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Updated Liquid Secondary Waste Grout Formulation and Preliminary Waste Form Qualification

July 2017

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

This report describes the results from liquid secondary waste grout (LSWG) formulation and cementitious waste form qualification tests performed by Pacific Northwest National Laboratory (PNNL) for Washington River Protection Solutions, LLC (WRPS). New formulations for preparing a cementitious waste form from a high-sulfate liquid secondary waste stream simulant, developed for Effluent Management Facility (EMF) process condensates merged with low activity waste (LAW) caustic scrubber, and the release of key constituents (e.g. ^{99}Tc and ^{129}I) from these monoliths were evaluated. This work supports a technology development program to address the technology needs for Hanford Site Effluent Treatment Facility (ETF) liquid secondary waste (LSW) solidification and supports future Direct Feed Low-Activity Waste (DFLAW) operations. High-priority activities included simulant development, LSWG formulation, and waste form qualification. The work contained within this report relates to waste form development and testing and does not directly support the 2017 integrated disposal facility (IDF) performance assessment (PA). However, this work contains valuable information for use in PA maintenance past FY17, and for future waste form development efforts. The provided data should be used by (i) cementitious waste form scientists to further understanding of cementitious dissolution behavior, (ii) IDF PA modelers who use quantified constituent leachability, effective diffusivity, and partitioning coefficients to advance PA modeling efforts, and (iii) the U.S. Department of Energy (DOE) contractors and decision makers as they assess the IDF PA program. The results obtained help fill existing data gaps, support final selection of a LSWG waste form, and improve the technical defensibility of long-term waste form performance estimates.

Specific LSWG formulation and waste form qualification testing efforts described in this report include:

1. formulation of new LSWG waste forms containing hydrated lime (HL) for a high-sulfate LSW simulant and solid-phase characterization of the cured LSWG cementitious waste forms
2. leach testing on select LSWG formulations to determine ^{99}Tc leachability of the cured LSWG cementitious waste forms as a function of pH, which will help account for variations in the waste form disposal surroundings
3. determination of effective diffusivity (D_{eff})¹ values for ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in both deionized water (DIW) and vadose zone pore water (VZPW) leach solutions to assess the long-term immobilization potential of the waste form under different leach environments
4. quantification of ^{99}Tc desorption K_d (distribution coefficient) values from the cementitious material under oxidizing conditions to support maintenance of the Hanford IDF PA predictions for ^{99}Tc transport
5. estimation of the empirical solubility of ^{99}Tc from $^{99}\text{Tc(IV)}$ -bearing solids under reducing conditions, which are expected to persist in young cementitious materials, to support maintenance of the IDF PA model predictions for ^{99}Tc transport
6. report results from extended leach testing, ^{99}Tc solubility experiments, and solid-phase characterization analysis of LSWG monoliths carried over from Fiscal Year (FY) 2015 testing (Um et al. 2016).

The key findings from this work are listed below and supported by the details following:

¹ Effective diffusion coefficients are called observed diffusion coefficients (D_{obs}) in EPA test methodologies. The two terms are synonymous.

1. **The new dry-blend formulation with HL addition should replace the Cast Stone formulation for sulfate-rich LSW waste streams.** All HL-containing formulations produced rigid monoliths, whereas the monoliths produced with the original Cast Stone formulation and high-sulfate simulant, (sulfate concentration 241 g/L), did not produce a hard monolith even after the 60-day curing period. However, a formulation with 20% HL, 35% ordinary Portland cement (OPC), and 45% blast furnace slag (BFS) does not provide sufficient sources of Ca^{2+} and Al^{3+} to ensure complete sequestration of sulfate concentrations, equal to 241 g/L in the simulant used, and this dry-solid formulation requires further optimization.
2. Solid-phase characterization of monoliths before and after leaching show an **increase in ettringite formation in those formulations containing HL**, which caused cracking in monoliths before and during leach testing.
3. The range of values reported for $^{99}\text{Tc } D_{\text{eff}}$ (10^{-9} to 10^{-14} cm^2/s) **determined from 28 to 100 day leaching intervals represent 100% saturation conditions.** These D_{eff} values represent the effects of diffusion-controlled processes in addition to physical and/or chemical processes that immobilize ^{99}Tc , such as the incorporation of ^{99}Tc in ettringite formed during later leach periods.
4. ^{99}Tc release, measured as **^{99}Tc desorption distribution coefficient (K_d)**, under oxidizing conditions (oxidation/reduction potential, $E_h > 100$ mV and after a 30-day sorption reaction) was determined to be 25.7 ± 5.9 mL/g. The reason this average value is higher than previously reported values (0–10 mL/g, Kaplan 2010) for oxidizing cementitious solids is probably that added BFS is still acting as a strong reductant during our desorption tests.
5. **Solubility tests for ^{99}Tc determined an overall average value range for solubility of $^{99}\text{Tc(IV)}$ to be 7.1×10^{-9} M – 1.1×10^{-8} M;** however a steady state ^{99}Tc solution concentration was not reached for all systems and further testing is recommended.

The new formulations for LSWG waste forms were developed using HL instead of fly ash (FA) and tested with one high-sulfate simulant that was developed based on projected compositions for a waste stream containing process condensates from the Effluent Management Facility (EMF) merged with low activity waste (LAW) caustic scrubber. The HL was added to increase Ca^{2+} available to react with and sequester sulfate through ettringite formation and to increase the pH to activate the BFS to maintain reducing conditions. Seven formulations tested the effects of different water-to-dry-mix (w/dm) ratios (0.6 vs. 0.75), different dry ingredients and relative compositions, and the addition of admixture (Xypex, Admix C-500 from Xypex Chemical Corp.), ^{99}Tc getter (Sn-treated apatite), or iodine getter (Ag-zeolite). In addition, the effect of cure time (28 days vs. 60 days) was evaluated for each formulation. Dry blend compositions included 20% HL, 35% OPC, and 45% BFS; 20% HL, 20% OPC, and 60% BFS; and the original Cast Stone formulation (8% OPC, 45% FA, and 47% BFS). All of the HL-containing monoliths were successfully formed by adding a water-reducing agent (MasterGlenium 3030 from BASF Corp.) at a ratio of 0.6 mL per 100 g of dry materials to reduce viscosity and improve flowability of the mix. LSWG monoliths with the original Cast Stone formulation did not completely harden after 28- and 60-day cure periods, which supports the conclusion that the current Cast Stone formulation (herein, test batch T5) with FA addition, instead of the HL addition, is not adequate for forming acceptable cementitious waste forms with sulfate-rich EMF/caustic scrubber simulant. All cured monoliths containing HL and analyzed by x-ray diffraction (XRD) showed the presence of ettringite and portlandite. White precipitates on the exterior of 28- and 60-day cured monoliths were determined to be Na-sulfate minerals thenardite (Na_2SO_4) or mirabilite (hydrated thenardite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$), suggesting that not all of the sulfate in the liquid simulant reacted with the added hydrate lime.

Results from EPA Method 1313 leach testing using monolith material with 20% HL, 35% OPC, and 45% BFS and a 0.6 w/dm ratio (T1), showed that with increasing pH, between pH 5.33 and 10.60, ^{99}Tc is more readily released into solution. Complete ^{99}Tc release from the solid material is not achieved within the 24-hour reaction period under all pH conditions tested by EPA Method 1313 (pH 2.07–12.62); however, ^{127}I is completely released within the testing period for all pH values between 2.07 and 10.60.

EPA Method 1315 leach testing was performed on monoliths cured for 28 and 60 days. All the leached monoliths showed crack formation at the end of the 100-day leach period; however, different curing times did not significantly affect ^{99}Tc , ^{127}I , NO_3^- , and Na^+ D_{eff} values. For ^{99}Tc , D_{eff} values for monoliths leached in DIW and in simulated Hanford VZPW after the 28-day leach period are within a range of 10^{-9} to 10^{-14} cm^2/s , except monoliths prepared with iodine getter (Ag-zeolite). Monoliths prepared with iodine getter were effective at reducing ^{127}I D_{eff} values by 3–4 orders of magnitude during the later stages of leaching (>28 days) relative to other monolith formulations. T1 monoliths with a lower w/dm ratio (0.6) or prepared with Xypex showed the lowest ^{99}Tc D_{eff} values. The addition of ^{99}Tc getter (Sn-apatite) did not significantly reduce ^{99}Tc D_{eff} values. The release of ^{99}Tc from HL-based monoliths is considered to be controlled by both diffusion and physical and/or chemical processes.

A dry blend of 20% HL, 35% OPC, and 45% BFS was tested at a w/dm ratio of 0.6 for comparison to tests performed in FY 2015 (Um et al. 2016) using a Hanford Tank Waste Treatment and Immobilization Plant (WTP)-treated off-gas condensate simulant. This dry blend formulation was used, with (T1) and without ^{99}Tc (T7), to perform ^{99}Tc solubility/sorption/desorption testing.

^{99}Tc desorption tests were performed using monolith material from 30-day ^{99}Tc sorption tests under reducing conditions. Sorption tests were conducted first using non- ^{99}Tc -spiked monolith material, size-reduced to 0.3–2 mm contacting ^{99}Tc spiked simulated cement pore water. Then the resultant ^{99}Tc -laden HL solid material was placed in non- ^{99}Tc -spiked cement pore water to promote ^{99}Tc desorption. The average ^{99}Tc desorption K_d value increased slightly after 120 days of contact, suggesting less ^{99}Tc partitions into the aqueous phase and that ^{99}Tc , presumably desorbed during early reaction periods, resorbs to the solid monolith material likely because of ongoing slow reduction from residual BFS. The average ^{99}Tc desorption K_d value is 25.7 ± 5.9 mL/g ; this is higher than ^{99}Tc desorption K_d values for oxidizing cementitious solids, probably because the residual BFS acts as a strong reductant throughout the 120 days of testing under reducing conditions.

Solubility tests of ^{99}Tc in the two crushed LSWG monoliths (T1 and T7) showed an aqueous ^{99}Tc concentration decrease with increasing reaction time for all samples. The difference in ^{99}Tc aqueous concentration between the three initial concentrations (2.0, 20, and 200 $\mu\text{g/L}$ ^{99}Tc) also decreased with reaction time for both T1 and T7 crushed material. For T1 experiments, the ^{99}Tc concentrations in all the supernatants converged to a similar single ^{99}Tc aqueous concentration of $\sim 1.1 \pm 0.12 \times 10^{-8}$ M, indicating solubility controlled by the $^{99}\text{Tc}(\text{IV})$ -bearing solid phase. For T7 experiments, an average ^{99}Tc aqueous concentration value of $7.1 \pm 0.65 \times 10^{-9}$ M is reported; however, the different initial ^{99}Tc concentrations (2.0, 20, and 200 $\mu\text{g/L}$) did not converge on a single final concentration value. An overall average value range for solubility of $^{99}\text{Tc}(\text{IV})$ can be reported as 7.1×10^{-9} M – 1.1×10^{-8} M based on the results of these two LSWG waste forms. Further testing is recommended beyond 150 days to determine whether steady-state final ^{99}Tc aqueous concentrations can be achieved.

