26E-08	2.22E-09	2.56E-09	1.28E-09	1.31E-09	7.99E-10
26	NO ₃	2.11E-08	1.76E-08	3.43E-08	1.84E-08	5.57E-09	5.42E-09	2.58E-09	7.75E-09	3.23E-09

Table A-8. EPA Diffusivities (cm²/s) for 2015 Samples – Outer Cores 9-1 through 9-6

Core	Species	D(i)T1	D(i)T2	D(i)T3	D(i)T4	D(i)T5	D(i)T6	D(i)T7	D(i)T8	D(i)T9
9-1	Cr	9.17E-08	4.53E-09	2.07E-09	9.24E-10	7.45E-10	3.88E-10	3.19E-10	1.15E-10	1.53E-10
9-1	S	2.70E-06	1.68E-07	9.70E-08	3.64E-08	1.77E-08	9.59E-09	1.11E-08	6.91E-09	6.79E-09
9-1	Na	2.17E-06	1.62E-07	1.08E-07	3.53E-08	2.27E-08	9.53E-09	1.15E-08	9.05E-09	8.03E-09
9-1	NO ₂	4.39E-06	2.29E-07	1.06E-07	4.71E-08	2.37E-08	1.63E-08	1.08E-08	6.96E-09	6.22E-09
9-1	NO ₃	4.94E-06	3.09E-07	1.57E-07	6.67E-08	3.41E-08	2.24E-08	1.61E-08	1.04E-08	1.02E-08
9-2	Cr	2.75E-11	1.13E-11	4.83E-12	6.59E-13	1.01E-12	4.66E-13	3.83E-13	1.35E-12	6.10E-13
9-2	S	1.43E-06	1.14E-07	4.57E-08	2.15E-08	1.23E-08	9.74E-09	8.90E-09	4.33E-09	1.33E-08
9-2	Na	6.14E-07	5.24E-08	2.76E-08	1.32E-08	9.15E-09	5.66E-09	5.41E-09	4.92E-09	8.86E-09
9-2	NO ₂	1.07E-06	5.41E-08	2.30E-08	2.08E-08	1.15E-08	1.09E-08	5.97E-09	4.28E-09	1.32E-08
9-2	NO ₃	1.56E-06	8.82E-08	3.58E-08	3.07E-08	1.72E-08	1.61E-08	9.40E-09	6.68E-09	1.54E-08
9-3	Cr	2.36E-07	3.83E-08	1.81E-08	3.88E-09	1.72E-09	1.04E-09	7.04E-10	3.94E-10	6.71E-10
9-3	S	3.81E-06	6.51E-07	2.57E-07	6.34E-08	1.76E-08	1.01E-08	1.28E-08	1.02E-08	1.57E-08
9-3	Na	3.32E-06	5.54E-07	2.26E-07	7.50E-08	3.49E-08	1.44E-08	1.36E-08	1.33E-08	1.88E-08