Information in the appendices of this report provide extended test results for LSWG waste forms prepared in FY 2015 activities reported in Um et al. (2016). Specifically, results pertaining to EPA Method 1315 leach testing through 406 days, solid-phase characterization by XRD and autoradiography imaging for ^{99}Tc , and solubility testing through 370 days are reported.

Based on the results, the new formulation using HL instead of FA should replace the Cast Stone formulation for high-sulfate LSW streams; however, further optimization and testing on the HL-incorporated dry blend recipe is needed for sulfate concentrations equal to those tested here for EMF liquid waste streams, 241 g/L. The results obtained in this task can help fill existing data gaps, support final selection of a LSWG waste form, and improve the technical defensibility of long-term waste form performance estimates for the upcoming IDF PA.

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Acronyms and Abbreviations

ASTM	ASTM International (West Conshohocken, PA)
BFS	blast furnace slag
CCD	charge coupled device
CMOS	complementary metal oxide semiconductor
CS	caustic scrubber
C-S-H	calcium-silicate-hydrate
DDI	double deionized (water)
D_{eff}	effective diffusivity
DFLAW	Direct Feed Low-Activity Waste
DIW	deionized water (18.2 MΩ·cm)
EC	electrical conductivity
E_h	oxidation/reduction potential
EMF	Effluent Management Facility
EPA	U.S. Environmental Protection Agency
EQL	estimated quantification limit
ERDF	Environmental Restoration Disposal Facility
ETF	Effluent Treatment Facility
FA	fly ash
FY	Fiscal Year
HL	hydrated lime, Ca(OH) ₂
IC	ion chromatography
ICP-MS	inductively coupled plasma mass spectroscopy
ICP-OES	inductively coupled plasma optical emission spectroscopy
IDF	Integrated Disposal Facility
iQID	ionizing-radiation quantum imaging detector
K_d	distribution coefficient
LAW	low-activity waste (Hanford)
LI	leachability index
LSW	liquid secondary waste
LSWG	liquid secondary waste grout
MC	moisture content
MG 3030	MasterGlenium 3030
ND	not detected
NIST	National Institute of Standards and Technology
OPC	ordinary Portland cement
ORP	oxidation reduction potential

PA	performance assessment
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
R&D	research and development
SHE	standard hydrogen electrode
SRNL	Savannah River National Laboratory
SWCS	secondary waste Cast Stone
VZPW	vadose zone pore water
w/dm	water to dry mix (ratio)
WRA	water-reducing additive
WRPS	Washington River Protection Solutions, LLC
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WWFTP	WRPS waste form testing program
XAS	x-ray absorption spectroscopy
XRD	x-ray diffraction

Units of Measure

°C	temperature in degree Celsius [$T(^{\circ}\text{C}) = T(\text{K}) - 273.15$]
cm	centimeter(s)
cm ² /s	square centimeter(s) per second
d	day(s)
g	gram(s)
K	temperature in degree Kelvin
L	liter(s)
M	molarity, mole(s)/liter
mBq	millibecquerel
mL	milliliter(s)
mm	millimeter(s)
mol	mole(s)
mv	millivolt(s)
N	normality, gram equivalent weight in a solution
ppm	parts per million
rpm	revolutions per minute
s	second(s)
S	siemens
wt%	weight percent
μ	micro (prefix, 10^{-6})

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1.0 Introduction

The Hanford Site Effluent Treatment Facility (ETF) is capable of treating a variety of aqueous waste streams including evaporator condensates from the 242-A Evaporator, burial trench leachates, contaminated groundwater, and, in the future, it will treat Integrated Disposal Facility (IDF) leachates. When the Hanford Tank Waste Treatment and Immobilization Plant (WTP) comes on line, a secondary waste stream composed of process condensates plus the caustic scrubber solution from the low-activity waste (LAW) melter off-gas treatment system will also be sent to the ETF for treatment. To support the Direct Feed Low-Activity Waste (DFLAW) initiative, an Effluent Management Facility (EMF) is planned to handle off-gas condensates from the LAW vitrification facility. The ETF-treated wastes will be solidified into a low-temperature, cementitious waste form that will be disposed of in the IDF. However, recent EMF waste stream composition projections predict relatively high sulfate concentrations, because sulfuric acid will be added at the EMF to lower the pH of the incoming stream and make it compatible with downstream ETF unit operations. This brought into question whether the preferred Cast Stone formulation (WRPS 2012), with ordinary Portland cement (OPC), fly ash (FA), and blast furnace slag (BFS), would be an adequate waste form for all ETF liquid secondary wastes (LSW). In 2006, Cooke et al. (2006) conducted a testing program to develop a formulation for a cementitious waste form for the solidification of the high-sulfate wastes after treatment in the ETF. Their recommended dry blend mix included 36 wt% OPC, 36 wt% BFS, and 28 wt% lime, and the waste simulant contained 30 wt% total solids (suspended and dissolved). The hydrated lime (HL) was added to sequester sulfate in ettringite $[\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26(\text{H}_2\text{O})]$ early in the curing phase, avoiding late ettringite formation that can lead to undesired swelling and cracking of the waste form and subsequent risk of ^{99}Tc release due to increased waste form surface area (Sundaram et al. 2011). In Fiscal Year (FY) 2015, Pacific Northwest National Laboratory (PNNL) conducted secondary waste formulation and testing with three different waste simulants (242-A evaporator, Environmental Restoration Disposal Facility [ERDF] leachates, and WTP off-gas condensates). The results showed that a new formulation of grout replacing FA with HL (20 wt% HL, 34 wt% OPC, and 45 wt% BFS) can reduce ^{99}Tc leachability compared to the current Cast Stone formulation (45 wt% FA, 8 wt% OPC, and 47 wt% BFS) (Um et al. 2016).

In FY 2016, Washington River Protection Solutions, LLC (WRPS) contracted PNNL and Savannah River National Laboratory (SRNL) to initiate a technology development program to address the technology needs for ETF LSW solidification and support future DFLAW operations. High-priority activities included simulant development, LSW grout formulation, and waste form qualification. In FY 2016, simulant development included preparing one updated simulant based on Halgren's calculation (Halgren 2015)¹ for the EMF process condensate merged with LAW caustic scrubber. Formulation of new cementitious waste forms with HL, referred to as liquid secondary waste grouts (LSWGs), and the subsequent test matrix were prepared based on lessons learned from previous testing programs and results (Sundaram et al. 2011; Westsik et al. 2013; Um et al. 2016).

FY 2016 waste form qualification efforts worked towards 1) demonstrating that the LSWG will meet IDF disposal requirements (Burbank 2002; DOE 2012) and 2) providing long-term waste form performance data, information on waste form degradation, and contaminant release mechanisms to support the IDF performance assessment (PA), which will ultimately enable startup and routine operations of the DFLAW flowsheet.

¹ Halgren DL. 2015. ETF Waste stream characteristics with DFLAW EMF source feed. SVF-2017, Rev. 2.xlsx, 16 March, 2015, Washington River Protection Solutions, Richland, Washington.

1.1 Objectives

The overall objectives of the LSWG testing program are to

- determine acceptable formulation(s) for the LSWG waste form,
- demonstrate IDF-acceptable waste form solidification using the updated LSW composition, and
- provide contaminant release data for IDF PA and risk assessment evaluations.

1.2 Report Contents and Organization

This report consists of ten sections and appendices. Section 1 provides an introduction and describes key objectives of the tests conducted for this study. Section 2 summarizes the characterization and analysis techniques used for solution and solid samples. Section 3 details simulant development and Section 4 describes LSWG formulation and characterization. Section 5 describes U.S. Environmental Protection Agency (EPA) Method 1313 leaching tests (EPA 2012) and Section 6 presents EPA Method 1315 effective (or observed) diffusivity leach tests (EPA 2013). Section 7 provides measured ^{99}Tc desorption distribution coefficients (K_d s) and discusses their implications. Section 8 presents ^{99}Tc solubility results. Section 9 provides a summary of all the results and recommendations, and finally Section 10 contains a list of references cited throughout the report. Additional data and information from FY 2016 tests and extended EPA 1315, ^{99}Tc solubility, and solid-phase characterization data carried over from FY 2015 testing are included in the appendices.

1.3 Quality Assurance

This work was funded by WRPS under contract 36437-161, *Secondary Waste Cast Stone Formulation and Waste Form Qualification*. The work was conducted as part of PNNL Project 68334, Liquid Secondary Waste Formulation Development.

All research and development (R&D) work at PNNL was performed in accordance with PNNL's Laboratory-level Quality Management Program, which is based on a graded application of NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, to R&D activities. In addition to the PNNL-wide quality assurance (QA) controls, the QA controls of the WRPS Waste Form Testing Program (WWFTP) QA program were also implemented for the work. The WWFTP QA program consists of the WWFTP Quality Assurance Plan (QA-WWFTP-001) and associated QA-NSLW-numbered procedures that provide detailed instructions for implementing NQA-1 requirements for R&D work. The WWFTP QA program is based on the requirements of NQA-1-2008, *Quality Assurance Requirements for Nuclear Facility Applications*, and NQA-1a-2009, *Addenda to ASME NQA-1-2008 Quality Assurance Requirements for Nuclear Facility Applications*, graded on the approach presented in NQA-1-2008, Part IV, Subpart 4.2, "Guidance on Graded Application of Quality Assurance (QA) for Nuclear-Related Research and Development."

Performance of this work and preparation of this report were assigned the technology level "Applied Research" and were conducted in accordance with procedure QA-NSLW-1102, *Scientific Investigation for Applied Research*. All staff members contributing to the work have technical expertise in the subject matter and received QA training before performing quality-affecting work. The "Applied Research" technology level provides adequate controls to ensure that the activities were performed correctly. Use of both the PNNL-wide and WWFTP QA controls ensured that all client QA expectations were addressed in performing the work.

2.0 Characterization and Analysis Methods

This section describes the characterization techniques used for leachate solution and solid sample analyses of samples generated during the LSWG formulation and testing activities. The characterization types are divided into two categories, solution and solid analysis, depending on the purpose and goal of the characterization. A summary of each characterization and analysis method used in this report is provided below.

2.1 Solution Analysis

The following instruments were used for analyzing solution samples (simulants and leachates) from the cementitious waste forms to identify and measure the concentration of detectable species or elements.

2.1.1 pH and Electrical Conductivity (EC) Measurement

The pH of the solution samples was measured with a solid-state YSI Inc. pH electrode and a pH meter (YSI MultiLab 4010-3). Before measurement, the pH probe was calibrated with National Institute of Standards and Technology (NIST)-traceable buffers (pH = 2.0, 4.0, 7.0, 10.0, or 13.0 at 25°C). The precision of each pH measurement was ± 0.10 pH units. A YSI conductivity sensor was used to measure the electrical conductivity (EC) of leachate solutions. The cell constant of the sensor was calibrated using a 1,413 $\mu\text{S}/\text{cm}$ standard, and then checked with a range of potassium chloride standard solutions, ranging from 100 $\mu\text{S}/\text{cm}$ to 10,000 $\mu\text{S}/\text{cm}$, and a blank containing deionized water (DIW). Calibration checks were repeated after every set of ten samples analyzed and at the end of analyses performed each day.

2.1.2 Alkalinity Measurement

The alkalinity (mg/L as CaCO_3) was measured using a standard acid titration method (total alkalinity at pH = 4.5). The alkalinity measurement procedure is equivalent to the U.S. Geological Survey method in the National Field Manual for the Collection of Water-Quality Data (USGS 2004).

2.1.3 Oxidation Reduction Potential (ORP, E_h) Measurement

A YSI 4210 ORP probe (connected to a YSI MultiLab 4010-3 meter) or a Hanna HI3131B ORP probe (connected to a Hanna HI5521 meter) was used to measure the ORP of the leachate solutions (Manahan 1994). The calibration of the probe was verified with ZoBell's standard solution (+230 mV at 20°C). The E_h values discussed in this report were corrected to E_h standard hydrogen electrode (SHE) values by adding 211 mV to the value measured by a YSI probe with the 3 M KCl reference, or by adding 208 mV to the value measured by a Hanna probe with the 3.5 M KCl reference (Nordstrom and Wilde 2005).

2.1.4 Analysis of Cations, Anions, ^{99}Tc , and ^{127}I

Concentrations of major cations in simulant, leachates, and solids' digests were analyzed using inductively coupled plasma optical emission spectroscopy (ICP-OES), while major anions were analyzed using ion chromatography (IC). Concentrations of ^{99}Tc and ^{127}I were analyzed using inductively coupled plasma mass spectroscopy (ICP-MS).

2.2 Solid Analysis

The instruments described below were used for identifying elements, minerals, solid-phase morphology, and chemical composition of bulk solid samples.

2.2.1 X-Ray Diffraction (XRD) Analysis

The mineralogy of solid samples was determined using a Rigaku Miniflex II XRD unit equipped with a Cu K α radiation ($\lambda = 1.5418 \text{ \AA}$ with 40 kV and 15 mA) source. The bulk samples were homogenized by grinding in an agate mortar and pestle, then ~10 wt% TiO₂ standard was mixed in. Samples were then loaded into zero background quartz sample holders, held within custom containers with Kapton windows to prevent dispersion of the radiological powders (when present) before scanning from 3 to 100 degrees 2 θ . Mineral identification was performed using Jade software (Materials Data Incorporated, California) with the International Centre for Diffraction Data XRD database. Quantification was performed by the whole pattern fitting (Rietveld) method using Topas software (v5, Bruker AXS, Germany) with the pattern for each phase calculated from published crystal structures (Inorganic Crystal Structure Database, Fachinformationszentrum Karlsruhe, Germany). For most samples, the phase fractions were scaled to 100% and absolute quantities of minerals, and amorphous material by difference, were determined with reference to the TiO₂ standard.

2.2.2 Single-Particle Digital Autoradiography (iQID)

Single-particle digital autoradiography experiments assessed the spatial distribution of ⁹⁹Tc within cross-sectioned monolith “pucks” using the ionizing-radiation Quantum Imaging Detector (iQID) (Miller et al. 2015). The iQID measures individual β -decay events to produce a digital image in real time. According to Miller et al. (2015), the iQID imager comprises a scintillator in direct contact with a micro-channel plate image intensifier and a lens for imaging the intensifier screen onto a charge-coupled device (CCD) or complementary metal oxide semiconductor (CMOS) camera sensor, all within a compact light-tight enclosure. Disks sectioned from within ~0.5" from the center of the monoliths were analyzed using the iQID. The disks' smooth surface was placed on a scintillation screen for collection times of 45 h. The effective physical size of each pixel during the image acquisition was 55.8 μm with the final images displayed having an effective pixel size of 111.5 μm (2 $\times$ 2 binning). The pixel value corresponds to the number of beta particles detected at that location during the 45 h image run. A test sample with small droplets of pertechnetate enclosed in Mylar film was also analyzed to ensure the β -decay signal arises from specific sample areas, with a strong correlation. Further information regarding development and use of the technique can be found in Miller et al. (2015).

3.0 Simulant Development

This section describes the simulant development of the EMF process condensate merged with LAW caustic scrubber. Simulant preparation details and solution analyses are included.

3.1 Simulant Composition

For the LSWG formulation in FY 2016, the EMF process condensate merged with LAW caustic scrubber simulant was prepared and used to make LSWG specimens. The projected compositions of the EMF process condensate merged with LAW caustic scrubber waste stream are based on Halgren's report (2015) ¹ and provided in Table 3.1 for comparison with WTP off-gas condensate used in FY 2015 (Russell et al. 2015). The simulant was prepared with ~30 wt% total solids (dissolved and suspended) and the final concentrations were selected based on charge-balanced compositions verified by simulant preparation from chemical reagents.

Table 3.1. Nominal Waste Compositions as Starting Point for Simulant (relative molar amount)

Chemical (relative molar amount)	EMF Process Condensate merged with LAW Caustic Scrubber (Halgren 2015)	WTP Off-gas Condensates (Russell et al. 2015)
NH ₄ ⁺	0.402	0.330
Cl ⁻	0.0003	0.006
F ⁻	0.0005	0.001
Na ⁺	0.248	0.295
NO ₃ ⁻	0.0384	0.117
NO ₂ ⁻	-	0.001
SO ₄ ²⁻	0.309	0.250
Total Moles	1.0	1.0
“-” = not included because of relatively low concentration and therefore not added to the simulants		

To understand the retention and release of radionuclides of concern, stable ¹²⁷I (as a surrogate of ¹²⁹I) was added to the simulant and then ⁹⁹Tc was spiked as needed. The spike levels are shown in Table 3.2.

¹ Halgren DL. 2015. ETF Waste stream characteristics with DFLAW EMF source feed. SVF-2017, Rev. 2.xlsx, 16 March, 2015, Washington River Protection Solutions, Richland, Washington.

Table 3.2. Spike Levels for Radionuclides in Simulants

Waste Constituent	EMF Process Condensate Merged with LAW Caustic Scrubber ^(a)	WTP Off-Gas Condensates ^(b)
<i>Radionuclides</i>		
	Mass Ratio to Na	Mass Ratio to Na
⁹⁹ Tc	1.87E-8	1.19E-5
¹²⁹ I	1.68E-7	9.39E-7
	Target Concentration (µg/L)	Target Concentration (µg/L)
⁹⁹ Tc	0.89E+1	3.90E+2
¹²⁹ I	7.83E+0	3.03E+1
(a) Derived from Halgren (2015) ¹		
(b) Derived from Russell et al. (2015)		

3.2 Simulant Preparation

The chemical simulant described in Section 3.1 (Simulant Composition) was initially prepared in a 250-mL flask at the target total solids concentration of 30 wt%. The order of chemical addition was determined based on chemical solubility knowledge and previous simulant development experience and was as follows:

1. sodium chloride
2. sodium fluoride
3. sodium iodide
4. sodium nitrate
5. sodium bicarbonate
6. ammonium sulfate
7. sodium sulfate.

Once a satisfactory recipe was established, based on observations and solution composition analysis, a larger, 25-kg batch of the simulant was prepared for use in the LSWG waste form preparation. Initial ¹²⁷I and ⁹⁹Tc concentrations in the prepared simulant were increased to levels much higher than target concentration values (Table 3.2) to ensure that ¹²⁷I and ⁹⁹Tc concentrations detected in EPA 1315 test leachates were above the estimated quantification limit (EQL) of ICP-MS: 1.26 µg/L and 0.165 µg/L for ¹²⁷I and ⁹⁹Tc, respectively. ¹²⁷I was added to the entire 25-kg batch of simulant. The amount of ⁹⁹Tc needed was preliminarily calculated and added to a 10.9 kg subsample of batch simulant using a ~10,000 ppm ⁹⁹Tc NH₄TcO₄ stock solution. The actual ⁹⁹Tc concentration in the simulant was verified by ICP-MS. The results of both the 250-mL and 25-kg batch preparations are discussed below.

¹ Halgren DL. 2015. ETF Waste stream characteristics with DFLAW EMF source feed. SVF-2017, Rev. 2.xlsx, 16 March, 2015, Washington River Protection Solutions, Richland, Washington.

3.2.1 250-mL Simulant Results

When the initial simulant was prepared in a 250-mL flask at 30 wt% total solids, chemicals went into solution fairly easily once all the water had been added. Before adding the entire amount of water, several chemicals remained partially undissolved. After the final mass of water was added and settling overnight, the simulant appeared to remain clear, indicating that all the chemicals remained in solution.

The actual recipe used for the small-scale, 250-mL batch of simulant without NaI is given in Table 3.3. The percentage of solids by weight shown in Table 3.3 includes both dissolved solids and any undissolved solids that formed. The percentage of solids by weight was determined by direct measurement of small aliquots of the simulant suspension. The weight of the suspension aliquot before and after drying was used to determine the percentage of total solids by weight.

Table 3.3. Recipe for EMF Process Condensate Merged with LAW Caustic Scrubber Simulant Based on 250-mL Volume

Chemical	Amount Added (g) Rounded to Two Decimal Places
NaCl	0.04
NaF	0.04
NaNO ₃	6.53
NaHCO ₃	0.02
(NH ₄) ₂ SO ₄	53.22
Na ₂ SO ₄ •10H ₂ O	69.80
Density (g/cm ³)	1.21
Wt% total solids	29.89

3.2.2 25-kg Simulant Results

When the 25-kg simulant batch was prepared at 30 wt% total solids, all the added chemical reagents went into solution fairly easily once all the water had been added and the large batch of simulant behaved very similarly to the small 250 mL lab-scale batch prepared previously. Before adding the entire amount of water, several chemicals remained partially undissolved. After adding all the water and mixing overnight, the large batch simulant appeared to remain clear, indicating that all the chemicals remained in solution.

The actual recipe used for the 25 kg of simulant is given in Table 3.4. The percentage of solids by weight shown in Table 3.4 includes both the dissolved solids and any undissolved solids that formed. The percentage of solids by weight was based on direct measurements of small aliquots of the simulant suspensions. The weights of the aliquots of suspension before drying and after drying were used to calculate the percentage of total solids by weight.