9-3	NO ₂	5.50E-06	7.93E-07	2.80E-07	8.41E-08	3.13E-08	2.05E-08	1.65E-08	9.47E-09	1.68E-08
9-3	NO ₃	7.14E-06	1.45E-06	4.19E-07	1.18E-07	4.62E-08	2.88E-08	2.02E-08	1.27E-08	2.71E-08
9-4	Cr	1.13E-08	1.63E-09	6.06E-10	1.25E-11	1.85E-10	1.07E-10	8.15E-11	3.71E-12	4.45E-11
9-4	S	7.18E-07	4.76E-08	3.73E-08	1.85E-08	7.38E-09	4.97E-09	6.61E-09	4.58E-09	7.13E-09
9-4	Na	6.66E-07	6.88E-08	4.80E-08	2.71E-08	1.50E-08	7.19E-09	8.02E-09	7.72E-09	1.03E-08
9-4	NO ₂	9.98E-07	8.32E-08	4.19E-08	3.46E-08	1.58E-08	1.13E-08	8.46E-09	6.36E-09	1.16E-08
9-4	NO ₃	1.66E-06	1.15E-07	5.84E-08	4.57E-08	2.15E-08	1.53E-08	1.20E-08	8.99E-09	1.24E-08
9-5	Cr	4.11E-13	4.23E-13	7.11E-13	2.08E-13	2.58E-13	1.30E-13	1.34E-13	2.62E-13	2.66E-13
9-5	S	2.54E-06	7.63E-07	4.89E-07	3.53E-07	1.77E-07	3.88E-08	4.24E-08	1.81E-08	2.06E-08
9-5	Na	2.20E-06	7.45E-07	5.59E-07	3.38E-07	2.43E-07	7.09E-08	5.50E-08	3.04E-08	3.73E-08
9-5	NO ₂	2.27E-06	7.63E-07	4.85E-07	4.26E-07	2.96E-07	1.07E-07	4.30E-08	1.92E-08	1.97E-08
9-5	NO ₃	3.78E-06	1.25E-06	8.26E-07	7.11E-07	5.38E-07	2.09E-07	9.51E-08	5.24E-08	7.61E-08
9-6	Cr	6.28E-10	1.40E-10	4.89E-10	2.03E-11	9.18E-12	4.38E-12	4.99E-12	7.79E-11	5.53E-11
9-6	S	1.48E-06	2.47E-07	8.48E-08	3.99E-08	1.69E-08	9.03E-09	1.36E-08	9.31E-09	8.84E-09
9-6	Na	1.51E-06	2.33E-07	8.88E-08	3.62E-08	2.52E-08	1.17E-08	1.27E-08	1.15E-08	1.01E-08
9-6	NO ₂	2.19E-06	2.18E-07	6.42E-08	4.58E-08	2.55E-08	1.72E-08	1.21E-08	8.29E-09	7.75E-09
9-6	NO ₃	2.85E-06	3.44E-07	1.02E-07	6.43E-08	3.75E-08	2.52E-08	1.79E-08	1.29E-08	1.27E-08