Table 3.4. Recipe for EMF Process Condensate Merged with LAW Caustic Scrubber Simulant Based on 25-kg Volume

Chemical	Amount Added (g) Rounded to Two Decimal Places
NaCl	2.94
NaF	3.16
NaI	1.98
NaNO ₃	520.60
NaHCO ₃	1.68
(NH ₄) ₂ SO ₄	4244.20
Na ₂ SO ₄ •10H ₂ O	5565.70
Density (g/cm ³)	1.22
Wt% total solids	30.04

3.3 Simulant Analysis Results

The ⁹⁹Tc-spiked simulant was analyzed by ICP-MS, ICP-OES, and IC to confirm simulant composition. Table 3.5 shows how the calculated results match the target (calculated from masses of reagents added) results. All but the ammonium, ¹²⁷I, and ⁹⁹Tc match the target composition within a 10% variance. A low ammonium concentration is expected, because some volatilizes during preparation, but the cause of the unexpectedly low ¹²⁷I concentration was not identified. In addition, the measured result for ⁹⁹Tc was slightly above a 10 % agreement with the calculated target. However, agreement between calculated and target concentrations for the primary simulant constituents implies that the simulant was prepared appropriately and that the unexpected ¹²⁷I and ⁹⁹Tc variances are limited to the spiking procedure.

Table 3.5. Calculated and Measured Concentrations of Elements in Simulant

Chemical	Amount Added (g/L)	Measured Result (g/L)	Difference (%)
SO ₄ ²⁻	241.2	240	-0.50
NH ₄ ⁺	37.4	31.6	-16
Na ⁺	47.7	46.5	-2.5
NO ₃ ⁻	19.3	18.9	-2.1
Cl ⁻	0.09	<2.5	-
F ⁻	0.07	<1.0	-
¹²⁷ I	0.10	0.064	-36
⁹⁹ Tc	0.012	0.0135	11
pH	-	6	-

4.0 Liquid Secondary Waste Grout Formulation and Characterization

A total of seven LSWG monolith formulations (six ^{99}Tc -spiked and one non- ^{99}Tc -spiked cementitious monoliths) were prepared for performance testing of different grout compositions. These monolith formulation variables included ^{99}Tc content, dry solids composition, free water-to-dry-mix (w/dm) ratio (0.6 vs. 0.75), commercially available admixture (Xypex), and two getters: silver exchanged zeolite (Ag-zeolite) as the ^{127}I -getter and Sn-treated apatite ($\text{Sn}_x\text{Ca}_y(\text{PO}_4)(\text{OH},\text{Cl},\text{F})$ (Sn-apatite) as the ^{99}Tc getter. The test matrix is shown in Table 4.1 for the seven LSWG monolith test batches. Test # (or T) 1 through 6 contained ^{99}Tc , while T7 contained no ^{99}Tc . Only one simulant, the Effluent Management Facility (EMF) process condensate merged with LAW caustic scrubber (CS), EMF/CS, was used to make the LSWG monoliths (Section 3.2.2). T7 monoliths were prepared from non-spiked EMF/CS simulant. Since there was no baseline composition for 0.75 w/dm, comparing the results of T2, T3, T4, and T6 would be limited, even though T1 with 0.6 w/dm could be used as an alternative baseline for them. A portion of EMF/CS simulant was allocated for spiking with ^{99}Tc and ^{127}I (stable iodine as surrogate for ^{129}I), before mixing with T1–T6 dry ingredients. Measured ^{99}Tc (0.0135 g/L) and ^{127}I (0.064 g/L) concentrations in spiked EMF/CS simulant (Table 3.5), were used to calculate initial ^{99}Tc and ^{127}I concentrations in the final monoliths. An additive to improve rheology of the grout slurry/paste before curing, MasterGlenium 3030 (MG 3030) from BASF Corp., was used in monolith formulations as a water-reducing additive (WRA).

The grout dry materials consist of four primary components. These components are HL [$\text{Ca}(\text{OH})_2$], OPC, BFS, and FA. A secondary dry material, Xypex (Admix C-500 from Xypex Chemical Corp.), consisting of pulverized Portland cement, silica sand, and an alkaline earth compound (zeolite), was used as an admixture in one grout formulation (T2) to reduce the porosity of the cured monoliths. Before mixing with the liquid components, dry materials were blended until homogeneous.

Table 4.1. Liquid Secondary Waste Grout Test Matrix

Test #	Simulant ^(a)	Water-to-Dry Mix (w/dm) Ratio	Dry Blend Addition ^(b)	Dry Materials	Admix ^(c)	Getter	WRA ^(d)
1	EMF/CS	0.6	20%, 35%, 45%	HL, OPC, BFS	–	–	3030
2	EMF/CS	0.75	20%, 35%, 45%	HL, OPC, BFS	Xypex	–	3030
3 ^(e)	EMF/CS	0.75	20%, 35%, 45%	HL, OPC, BFS	–	^{127}I	3030
4	EMF/CS	0.75	20%, 20%, 60%	HL, OPC, BFS	–	–	3030
5	EMF/CS	0.75	8%, 45%, 47%	OPC, FA, BFS	–	–	3030
6 ^(e)	EMF/CS	0.75	20%, 35%, 45%	HL, OPC, BFS	–	^{99}Tc	3030
7 ^(f)	EMF/CS	0.6	20%, 35%, 45%	HL, OPC, BFS	–	–	3030

a. See Table 3.1 for simulant composition.

b. The three dry blend materials were mixed together by placing the dry ingredients in a plastic bag and manipulating the bag until the dry mixture appeared to be homogeneous.

c. Xypex was used as additional admixture based on 5 wt% of dry mix.

d. Water-reducing additive (WRA): MG 3030 (BASF Corp.) was used to enhance the cement rheology based on 0.6 mL of MG 3030 per 100 g of dry mix.

e. Test #3 was conducted with ^{127}I getter (Ag-zeolite) at a loading of 5 wt% of the total dry mix mass, while Test #6 was conducted with ^{99}Tc getter (Sn-apatite) at a loading of 5 wt% of the total dry mix mass.

f. EMF/CS without ^{99}Tc spike used.

4.1 Preparation of Liquid Secondary Waste Monoliths

Before mixing batches of grout, the EMF/CS simulant and mix of dry materials were prepared separately. Dry blend materials were mixed together by placing the dry ingredients in a sealed plastic bag and manually manipulating the bag until the dry mixture appeared to be homogeneous. For T2, Xypex was added to the initial dry blend before homogenization. Aliquots of previously prepared simulant spiked with ^{99}Tc and ^{127}I were reacted with I getter (Ag-zeolite) and ^{99}Tc getter (Sn-apatite) for T3 and T6, respectively, for at least 48 h before mixing the simulant-getter slurry with the other dry ingredients (Asmussen et al. 2016). LSWG monolith test batches were then prepared over the course of eight days: non- ^{99}Tc -spiked LSWG monoliths (T7 in Table 4.1) were prepared first, then six days later ^{99}Tc -spiked LSWG monoliths from batches T1, T2, T4, and T5 were prepared, and finally T3 and T6 monoliths were prepared on day eight.

4.1.1 Dry Ingredients

The grout monoliths were made using three of four primary dry ingredients that were blended together in different ratios. Primary dry ingredient combinations included HL + OPC + BFS or FA + OPC + BFS. In each case, these specific materials were selected for their high-volume commercial availability and continuity with previous grout formulation work.

OPC and BFS used in this work were supplied by Lafarge North America Inc. in Pasco, Washington. According to the OPC mill test report, R-TI-15-04, this is a Type I/II Portland cement produced in Richmond, British Columbia. BFS, commonly referred to by the trade name NewCem®, meets ASTM C-989 (ASTM 2014) requirements for class 100 ground granulated BFS and was processed at Lafarge's Seattle, Washington plant. FA used in this work qualifies as both class F and class C FA and was sourced from the Centralia, Washington power plant. The OPC, BFS, and FA are the same materials used in previous work detailed in Westsik et al. (2013), Serne et al. (2015), and Um et al. (2016). Hydrated lime, calcium hydroxide [$\text{Ca}(\text{OH})_2$], was sourced from the Graymont Rivergate facility in Portland, Oregon. Xypex (Admix C-500), a product of the Xypex Chemical Corporation (Richmond BC, Canada), was supplied by SRNL. The Ag-zeolite was purchased from Sigma-Aldrich Corporation (St. Louis, MO) as $>840\text{ }\mu\text{m}$ pellets. The pellets were crushed with a mortar and pestle to a size $<300\text{ }\mu\text{m}$ before use. Sn-apatite was prepared by the RJ Lee group (Richland, WA) according to a previously published method (Duncan et al. 2012) and was stored in a desiccator during transport and until use to avoid re-oxidation.

4.1.2 Grout Mixing/Monolith Production

Grout mixing and monolith production followed the procedure outlined in Westsik et al. (2013) and Um et al. (2016). This chosen procedure has been consistently implemented and improved over time and would provide good comparability of results from work performed in the past by staffs at both PNNL and SRNL.

4.1.2.1 Grout Mixing Summary

Grout mixing and monolith production followed this general outline;

1. addition of dry ingredients to stirring simulant, 5 minute target duration
2. addition of MG 3030 to wetted dry-blend-simulant slurry
3. continued mixing, total of 15 minutes from start of step 1 above

4. filling of monolith forms with the well mixed slurry
5. de-airing of filled forms
6. 28-day (or 60-day) curing in a humid environment at room temperature.

4.1.2.2 Grout Monolith Production

Grout mixing was performed with a Caframo BDC1850 variable speed overhead stirrer. This style of mixer was used to accommodate a custom 3.5" diameter impeller designed and provided by SRNL. The impeller and mixer head were joined by a 3/8" shaft and the combined mixer apparatus was supported by a Caframo A210 heavy-duty stand and A120 heavy-duty clamp. The mixer shaft was lowered into a two-liter plastic mixing beaker until the bottom of the impeller was between 0.75 and 1.25 inches from the bottom of the beaker. More details about this setting can be found in Westsik et al. (2013) and Serne et al. (2015). The beaker was offset from the mixer shaft so that the impeller was between 0.25 and 0.5 inches from one sidewall. This offset helped to minimize the creation of a central vortex, and thus air entrainment, during mixing. With the beaker of simulant in place under the mixer, the mixer's stirrer was started at about 200 rpm. Vortex creation and modest air entrainment was acceptable at this point. With the mixer's stirrer turning at about 200 rpm, the homogenized bag of dry ingredient pre-mix was slowly added to the simulant. To facilitate clean transfer from the bag to the beaker, a 2" diagonal cut was made across one corner of the bag. This corner opening funnels the dry pre-mix into the desired location in the beaker and allows for good control during addition to the beaker. A timer was used to make sure that all dry ingredients were added to the mixing beaker within approximately 5 minutes (Figure 4.1). As the dry pre-mix was added, the stirrer's rotation speed was increased in order to maintain obvious surface movement in the slurry with minimal formation of a central vortex and associated air entrainment.