Table A-9. EPA Diffusivities (cm²/s) for 2015 Samples – Middle Cores 10-7 through 10-12

Core	Species	D(i)T1	D(i)T2	D(i)T3	D(i)T4	D(i)T5	D(i)T6	D(i)T7	D(i)T8	D(i)T9
10-7	Cr	6.45E-09	2.04E-09	3.10E-09	2.52E-10	1.46E-10	8.03E-11	5.50E-11	2.22E-10	9.29E-12
10-7	S	1.36E-06	3.13E-07	9.19E-08	3.09E-08	1.23E-08	6.85E-09	8.46E-09	4.81E-09	6.13E-09
10-7	Na	9.44E-07	2.09E-07	7.00E-08	2.70E-08	1.62E-08	7.69E-09	6.85E-09	7.16E-09	7.01E-09
10-7	NO ₂	1.77E-06	2.81E-07	5.23E-08	3.08E-08	1.48E-08	1.07E-08	6.67E-09	4.17E-09	6.61E-09
10-7	NO ₃	2.39E-06	4.25E-07	7.99E-08	4.36E-08	2.17E-08	1.54E-08	1.05E-08	6.81E-09	7.88E-09
10-8	Cr	2.07E-08	1.49E-08	8.87E-09	2.40E-09	1.41E-09	7.74E-10	6.42E-10	1.48E-10	3.96E-10
10-8	S	4.68E-07	3.23E-07	1.21E-07	4.80E-08	2.21E-08	1.25E-08	1.88E-08	1.18E-08	1.50E-08
10-8	Na	4.90E-07	2.81E-07	1.21E-07	6.05E-08	3.43E-08	1.62E-08	1.59E-08	1.66E-08	1.49E-08
10-8	NO ₂	1.96E-08	4.07E-07	1.11E-07	7.44E-08	3.81E-08	2.43E-08	1.78E-08	1.24E-08	1.65E-08
10-8	NO ₃	2.70E-08	5.80E-07	1.67E-07	1.05E-07	5.69E-08	3.60E-08	2.78E-08	2.17E-08	2.22E-08
10-9	Cr	1.44E-07	5.18E-08	2.56E-08	4.98E-09	1.48E-10	1.94E-09	1.17E-09	4.28E-10	5.67E-10
10-9	S	2.39E-06	1.20E-06	2.67E-07	6.89E-08	2.73E-08	1.26E-08	2.73E-08	1.09E-08	1.28E-08
10-9	Na	2.54E-06	1.07E-06	2.89E-07	7.60E-08	3.99E-08	1.70E-08	1.68E-08	1.52E-08	1.41E-08
10-9	NO ₂	4.55E-06	1.59E-06	2.45E-07	8.39E-08	4.24E-08	2.38E-08	1.84E-08	1.19E-08	1.69E-08
10-9	NO ₃	5.97E-06	2.33E-06	4.08E-07	1.25E-07	6.29E-08	3.51E-08	2.94E-08	2.01E-08	2.45E-08
10-10	Cr	3.38E-09	1.75E-09	5.55E-10	2.95E-10	3.06E-09	9.61E-11	5.98E-11	9.46E-13	2.26E-11
10-10	S	8.46E-07	5.86E-07	2.16E-07	8.12E-08	3.00E-08	1.52E-08	2.01E-08	1.74E-08	1.93E-08
10-10	Na	8.67E-07	4.87E-07	1.75E-07	7.24E-08	3.93E-08	1.82E-08	1.62E-08	1.68E-08	1.53E-08
10-10	NO ₂	1.68E-06	8.27E-07	2.24E-07	8.58E-08	4.21E-08	2.71E-08	1.81E-08	1.24E-08	1.26E-08
10-10	NO ₃	2.19E-06	1.19E-06	2.92E-07	1.22E-07	6.13E-08	3.93E-08	2.76E-08	2.83E-08	2.23E-08
10-11	Cr	1.63E-11	8.63E-12	9.11E-12	3.25E-12	3.93E-12	2.17E-12	4.75E-12	5.58E-12	2.10E-12
10-11	S	5.46E-07	1.64E-07	9.75E-08	5.15E-08	2.07E-08	9.97E-09	1.49E-08	6.44E-09	4.79E-09
10-11	Na	4.93E-07	1.58E-07	7.87E-08	4.01E-08	2.72E-08	1.21E-08	1.44E-08	1.09E-08	9.63E-09
10-11	NO ₂	8.12E-07	2.16E-07	1.02E-07	6.72E-08	3.25E-08	1.93E-08	1.72E-08	8.66E-09	7.39E-09
10-11	NO ₃	1.11E-06	2.91E-07	1.44E-07	8.81E-08	4.42E-08	2.59E-08	2.21E-08	1.12E-08	1.08E-08
10-12	Cr	6.87E-12	3.89E-12	4.21E-12	1.53E-12	1.13E-12	6.09E-13	7.17E-13	1.18E-12	1.22E-12
10-12	S	2.99E-06	6.06E-07	4.22E-07	1.83E-07	6.70E-08	4.72E-08	1.14E-07	2.31E-08	3.36E-08
10-12	Na	2.37E-06	4.87E-07	3.23E-07	1.53E-07	9.50E-08	5.36E-08	4.38E-08	3.37E-08	3.74E-08
10-12	NO ₂	2.87E-06	5.98E-07	3.06E-07	1.71E-07	9.65E-08	7.08E-08	4.19E-08	2.49E-08	3.47E-08
10-12	NO ₃	4.41E-06	9.97E-07	5.42E-07	2.82E-07	1.63E-07	1.24E-07	7.88E-08	5.26E-08	6.91E-08

Table A-10. EPA Diffusivities (cm²/s) for 2015 Samples – Inner Cores 11-13 through 11-18