Figure 4.1. Homogeneous Grout Slurry Mixing (left), Adding MG 3030 (middle), and Filling Form with Grout Slurry (right)

As soon as all of the dry pre-mix had been added to the mixing beaker, MG 3030 was slowly added near the vortex (Figure 4.1 middle). The MG 3030 significantly reduced viscosity and allowed the grout to be “burped” to release entrained air by stopping the mixer for 15–30 seconds and tapping the beaker on the benchtop. Mixing continued until 15 minutes had elapsed since the beginning of dry pre-mix addition. This time was spent ensuring grout homogeneity by scraping the beaker sides and mixer shaft with a spatula as needed. Mixer speed was adjusted to the highest possible level without risking air entrainment. This speed varied from batch to batch and was occasionally decreased during mixing as grout shear properties changed over time.

At the end of the mixing period, the grout slurry was poured into 2" internal diameter $\times$ 4" high cylindrical forms (Figure 4.1 right). These forms consist of relatively thin-walled plastic mailing tubes with push-on plastic caps. These mailing tubes were sourced from Icon Plastics in Costa Mesa, California. Each batch of grout was expected to fill approximately eight to nine forms. The forms were initially filled about three-quarters full to minimize risk of spillage during mechanical agitation to release entrained air in the grout material. Not all grouts appeared to have entrained air, but all monoliths were agitated to make sure that minimal entrained air was cured into the monoliths. De-airing required a minute or less per monolith. De-airing was considered complete when visual inspection detected the cessation of new bubbles rising to the surface of the grout slurry. The forms were then completely filled, gently de-aired, and covered with perforated caps. The caps were left a few millimeters higher than the upper surface of the grout in order to form a level grout surface and minimize surface imperfections induced by contact with the cap during the slurry setting. Three additional forms, filled one-quarter to one-half full, were also prepared for each grout formulation and used for moisture content (MC) measurements. All forms were labeled with the year and sample identifier of the following format:

16-SWCS-T#-N

where 16 = last two digits of calendar year
 SWCS = secondary waste Cast Stone
 T# = Test # from Table 4.1
 N = monolith number (1–12).

The filled and capped forms were placed into racks, which were then stacked into 5-gallon buckets. Before the racks were installed, the buckets were preloaded with 3/8" to 1" of DIW to maintain a humid environment (relative humidity: ~80–100 %) inside the sealed bucket at room temperature. Monoliths were allowed to cure at room temperature and with high humidity for a minimum of 28 or 60 days inside the sealed buckets. The extended 60-day curing was prepared to test the effect of different curing durations on waste form formation and ^{99}Tc diffusivity.

4.2 Cementitious Waste Form Monolith Characterizations

After the monoliths had cured for at least 28 or 60 days, the forms were removed from the 5-gallon buckets to inspect the monoliths for any free liquids, surface cracks, surface voids, irregular shapes, and/or loose chips. The diameter and length of each hardened monolith were measured using calipers in a minimum of three places (diameter at three axial locations—bottom, middle, and top—and length at three rotational orientations mutually separated by about 120 degrees from an arbitrary starting location) to determine the average length and diameter of the monoliths. Each monolith was weighed and stored individually in two moisture-proof resealable bags with a wet paper towel in the outer bag to maintain humidity, and the inner bag, which contained the monolith, left open to allow moisture to equilibrate. All the monoliths were prepared for additional tests and analysis to minimize the lag time within 1-2 days after 28 or 60 days curing.

4.2.1 Visual Inspection of the Cured Monoliths

All the 28-day cured monoliths, except T5 monoliths prepared using the current Cast Stone formulation (OPC, BFS, and FA), showed solid cylindrical forms with many white precipitates on the surface (Figure 4.2, left). To determine the mineralogy of these white precipitates, samples were collected by scraping the monolith surface with a metal scoopula, and analyzed by XRD (See Section 4.2.2 below). In addition, some cracks were found in both 28-day and 60-day cured monoliths prepared with the HL addition (Figure 4.2 middle and right).

T5 monoliths did not completely harden (or set) after 28 days (Figure 4.3 left) and, despite continuous extended curing aimed at forming a more solid monolith waste form, after 60 days, remained fragile and were not completely solidified. This observation indicates that the current Cast Stone formulation (T5) with FA addition, rather than HL addition, is not adequate for forming competent cementitious waste forms with sulfate-rich EMF/CS simulant, as found in a previous study (Um et al. 2016). Furthermore, because none of the T5 LSWG monoliths hardened (set), T5 monoliths were not used during EPA Method 1315 testing.

Figure 4.2. 28-Day Cured T2 Monolith with White Precipitates on the Surface (left), 28-Day Cured T1 Monolith with Cracks (middle), and 60-Day Cured T4 Grout Monolith with Cracks (right)

Figure 4.3. 28-Day Cured T5 Monolith for the Current Cast Stone Formulation (left) and 60-Day Cured T5 Monolith for the Current Cast Stone Formulation (right)

4.2.2 XRD Analysis for Mineral Content

XRD analysis of the white precipitates formed on the surface of monoliths cured for 28 days (Figure 4.2, left) and 60 days (Figure 4.2, right) showed thenardite (Na_2SO_4) or mirabilite (hydrated thenardite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) as the major mineral phase formed (60–98 wt%) with minor amounts of ettringite (<22 wt%), portlandite (<10 wt%), calcite (<6 wt%), and gypsum (<3 wt%) (Figure 4.4). Mineral phase fractions were quantified by scaling the crystalline phases to 100% without the TiO_2 reference standard. Noticeable white precipitates were found in both 28- and 60-day HL-containing cured monoliths. Identification of the white precipitates formed on the surfaces of monoliths as Na_2SO_4 suggests that some sulfate in the EMF/CS simulant did not react fully with the added HL in the new LSWG formulation. The

same white precipitates found in FY 2016 monoliths were not observed in any monoliths prepared for WTP-treated off-gas condensate simulant with the same 20 wt% HL addition in previous waste form testing in FY 2015 (Um et al. 2016). Because the sulfate concentration in the EMF/CS simulant, $\text{SO}_4^{2-} = 241 \text{ g/L}$ (See Table 3.5), is much higher than that of WTP-treated off-gas condensate, $\text{SO}_4^{2-} = 122 \text{ g/L}$ (Um et al. 2016), monoliths prepared with 20% HL (T1, T2, T3, T4, T6, and T7 in Table 4.1) are not considered to provide enough Ca and Al to react with the elevated levels of sulfate in the EMF/CS simulant to form adequate amounts of ettringite in the early stages of curing.

Figure 4.4. XRD Patterns of White Precipitates Formed on T3 and T6 60-Day Cured Monoliths. XRD patterns of thenardite (Na_2SO_4) and mirabilite (hydrated thenardite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) are identical.

The XRD patterns of bulk samples from six ^{99}Tc -spiked and one non- ^{99}Tc -spiked powdered monoliths are shown in Figure 4.5 along with the reference pattern for TiO_2 (rutile). Quantitative analysis of XRD patterns collected from samples with added TiO_2 reference are provided in Table 4.2. All samples showed the presence of ettringite [$\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26\text{H}_2\text{O}$] as the primary crystalline phase, with a range of content from 19 to 26 wt%, except for the T5 monolith. For the T5 monolith, gypsum [$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$] was the major mineral phase (~25 wt%), while neither ettringite nor portlandite were observed in T5 samples even after 60 days curing (Table 4.2). Instead, thenardite [Na_2SO_4] was the second major mineral phase (~5 wt%), due to the absence of HL as an additional Ca source needed for ettringite formation. A slight increase of ettringite and decrease of portlandite minerals was found in 60-day cured monoliths prepared with the HL addition (T2, T3, T4, and T6) compared to 28-day cured monoliths with the HL addition (T1 and T7). In addition, more gypsum mineral was found in T2, T3, T4, and T6 monoliths (5–10 wt%), compared to T1 and T7 monoliths (2.5–2.6 wt%), likely due to the higher water-to-dry mix ratio, 0.75 vs. 0.6, which provided more sulfate for ettringite formation. In general, the XRD analysis of monoliths prepared with the HL addition showed similar XRD patterns, with ettringite as the major mineral phase and minor amounts of portlandite, calcite, larnite, hydrocalumite, quartz, and gypsum. Most of the cured monoliths were dominated by amorphous phases ranging from 52 to 63 wt%, which is attributed to calcium-silicate-hydrate (C-S-H) gel in the cementitious solid material.

Figure 4.5. XRD Patterns of Monoliths with Different Curing Durations (28 and 60 Days)

Table 4.2. XRD Analysis for Mineral Content

Test #	Curing time (day)	XRD Analysis (wt%)(^a)								
		Ettringite	Portlandite	Calcite	Larnite	Thenardite	Hydrocalumite	Quartz	Gypsum	CSH(^b)
1	28	21	6.6	3.4	5.1	–	0.6	–	2.6	61
2	60	23	3.2	4.4	4.8	–	–	3.1	10	52
3	60	23	2.8	5.8	3.8	–	–	1.7	–	63
4	60	23	1.3	3.2	3.3	–	–	4.0	5.0	60
5	60	–	–	1.6	–	5.1	–	4.5	25	63
6	60	26	2.6	3.7	5.8	–	–	0.3	6.3	56
7(^c)	28	19	7.2	3.6	4.5	–	0.7	–	2.5	63

a. Chemical formulas of minerals: ettringite $[\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26\text{H}_2\text{O}]$, portlandite $[\text{Ca}(\text{OH})_2]$, calcite $[\text{CaCO}_3]$, larnite $[\text{Ca}_2\text{SiO}_4]$, thenardite $[\text{Na}_2\text{SO}_4]$, hydrocalumite $[\text{Ca}_4\text{Al}_2(\text{OH})_{12}(\text{OH})_2\cdot 6\text{H}_2\text{O}]$, gypsum $[\text{CaSO}_4\cdot 2\text{H}_2\text{O}]$, and quartz $[\text{SiO}_2]$

b. CSH : calcium silicon hydrated amorphous phase

c. Non-⁹⁹Tc-spiked monoliths (T7)

– not detected

4.2.3 Moisture Content Measurement of Monoliths

One partially filled 28-day and 60-day cured monolith from each test batch was placed in an oven set at $105 \pm 3^\circ\text{C}$ for 48 ± 1 h to measure the monolith MC. To assure a constant dry mass of the partial monolith, the monolith was removed from the oven after 24 ± 1 h, and allowed to cool to room temperature, in a desiccated environment, before a dry weight measurement of the monolith sample was made. Then the partial monolith was returned to the same oven for an additional 24 ± 1 h before it was cooled to room temperature and the dry mass was measured. The two dry mass readings had to be within 1.0% of one another for the dry mass to be considered constant. If a constant mass was not obtained, the procedure above was repeated for one or more additional 24-h drying cycles until two sequential readings for dry mass met the constant-mass requirements. MC of the each partial monolith was determined by the difference in mass between the monolith sample before and after drying at $105 \pm 3^\circ\text{C}$ using Equation (4.1) below:

$$\text{MC (\%)} = [(M_{\text{wet}} - M_{\text{dry}})/M_{\text{wet}}] \times 100 \quad (4.1)$$

where M_{wet} = initial wet mass of monolith (g); M_{dry} = next-to-last dry mass of monolith after drying (g).

The final moisture content and dry solids fraction $\{1 - [\text{MC}(\%)/100]\}$ for each monolith are shown in Table 4.3. The MC of the T1 monolith prepared with 0.6 w/dm ratio (30–31 %) is slightly lower than those (34–36 %) of T2, T3, T4, and T6 monoliths prepared with 0.75 w/dm ratio for both 28- and 60-day curing conditions. Monoliths prepared with 0.75 w/dm ratio for 28-day curing showed very similar MC and dry solids fraction. All monoliths except the T6 monolith also showed a minor decrease in MC after 60-day curing compared to those for 28-day curing. This is likely due to increased ettringite formation, (as determined by XRD analysis [Table 4.2]), which fills the cement pores, thus reducing the stored water content. The lowest MC values for both 28-day (35.1 %) and 60-day (33.6 %) curing conditions under the same 0.75 w/dm were found in T2 monoliths and attributed to the addition of Xypex, which reduces and seals monolith pores.

Table 4.3. Moisture Content of the Differently Cured Monoliths

	Test #					
	1	2	3	4	5	6
After 28 days curing						
Moisture Content (%)	31.0	35.1	35.4	35.8	NA ^(a)	35.4
Dry fraction	0.69	0.65	0.65	0.64	NA ^(a)	0.65
After 60 days curing						
Moisture content (%)	30.2	33.6	35.1	35.0	NA ^(a)	35.6
Dry fraction	0.70	0.66	0.65	0.65	NA ^(a)	0.64

a. NA = “not analyzed” because of incomplete set of T5 monoliths after 28-day and 60-day curing periods.

5.0 EPA Method 1313 Leach Testing

The EPA Method 1313 test, “Liquid-Solid Partitioning as a Function of Extract pH using a Parallel Batch Extraction Procedure,” is a static test method designed to provide a liquid-solid partitioning curve as a function of pH. Batch extraction experiments were conducted using dilute nitric acid in double deionized water (DDI), in a fixed pH range of 2 to 13 and at a fixed liquid-solid ratio of 10 mL/g-dry. The associated test instruction (TI-SWCS-014)¹ required method testing on monoliths T1 and T5; however, T5 monoliths did not set during the curing process (Section 4.0), so EPA Method 1313 testing was not completed. The EPA Method 1313 test was performed only on 28-day cured T1 monolith material, though preliminary testing to determine the amount of acid to use to get to desired pH values used 28-day cured T7 monoliths.

5.1 Methods and Materials

The monoliths used for the EPA Method 1313 testing were crushed to a size fraction <0.3 mm. The MC of the size-reduced samples was also determined using the procedure described in Section 4.2 and used to determine the correct volume of DDI required to bring each batch container to the desired liquid-solid ratio of 10 mL/g-dry solid. Before conducting EPA Method 1313 testing on ⁹⁹Tc-containing monolith T1, a pre-titration curve was generated using monolith T7 for more accurate sample preparation during T1 testing. Monolith T7 was formulated according to TI-SWCS-013², “Preparation of Secondary Waste Grout Monolith Specimens,” and has the same formulation as T1, but was not spiked with ⁹⁹Tc. Based on previous secondary waste Cast Stone testing (Westsik et al. 2013; Serne et al. 2015), the measured pH of the leachate solutions for the Cast Stone monoliths was expected to be high (pH ~12 to 13). Therefore, to achieve a pre-titration curve that covered the desired pH range (pH 2–13), varying amounts of nitric acid (HNO₃) were added to 10 g of <0.3 mm size-reduced T7 powder samples for five parallel batch extraction experiments to decrease the pH after 24 hours reaction on an end-over-end shaker. Stock solutions of 2 M and 4 M HNO₃ concentrations were prepared using HNO₃ Optima (16 M) and used for both the pre-titration and T1 tests using the EPA Method 1313 method. Based on the pre-titration and MC results, the EPA Method 1313 test samples were prepared by adding 20 g of <0.3 mm size-reduced T1 material to a predetermined amount of 2 M or 4 M HNO₃ solution. All samples were brought to a final volume with DDI to achieve a fixed liquid-to-solid ratio of 10 mL/g. After the addition of acidic solutions to each powder sample, the sample tubes were taped closed to prevent leaking, placed on an end-over-end shaker, and allowed to mix at room temperature for 24 (±2) hrs. No significant impact or change was observed in all samples right after adding relatively concentrated HNO₃ because of the small amount of HNO₃ solution added and the short period of reaction before being diluted with DDI. After mixing, the tubes were removed from the shaker and allowed to stand for at least 15 minutes before filtering the solution using a syringe and 0.45 µm filter. One aliquot of filtrate was used to measure pH, EC, and E_h , and the remaining filtrate was separated into two aliquots: one for ⁹⁹Tc and cation analyses using ICP-MS and ICP-OES and the second for iodine analysis using ICP-MS. The iodine subsample was spiked with 100 µL of Inorganic Venture (CAT#: UNS-2B, Christiansburg, VA), a substitute for Spectrosol, before analysis.

¹ Um W. 2016. Test Instruction (TI-SWCS-014) for Secondary Waste Cast Stone Monolith EPA 1313 Leach Test, Pacific Northwest National Laboratory, Richland, Washington.

² Um W. 2016. Test Instruction (TI-SWCS-013) for Preparation of Secondary Waste Grout Monolith Specimens, Pacific Northwest National Laboratory, Richland, Washington.

5.2 Results and Discussion

The MCs of monoliths T1 and T7 were determined from <0.3 mm size-reduced samples, measured in triplicate and averaged to obtain the values reported in Table 5.1. Little variability was expected due to almost identical LSWG formulations, and this is reflected in the MC values: 26.40 % and 25.90 % for T1 and T7, respectively. However, the MC of <0.3 mm size-fractionated T1 is lower than the MC determined for larger size fractions (Sections 4.2.3 and 7.1.1) up to 5 %, due to moisture loss during the size-reduction process.

Table 5.1. Average Moisture Content of Powdered Secondary Waste Monoliths for EPA Method 1313 Tests

Secondary Waste Monoliths	Moisture Content (wt%)
T1	26.40 ± 0.13%
T7	25.90 ± 0.37%

Results from pH, EC, and E_h analyses for T1 EPA Method 1313 filtrates are provided in Table 5.2. A comparison of EC as a function of pH is shown in Figure 5.1A and illustrates a linear increase in EC with decreasing pH. An increase in EC is indicative of more dissolved ions present in solution, a result of solute release during monolith dissolution as well as increased nitrate ion concentration at low pH. This correlation is supported by reported concentrations for major cations in solution (Table 5.3), of which Ca, Fe, Si, and Mg concentration measurements by ICP-OES all reflect an increase in concentration with decreasing pH. Measured E_h values also increase with decreasing pH, indicating an increase in oxidizing conditions under acidic pH conditions. All E_h values were SHE corrected by adding +211 mV to the measured E_h value, as instructed according to the YSI probe manual when using a 3 M KCl reference solution at 20°C. At pH 7.91, an increase in E_h is measured before it continues to decrease with increasing pH. This bump in E_h could be attributed to the propensity for Fe(III) to precipitate out of solution as Fe(OH)₃(s) at circumneutral and higher pH levels, and is corroborated by the non-detectable levels of total Fe concentration measured by ICP-OES starting at pH 7.91.

Table 5.2. Measured pH, EC, E_h , ^{99}Tc , and ^{127}I in Solution from EPA Method 1313 Leaching Test

Monolith #	pH	EC mS/cm	$E_h^{(a)}$ mV	[^{99}Tc] μg/g	[^{127}I] μg/g
T1	12.62	20.6	147.5	4.470	24.60
	12.20	25.4	166.3	4.750	35.10
	10.60	37.3	237.3	5.860	41.60
	10.20	47.6	258	3.360	39.50
	9.33	57.3	310	2.000	42.30
	7.91	65.2	373	1.010	41.70
	5.33	74.6	319	0.363	39.80
	3.39	83.5	519	0.706	42.50
	2.07	97.2	661	1.340	28.10
a. SHE corrected, +211 mV according to YSI probe manual for measurements made at 20°C.					

^{99}Tc concentration ($\mu\text{g/g}$ of solid) as a function of final pH is tabulated in Table 5.2 and shown in Figure 5.1C. With increasing pH, ^{99}Tc is more readily released into solution, exhibiting a minimum (0.363 $\mu\text{g/g}$) and maximum (5.860 $\mu\text{g/g}$) in released ^{99}Tc concentration at pH 5.33 and pH 10.60, respectively. At elevated pH levels, anion release into solution is favored due to the repulsive force between anions and negatively charged surfaces on the cementitious solid at high pH levels. Considering that ^{99}Tc release into solution is expected to be in the form of pertechnetate (TcO_4^-), the observed increase in ^{99}Tc release with increasing pH is justified. For pH levels 12.20 and 12.62, there is a decrease of over 1 $\mu\text{g/g}$ in released ^{99}Tc . This decrease correlates with a decrease in Ca concentration (Table 5.3), which could be due to the precipitation of calcite at pH levels greater than 10 and is capable of blocking ^{99}Tc release as it forms on the monolith surface (Chung et al. 2012). Finally, given the starting ^{99}Tc concentration in the solid, 7.46 $\mu\text{g/g}$ (Table 6.1 in Section 6), these results suggest that complete ^{99}Tc release from the solid material is not achieved within the 24-hour reaction period under all pH conditions tested by EPA Method 1313.

Table 5.3. Concentrations of Major Cations in Filtrate Collected for EPA Method 1313 Leaching Test Performed on Secondary Waste Monolith T1

pH	Ca	Na	K	Si	S	Fe	Mg
	$\mu\text{g/L}$	$\mu\text{g/L}$	$\mu\text{g/L}$	$\mu\text{g/L}$	$\mu\text{g/L}$	$\mu\text{g/L}$	$\mu\text{g/L}$
12.62	8.01E+05	2.63E+06	1.44E+05	5.04E+03	1.17E+06	3.37E+02	7.09E+02
12.20	2.75E+06	2.58E+06	1.52E+05	3.79E+04	3.97E+05	4.29E+03	7.23E+03
10.60	7.60E+06	2.73E+06	1.80E+05	1.28E+04	4.31E+05	ND ^(a)	1.66E+03
10.20	1.15E+07	2.64E+06	1.43E+05	8.25E+03	4.62E+05	ND ^(a)	2.81E+03
9.33	1.49E+07	2.64E+06	1.29E+05	7.27E+03	4.62E+05	ND ^(a)	1.86E+05
7.91	1.86E+07	2.73E+06	1.23E+05	3.27E+03	4.90E+05	ND ^(a)	6.69E+05
5.33	2.23E+07	2.80E+06	1.58E+05	9.94E+03	4.90E+05	2.49E+03	1.05E+06
3.39	2.45E+07	2.85E+06	2.04E+05	4.43E+04	5.21E+05	3.97E+05	1.27E+06
2.07	2.67E+07	3.12E+06	2.52E+05	5.79E+06	5.92E+05	6.88E+05	1.42E+06

a. ND indicates “not detected,” sample concentration below quantification level for Fe (<100 $\mu\text{g/L}$).