Core	Species	D(i)T1	D(i)T2	D(i)T3	D(i)T4	D(i)T5	D(i)T6	D(i)T7	D(i)T8	D(i)T9
11-13	Cr	1.99E-12	1.53E-12	2.00E-12	6.96E-13	1.15E-12	6.47E-13	8.98E-13	1.87E-12	5.92E-13
11-13	S	1.52E-06	2.15E-07	1.22E-07	8.71E-08	3.99E-08	2.28E-08	3.78E-08	2.30E-08	1.99E-08
11-13	Na	7.27E-07	1.17E-07	7.06E-08	5.94E-08	2.85E-08	1.44E-08	1.50E-08	1.58E-08	1.14E-08
11-13	NO ₂	1.30E-06	1.53E-07	8.77E-08	7.40E-08	4.07E-08	2.57E-08	1.73E-08	1.15E-08	1.05E-08
11-13	NO ₃	2.01E-06	2.45E-07	1.48E-07	1.10E-07	6.59E-08	4.25E-08	3.10E-08	2.21E-08	2.08E-08
11-14	Cr	5.75E-08	1.19E-08	3.14E-09	5.25E-10	3.37E-10	1.71E-10	1.14E-10	2.08E-11	4.06E-11
11-14	S	3.39E-06	8.21E-07	2.25E-07	7.05E-08	2.58E-08	1.36E-08	1.79E-08	1.11E-08	9.93E-09
11-14	Na	3.01E-06	6.15E-07	1.67E-07	5.94E-08	2.85E-08	1.51E-08	1.29E-08	1.27E-08	9.25E-09
11-14	NO ₂	5.19E-06	8.13E-07	1.36E-07	7.34E-08	3.51E-08	2.37E-08	1.45E-08	9.93E-09	8.18E-09
11-14	NO ₃	7.05E-06	1.36E-06	2.39E-07	1.08E-07	5.30E-08	3.53E-08	2.26E-08	1.57E-08	1.62E-08
11-15	Cr	4.27E-08	4.39E-08	4.42E-08	5.86E-09	1.85E-09	1.51E-09	6.90E-10	3.48E-10	4.39E-10
11-15	S	9.12E-07	1.60E-06	5.02E-07	7.93E-08	2.54E-08	9.33E-09	2.56E-08	1.22E-08	1.21E-08
11-15	Na	9.99E-07	1.30E-06	3.35E-07	6.63E-08	2.92E-08	1.34E-08	1.32E-08	1.27E-08	1.28E-08
11-15	NO ₂	1.84E-06	1.91E-06	2.68E-07	5.34E-08	2.67E-08	1.71E-08	1.30E-08	7.98E-09	1.14E-08
11-15	NO ₃	2.53E-06	2.89E-06	4.94E-07	8.78E-08	4.44E-08	2.79E-08	2.27E-08	1.90E-08	2.21E-08
11-16	Cr	1.86E-08	3.86E-09	1.55E-09	6.47E-10	5.19E-10	2.78E-10	1.81E-10	2.71E-10	4.48E-10
11-16	S	7.84E-07	2.86E-07	2.18E-07	5.40E-08	2.83E-08	1.61E-08	3.95E-08	6.71E-08	1.05E-07
11-16	Na	8.39E-07	2.94E-07	1.86E-07	7.38E-08	4.67E-08	2.36E-08	2.17E-08	4.33E-08	6.17E-08
11-16	NO ₂	1.35E-06	4.69E-07	2.45E-07	1.00E-07	6.09E-08	4.22E-08	2.74E-08	6.22E-08	9.00E-08
11-16	NO ₃	1.79E-06	6.16E-07	3.49E-07	1.33E-07	8.34E-08	5.87E-08	5.02E-08	1.07E-07	1.49E-07
11-17	Cr	2.40E-10	6.74E-11	3.24E-11	9.45E-12	5.65E-12	3.18E-12	1.89E-12	3.90E-12	1.48E-12
11-17	S	1.71E-06	1.28E-07	4.62E-08	2.45E-08	1.35E-08	8.01E-09	1.40E-08	7.51E-09	1.39E-08
11-17	Na	1.34E-06	1.26E-07	4.72E-08	3.02E-08	2.01E-08	1.07E-08	1.04E-08	1.10E-08	1.42E-08
11-17	NO ₂	2.41E-06	1.28E-07	5.37E-08	4.43E-08	2.72E-08	1.81E-08	1.27E-08	9.13E-09	1.78E-08
11-17	NO ₃	3.24E-06	1.84E-07	8.09E-08	5.68E-08	3.53E-08	2.38E-08	1.75E-08	1.30E-08	2.44E-08
11-18	Cr	9.80E-13	1.52E-12	1.60E-12	4.93E-13	4.45E-13	2.85E-13	4.69E-13	6.57E-13	6.11E-13
11-18	S	6.55E-07	6.70E-07	2.78E-07	1.34E-07	6.39E-08	2.72E-08	2.80E-07	1.78E-08	4.36E-08
11-18	Na	6.06E-07	4.94E-07	2.57E-07	1.46E-07	8.11E-08	4.41E-08	4.54E-08	2.74E-08	3.41E-08
11-18	NO ₂	7.13E-07	5.52E-07	2.28E-07	1.55E-07	9.59E-08	5.34E-08	4.03E-08	1.87E-08	2.76E-08
11-18	NO ₃	1.53E-06	9.50E-07	4.05E-07	2.58E-07	1.67E-07	9.87E-08	7.76E-08	3.85E-08	5.20E-08