Released ^{127}I remained generally constant, between 35 and 40 $\mu\text{g/g}$, over the tested pH range (Table 5.2 and Figure 5.1D), except with an approximate 14 to 18 $\mu\text{g/g}$ decrease in concentration at the tested end points, pH 2.07 and pH 12.62. This indicates that under the pH conditions tested, little to no retention of ^{127}I occurs and most of the initial ^{127}I is released. At low pH conditions, close to pH 2.0, the decrease in ^{127}I release is attributed to the electrostatic attraction between anions and the positively charged surfaces that promote ^{127}I retention and some volatile loss of I_2 (g) at low pH. In addition, at pH levels greater than 12, ^{127}I release is also limited due to calcite formation on the surface that prevents continuous dissolution and ^{127}I release. Release of ^{127}I (~40 $\mu\text{g/g}$) beyond the initial concentration (35.5 $\mu\text{g/g}$) for pH levels between 3.39 and 12.20 could be due to trace amounts of ^{127}I in the starting dry materials, error during sample preparation before analysis by ICP-MS, or instrument error.

Major cations measured in EPA Method 1313 filtrates for monolith T1 are provided in Table 5.3. For Na, K, and S there is no significant change in concentration across the entire final pH range observed. As previously mentioned, measured Ca and Mg concentrations significantly decrease, by close to two orders of magnitude, at pH levels greater than 10, which could be due to calcite and dolomite (or brucite) precipitation formed on the sample surfaces (Chung et al. 2012). For Si, concentrations vary between 10^3

and $10^4 \mu\text{g/g}$ except at the acidic end point, pH 2.07, where an increase in concentration by two orders of magnitude is measured, likely due to large amounts of Si release as more of the LSWG dissolves. Non-detectable levels of Fe under increasingly basic conditions is expected to be the result of $\text{Fe}(\text{OH})_3(\text{s})$ precipitation, as previously mentioned. Finally, Mg concentrations steadily increase with decreasing pH as the solid material dissolves, releasing cations into solution.

Figure 5.1. Secondary Waste Monolith T1 EPA Method 1313 Results for (A) Electrical Conductivity, (B) E_h , (C) Released ^{99}Tc , and (D) Released ^{127}I as a Function of final pH.

6.0 EPA Method 1315 Leaching Test

The EPA Method 1315 leach test measures the effective (or observed) diffusivity of key constituents including technetium, iodide, nitrate, and sodium using a semi-dynamic leaching procedure, on cured LSWG cylindrical monoliths for a minimum of 63 days leaching in DIW. The effective diffusion coefficient accounts for all physical and chemical retention factors influencing mass transfer of the contaminant of concern and is calculated according to Fick's second law of diffusion. Leach testing was performed in accordance with the instructions and approach described in EPA Method 1315 (EPA 2013); however, the cumulative leaching time was extended to 100 days and a second leachant, IDF vadose zone pore water (VZPW), was used in addition to DIW to leach companion LSWG monoliths.

6.1 Methods and Materials

The EPA Method 1315 test is a semi-dynamic leach test that consists of submerging a monolith in leachant at a fixed ratio of liquid volume to solid geometric surface area. Monoliths whose composition are shown in Table 4.1 were placed into the centers of leaching vessels containing sufficient leachant, either DIW or VZPW, to maintain a solution-to-solid geometric surface area ratio of 9 ± 1 mL/cm². Monolith stands and holders were used to maximize the contact area of the monolith with the leaching solution. The surface area of each monolith and the DIW or VZPW target volumes were calculated before starting the EPA Method 1315 leach test based on measurements described in Section 4.2. The VZPW simulant was prepared using the recipe described in previous work by Um et al. (2016) and Serne et al. (2015).

Appropriate containers (2-liter plastic buckets) with lids were used to fully immerse each monolith in the leaching solution. Duplicate monoliths from each test batch were leached in DIW, labeled 1 and 2, and in VZPW, labeled 3 and 4. Leachate sampling was done at fixed intervals, with cumulative leach times of 0.08, 1, 2, 7, 14, 28, 42, 49, and 63 days. Additional leachate samplings were taken at a cumulative leaching time of 100 days, which is beyond the times prescribed in EPA Method 1315. At each sampling interval, the monolith was removed from the leaching solution, the monolith mass was recorded after draining as much surface water as possible, and it was placed in a new 2-L bucket containing fresh DIW or VZPW leachant. The contacted leachate pH, E_h , EC, and alkalinity were measured at each time interval and recorded on the data sheet. The remaining leachate was subsampled into several aliquots (each ~20 mL) for subsequent analysis. Analysis focused on leached components for which effective or observed diffusivities are needed (e.g., ⁹⁹Tc, ¹²⁷I, NO₃⁻, and Na⁺) and overall chemical composition. Analytical methods used include ICP-OES for cation concentrations, ICP-MS for ⁹⁹Tc and ¹²⁷I concentrations, and IC for anion concentrations.

Initial concentrations, C(0), of the constituents of interest in the pre-leached LSWGs, specifically ⁹⁹Tc, ¹²⁷I, NO₃⁻, and Na⁺, are given in Table 6.1. Initial ⁹⁹Tc, ¹²⁷I, NO₃⁻, and Na⁺ concentrations in the cured monoliths were calculated from the constituent's initial concentration in the EMF/CS simulant (Table 3.5) and the mass of dry ingredients and liquid simulant used. This approach is based on the assumption that there is no leachable ⁹⁹Tc and relatively negligible ¹²⁷I, NO₃⁻, or Na⁺ sources in the dry ingredients. Although the spiked ¹²⁷I concentration is much higher than the actual ¹²⁹I concentration in the Hanford waste stream, the highest ¹²⁷I loading in this report (~0.05 wt%, Table 6.1) is lower than the ¹²⁷I concentration limit (0.14 wt%) determined to impact the loading sensitivity of ¹²⁷I leaching (Serne et al. 2015). However, excess ¹²⁷I may affect the geochemical behavior of ¹²⁷I, including increased mobility due to limited sorption sites. Relatively lower contaminant concentrations were found in T1 monoliths compared to others due to the lower w/dm ratio, 0.6, used to prepare T1 as opposed to the 0.75 w/dm ratio used for T2, T3, T4, and T6 monoliths.

Table 6.1. Initial Concentrations, C(0), of ^{99}Tc , ^{127}I , NO_3^- and Na^+ used in Diffusivity Calculations

Test Batch #	Days Cured (day)	^{99}Tc (mg/kg-dry)	^{127}I (mg/kg-dry)	NO_3^- (mg/kg-dry)	Na^+ (mg/kg-dry)
1	28	7.46E+00	3.55E+01	1.04E+04	2.56E+04
2	28	8.89E+00	4.23E+01	1.24E+04	3.05E+04
3	28	8.93E+00	4.25E+01	1.25E+04	3.06E+04
4	28	8.99E+00	4.27E+01	1.26E+04	3.08E+04
5	28	NA ^(a)	NA ^(a)	NA ^(a)	NA ^(a)
6	28	8.93E+00	4.25E+01	1.25E+04	3.06E+04
1	60	7.38E+00	3.51E+01	1.03E+04	2.53E+04
2	60	8.69E+00	4.13E+01	1.22E+04	2.98E+04
3	60	8.89E+00	4.23E+01	1.24E+04	3.05E+04
4	60	8.88E+00	4.22E+01	1.24E+04	3.05E+04
5	60	NA ^(a)	NA ^(a)	NA ^(a)	NA ^(a)
6	60	8.96E+00	4.26E+01	1.25E+04	3.07E+04
(a) NA=“not analyzed” because T5 monoliths did not set after 28- and 60-day curing periods.					

The observed or effective diffusivities for ^{99}Tc , ^{127}I , NO_3^- , and Na^+ were calculated using the analytical solution for Fick’s second law and Equation (6.1) for simple radial diffusion from a cylinder into an infinite bath as detailed by EPA Method 1315 (EPA 2013). The effective or observed diffusion coefficient, D_{eff} or D_{obs} , accounts for all physical and chemical retention factors influencing mass transfer of the contaminant of concern. In this report, the term “effective diffusion coefficient” is used and is equivalent to the term “observed diffusion coefficient” used in EPA Method 1315, the symbol D used in ANSI/ANS-16.1 (ANSI/ANS 2003), and the symbol D_e used in the ASTM C1308-08 (ASTM 2008) method. In some literature, this parameter, the D_{eff} value in Equation (6.1), is called the apparent diffusion coefficient, D_a (see, for example, Grathwohl [1998]). All of these names are equivalent and are “quantified” in standard leach tests.

$$D_{eff} = 10000 * D_{obs(i)} = \pi \left[\frac{M_{ti}}{2\rho C_o (\sqrt{t_i} - \sqrt{t_{i-1}})} \right]^2 \quad (6.1)$$

where

- D_{eff} = effective diffusion coefficient (cm^2/s)
- $D_{obs(i)}$ = observed effective diffusivity of a specific constituent for leaching interval i (m^2/s)
- M_{ti} = mass of specific constituent released during leaching interval i (mg/m^2)
- t_i = cumulative contact time after leaching interval i (s)
- t_{i-1} = cumulative contact time after the previous leaching interval, $i - 1$ (s)
- C_o = initial concentration of constituent in the dry grout ($\text{mg}/\text{kg-dry}$)
- ρ = grout dry bulk density ($\text{kg-dry}/\text{m}^3$), determined as oven dried mass divided by the calculated volume of the monolith.

The leachability index (LI), a unitless parameter derived from the interval effective diffusion coefficient values (D_i , here using D_{eff}), is calculated using Equation (6.2), in which β is a defined constant ($1.0 \text{ cm}^2/\text{s}$) from ANSI/ANS-16.1 (ANSI/ANS 2003). A low diffusivity results in a larger LI.

$$LI_i = \frac{1}{n} \sum_{i=1}^n \left[\log \left(\frac{\beta}{D_i} \right) \right]_n \quad (6.2)$$

6.2 Results and Discussion

The calculated effective diffusivity coefficients (D_{eff}) and LI values for ^{99}Tc , $^{127}\text{I}^-$, NO_3^- , and Na^+ through 100 cumulative leaching days are provided in Table 6.2 through Table 6.5. Duplicate monoliths cured for 28 days are differentiated by the test number followed by either 1 or 2 for DIW-leached monoliths and 3 or 4 for VZPW-leached monoliths, e.g., T1-1 and T1-2 for DIW and T1-3 and T1-4 for VZPW. Table 6.2 and Table 6.4 include D_{eff} and LI values for 28-day cured monoliths leached in DIW and VZPW, respectively. Duplicate monoliths cured for 60 days are differentiated by the test number followed by either 5 or 6 for DIW-leached monoliths and 7 or 8 for VZPW-leached monoliths, e.g., T2-5 and T2-6 for DIW and T2-7 and T2-8 for VZPW. The exception is T1, where T1-5 was used for EPA 1313 testing; therefore, 60-day cured monoliths T1-6 and T1-7 were used for leaching in DIW and T1-8 and T1-9 were leached in VZPW. Table 6.3 and Table 6.5 include D_{eff} and LI values for 60-day cured monoliths leached in DIW and VZPW, respectively. T5 monoliths for the current Cast Stone formulation were not tested by EPA Method 1315 due to insufficient curing, or hardening, after both the 28- and 60-day curing periods (Figure 4.3).