Appendix B. Leachate pH and Conductivity

Table B-1. pH Data for 2014 Samples

Interval	Cumulative Time (days)	1A	2C	3C	4B	5C	6B	6C	6D	7D	8D	15	16	21	26
T01	0.08	10.7	11.5	11.4	11.5	11.5	11.5	11.4	11.0	10.9	11.1	10.4	10.4	10.2	11.5
T02	1	11.2	11.4	11.2	11.0	11.7	11.6	11.6	11.5	11.5	11.5	11.3	11.1	11.0	11.4
T03	2	10.0	10.4	11.2	11.5	11.4	11.6	11.5	10.6	10.0	10.6	11.5	11.4	11.3	10.4
T04	7	10.0	10.0	11.6	11.6	11.6	11.7	11.7	10.1	9.8	10.3	11.8	11.7	11.5	10.0
T05	14	11.2	10.0	11.5	11.4	11.3	11.6	11.4	11.5	11.4	11.6	11.7	11.6	11.3	10.0
T06	28	11.1	11.5	11.4	11.5	11.6	11.8	11.6	11.5	11.3	11.4	11.8	11.8	11.5	11.5
T07	42	11.0	11.2	11.4	11.6	11.4	11.6	11.5	11.3	10.5	11.3	11.6	11.6	11.3	11.2
T08	49	10.7	10.9	10.9	10.9	11.1	11.2	11.1	11.0	10.6	11.0	11.2	11.2	10.9	10.9
T09	63	10.8	11.0	11.0	11.2	11.2	11.3	11.2	11.2	10.3	11.0	11.4	11.5	11.1	11.0

Table B-2. Conductivity Data (mS/cm) for 2014 Samples

Interval	Cumulative Time (days)	1A	2C	3C	4B	5C	6B	6C	6D	7D	8D	15	16	21	26
T01	0.08	1.1	3.6	3.3	3.4	3.7	3.9	3.4	2.4	2.1	2.5	0.6	0.5	0.5	0.4
T02	1	1.7	2.7	1.7	1.2	4.3	3.5	4.2	3.0	3.2	2.8	1.9	1.3	1.2	1.6
T03	2	0.7	0.9	1.7	2.0	2.0	1.8	2.1	1.2	0.9	1.1	2.0	1.8	1.4	1.1
T04	7	1.7	1.9	3.3	2.6	2.6	3.6	3.8	2.4	1.9	2.3	3.8	3.6	2.4	2.8
T05	14	1.3	1.2	1.8	1.7	1.5	2.5	2.0	2.2	1.8	2.0	2.1	2.4	1.5	1.4
T06	28	1.4	2.2	2.0	2.4	2.6	3.1	2.5	2.7	1.9	2.2	3.2	2.9	1.4	1.9
T07	42	1.0	1.2	1.5	1.7	1.4	2.3	1.6	1.6	1.0	1.6	2.4	2.0	1.2	1.2
T08	49	0.5	0.7	0.6	0.6	0.8	1.1	0.9	0.9	0.5	0.8	1.0	1.0	0.6	0.5
T09	63	0.7	1.0	1.0	1.2	1.2	1.6	1.3	1.3	0.7	1.1	1.8	1.9	1.0	0.8

Table B-3. pH Data for 2015 Samples

Interval	Cumulative Time (days)	9-1	9-2	9-3	9-4	9-5	9-6	10-7	10-8	10-9
T01	0.08	12.3	12.1	12.5	12.3	12.7	12.6	12.4	12.6	12.7
T02	1	12.2	12.0	12.4	12.2	12.6	12.4	12.3	12.4	12.6
T03	2	12.0	11.8	12.2	12.0	12.5	12.2	12.1	12.2	12.4
T04	7	12.0	11.8	12.2	12.1	12.5	12.2	12.1	12.2	12.3
T05	14	12.0	11.8	12.1	12.0	12.5	12.1	12.0	12.1	12.2
T06	28	12.1	11.9	12.3	12.2	12.6	12.3	12.2	12.3	12.4
T07	42	12.0	11.6	12.0	11.9	12.3	12.1	11.9	12.0	12.1
T08	49	11.9	11.7	12.0	11.9	12.3	12.0	11.9	12.0	12.1
T09	63	12.3	12.1	12.6	12.5	12.9	12.4	12.3	12.5	12.5
Interval	Cumulative Time (days)	10-10	10-11	11-12	11-13	11-14	11-15	11-16	11-17	11-18
T01	0.08	12.8	12.4	12.7	12.4	12.8	12.7	12.6	12.6	12.6
T02	1	12.5	12.3	12.6	12.3	12.6	12.7	12.5	12.4	12.6
T03	2	12.3	12.1	12.4	12.0	12.3	12.4	12.3	12.1	12.4
T04	7	12.3	12.2	12.5	12.2	12.3	12.3	12.3	12.1	12.4
T05	14	12.2	12.1	12.3	12.0	12.1	12.2	12.2	12.1	12.4
T06	28	12.4	12.3	12.6	12.3	12.3	12.3	12.4	12.3	12.6
T07	42	12.1	12.0	12.3	12.0	12.0	12.0	12.1	12.0	12.4
T08	49	12.1	11.9	12.2	11.9	12.0	12.1	12.1	11.9	12.2
T09	63	12.5	12.3	12.8	12.3	12.3	12.5	12.7	12.5	12.8

Table B-4. Conductivity Data (mS/cm) for 2015 Samples.

Interval	Cumulative Time (days)	9-1	9-2	9-3	9-4	9-5	9-6	10-7	10-8	10-9
T01	0.08	6.6	3.8	7.7	4.4	9.7	6.8	5.2	3.9	7.8
T02	1	5.6	2.8	9.9	4.4	12.0	6.8	6.3	7.4	13.5
T03	2	2.7	1.6	4.6	1.9	6.6	2.9	2.4	3.3	5.0
T04	7	5.5	2.9	7.4	4.8	15.0	5.6	4.6	6.3	7.9
T05	14	4.2	2.3	5.0	3.5	12.1	4.3	3.2	4.6	5.5
T06	28	4.1	2.7	5.2	3.9	11.2	4.7	3.5	4.9	5.4
T07	42	3.2	1.8	3.6	2.8	6.7	3.4	2.5	3.5	3.9
T08	49	1.5	0.9	1.7	1.4	3.0	1.6	1.2	1.7	1.8
T09	63	2.0	1.6	3.1	2.2	4.8	2.1	1.8	2.6	2.6
Interval	Cumulative Time (days)	10-10	10-11	11-12	11-13	11-14	11-15	11-16	11-17	11-18
T01	0.08	5.9	4.6	7.2	4.1	9.0	6.6	5.8	6.6	5.7
T02	1	10.1	5.3	10.3	4.8	10.8	14.7	8.2	5.4	10.2
T03	2	4.1	2.7	5.0	2.6	4.3	6.0	4.4	2.4	5.0
T04	7	7.4	5.4	10.5	5.5	6.5	7.5	7.6	4.8	10.3
T05	14	5.2	3.9	8.0	4.1	4.4	5.1	5.8	3.8	7.7
T06	28	5.6	4.2	8.9	4.7	5.0	4.9	6.2	4.3	8.6
T07	42	3.8	3.2	6.0	3.2	3.3	3.4	4.3	3.0	6.5
T08	49	1.9	1.3	2.9	1.5	1.5	1.8	2.5	1.3	2.7
T09	63	2.8	1.8	4.5	2.1	1.9	2.6	5.0	2.4	4.4

Distribution:

T. B. Brown, 773-A
M. E. Cercy, 773-42A
D. A. Crowley, 773-43A
D. E. Dooley, 773-A
A. P. Fellingner, 773-42A
C. C. Herman, 773-A
D. T. Hobbs, 773-A
E. N. Hoffman, 999-W
J. E. Hyatt, 773-A
K. M. Kostelnik, 773-42A
B. B. Looney, 773-42A
D. A. McGuire, 773-42A
T. O. Oliver, 773-42A
F. M. Pennebaker, 773-42A
G. N. Smoland, 773-42A
B. J. Wiedenman, 773-42A
W. R. Wilmarth, 773-A
Records Administration (EDWS)
H. H. Burns, 773-41A
A. D. Cozzi, 999-W
S. D. Fink, 773-A
G. P. Flach, 773-42A
K. M. Fox, 999-W
E. K. Hansen, 999-W
K. A. Hill, 999-W
W. P. Kubilius, 999-W
C. A. Langton, 773-42A
D. J. McCabe, 773-42A
D. L. McClane, 999-W
M. R. Poirier, 773-42A
A. A. Ramsey, 999-W
M.M. Reigel, 773-42A
R. R. Seitz, 773-42A
M. E. Stone, 999-W
C. L. Trivelpiece, 999-W
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Michael_G_Thien@rl.gov