For non-detected (ND) ^{127}I and NO_3^- concentrations in the leachates, the EQL values of ICP-MS for ^{127}I ($<0.063 \mu\text{g/L}$) and IC for NO_3^- ($<12.5 \text{ mg/L}$) concentrations were used to calculate ^{127}I and NO_3^- less than D_{eff} and greater than LI values, respectively. Control leachate samples, from buckets containing only DIW or VZPW, were also collected at each sampling interval to determine the background concentrations of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ . Background concentrations were used to determine the actual concentration leached from the monolith by subtracting the background concentration from the measured leachate concentration for each sampling interval. No ND, zero, or negative leachate concentration values were encountered for ^{99}Tc and Na^+ during the cumulative 100-day leaching test. For ^{127}I , ND concentrations were measured only for T3 monolith leachates, in both DIW and VZPW leaching solutions, due to the presence of the iodine getter, Ag-zeolite (Table 4.1). Several NO_3^- background-corrected VZPW leachates showed zero or negative values because the NO_3^- concentration in the VZPW leachate was the same as or smaller than the background concentration (Table 6.3 and Table 6.5). That is the nitrate concentration in the waste simulant was so small that its release from the waste form was dwarfed by the nitrate concentration in the starting VZPW. In these instances, either the IC EQL value for NO_3^- or the average value of the actual concentrations collected before and after the constituent's leaching interval were used to determine D_{eff} and LI values.

Table 6.2. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in DIW Leaching Solution after 28-Day Curing

Cumulative Leach Time (day)	T1-1 for ^{99}Tc		T1-2 for ^{99}Tc		T1-1 for ^{127}I		T1-2 for ^{127}I		T1-1 for NO_3^-		T1-2 for NO_3^-		T1-1 for Na^+		T1-2 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.21E-09	8.9	6.77E-10	9.2	3.01E-09	8.5	1.57E-09	8.8	4.57E-10	9.3	2.57E-10	9.6	1.42E-08	7.8	6.45E-09	8.2
1.0	1.04E-08	8.0	9.19E-09	8.0	1.81E-08	7.7	1.76E-08	7.8	2.70E-09	8.6	2.45E-09	8.6	4.18E-08	7.4	4.25E-08	7.4
2.0	1.43E-08	7.8	1.74E-08	7.8	2.35E-08	7.6	3.02E-08	7.5	3.21E-09	8.5	4.09E-09	8.4	5.05E-08	7.3	6.59E-08	7.2
7.0	2.10E-08	7.7	1.69E-08	7.8	3.41E-08	7.5	3.21E-08	7.5	4.16E-09	8.4	4.07E-09	8.4	6.59E-08	7.2	6.67E-08	7.2
14.0	2.17E-08	7.7	4.16E-09	8.4	3.53E-08	7.5	1.53E-08	7.8	4.07E-09	8.4	1.94E-09	8.7	7.35E-08	7.1	2.88E-08	7.5
28.0	4.65E-11	10.3	1.88E-11	10.7	1.37E-08	7.9	9.62E-09	8.0	1.53E-09	8.8	1.28E-09	8.9	4.21E-08	7.4	2.61E-08	7.6
42.0	1.10E-12	12.0	7.06E-13	12.2	9.40E-09	8.0	3.28E-09	8.5	8.98E-10	9.0	4.88E-10	9.3	4.72E-08	7.3	1.72E-08	7.8
49.0	2.38E-13	12.6	2.49E-13	12.6	4.76E-09	8.3	1.88E-09	8.7	4.74E-10	9.3	3.42E-10	9.5	2.90E-08	7.5	9.45E-09	8.0
63.0	1.79E-13	12.7	1.93E-13	12.7	4.83E-09	8.3	2.14E-09	8.7	4.36E-10	9.4	3.39E-10	9.5	3.25E-08	7.5	1.14E-08	7.9
100.0	1.50E-13	12.8	1.45E-13	12.8	3.02E-09	8.5	1.48E-09	8.8	3.06E-10	9.5	2.49E-10	9.6	2.20E-08	7.7	8.87E-09	8.1
Cumulative Leach Time (day)	T2-1 for ^{99}Tc		T2-2 for ^{99}Tc		T2-1 for ^{127}I		T2-2 for ^{127}I		T2-1 for NO_3^-		T2-2 for NO_3^-		T2-1 for Na^+		T2-2 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	3.99E-10	9.4	1.20E-09	8.9	5.33E-09	8.3	8.19E-09	8.1	1.56E-09	8.8	2.29E-09	8.6	1.83E-08	7.7	3.67E-08	7.4
1.0	3.25E-09	8.5	9.21E-09	8.0	4.02E-08	7.4	4.75E-08	7.3	1.13E-08	7.9	1.30E-08	7.9	7.01E-08	7.2	8.57E-08	7.1
2.0	2.63E-09	8.6	8.54E-09	8.1	4.36E-08	7.4	5.59E-08	7.3	1.27E-08	7.9	1.53E-08	7.8	9.36E-08	7.0	1.13E-07	6.9
7.0	1.20E-09	8.9	8.35E-09	8.1	5.50E-08	7.3	6.81E-08	7.2	1.45E-08	7.8	1.76E-08	7.8	1.02E-07	7.0	1.30E-07	6.9
14.0	6.89E-11	10.2	1.15E-09	8.9	2.97E-08	7.5	3.87E-08	7.4	7.54E-09	8.1	9.59E-09	8.0	7.36E-08	7.1	9.90E-08	7.0
28.0	5.12E-12	11.3	1.15E-11	10.9	9.50E-09	8.0	1.52E-08	7.8	2.31E-09	8.6	3.81E-09	8.4	5.07E-08	7.3	7.96E-08	7.1
42.0	1.65E-13	12.8	3.69E-13	12.4	1.86E-09	8.7	3.67E-09	8.4	4.66E-10	9.3	9.86E-10	9.0	3.90E-08	7.4	4.77E-08	7.3
49.0	1.42E-13	12.8	1.73E-13	12.8	2.01E-09	8.7	2.01E-09	8.7	4.84E-10	9.3	4.77E-10	9.3	3.38E-08	7.5	3.06E-08	7.5
63.0	4.61E-14	13.3	7.21E-14	13.1	4.19E-10	9.4	1.02E-09	9.0	1.30E-10	9.9	2.44E-10	9.6	1.33E-08	7.9	1.78E-08	7.8
100.0	2.56E-14	13.6	3.14E-14	13.5	1.50E-10	9.8	2.76E-10	9.6	3.42E-11	10.5	5.40E-11	10.3	2.88E-09	8.5	3.52E-09	8.5

Table 6.2. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in DIW Leaching Solution after 28-Day Curing (Cont.)

Cumulative Leach Time (day)	T3-1 for ^{99}Tc		T3-2 for ^{99}Tc		T3-1 for ^{127}I		T3-2 for ^{127}I		T3-1 for NO_3^-		T3-2 for NO_3^-		T3-1 for Na^+		T3-2 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.54E-09	8.8	2.96E-09	8.5	1.74E-14	13.8	1.80E-14	13.7	2.28E-10	9.6	4.56E-10	9.3	6.44E-09	8.2	1.39E-08	7.9
1.0	4.62E-08	7.3	8.17E-08	7.1	2.87E-15	14.5	2.97E-15	14.5	4.27E-09	8.4	7.81E-09	8.1	4.76E-08	7.3	8.00E-08	7.1
2.0	7.49E-08	7.1	8.34E-08	7.1	8.47E-15	14.1	8.75E-15	14.1	6.63E-09	8.2	7.88E-09	8.1	8.28E-08	7.1	9.54E-08	7.0
7.0	8.13E-08	7.1	1.54E-07	6.8	3.83E-15	14.4	3.96E-15	14.4	6.61E-09	8.2	1.23E-08	7.9	8.51E-08	7.1	1.40E-07	6.9
14.0	1.08E-07	7.0	7.41E-08	7.1	4.84E-13	12.3	5.00E-13	12.3	7.51E-09	8.1	5.11E-09	8.3	1.12E-07	7.0	7.63E-08	7.1
28.0	3.66E-08	7.4	3.56E-08	7.4	6.05E-14	13.2	6.25E-14	13.2	2.29E-09	8.6	1.98E-09	8.7	4.76E-08	7.3	4.21E-08	7.4
42.0	1.58E-08	7.8	2.56E-08	7.6	4.11E-13	12.4	4.25E-13	12.4	8.14E-10	9.1	1.06E-09	9.0	3.26E-08	7.5	4.21E-08	7.4
49.0	1.04E-08	8.0	7.62E-09	8.1	2.16E-12	11.7	2.23E-12	11.7	8.58E-10	9.1	5.54E-10	9.3	2.72E-08	7.6	2.15E-08	7.7
63.0	3.26E-09	8.5	2.49E-09	8.6	6.62E-13	12.2	6.84E-13	12.2	5.20E-10	9.3	5.37E-10	9.3	1.90E-08	7.7	2.48E-08	7.6
100.0	3.24E-12	11.5	2.16E-13	12.7	1.37E-13	12.9	1.41E-13	12.9	2.80E-10	9.6	2.25E-10	9.6	9.06E-09	8.0	1.00E-08	8.0
Cumulative Leach Time (day)	T4-1 for ^{99}Tc		T4-2 for ^{99}Tc		T4-1 for ^{127}I		T4-2 for ^{127}I		T4-1 for NO_3^-		T4-2 for NO_3^-		T4-1 for Na^+		T4-2 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.55E-09	8.8	2.26E-09	8.6	6.05E-09	8.2	8.04E-09	8.1	4.32E-10	9.4	5.50E-10	9.3	9.77E-09	8.0	1.20E-08	7.9
1.0	2.81E-08	7.6	3.04E-08	7.5	8.70E-08	7.1	8.99E-08	7.0	5.52E-09	8.3	5.66E-09	8.2	7.62E-08	7.1	8.03E-08	7.1
2.0	3.17E-08	7.5	4.49E-08	7.3	9.02E-08	7.0	1.28E-07	6.9	5.83E-09	8.2	8.55E-09	8.1	9.07E-08	7.0	1.41E-07	6.9
7.0	3.13E-08	7.5	4.02E-08	7.4	9.59E-08	7.0	9.84E-08	7.0	6.19E-09	8.2	6.66E-09	8.2	1.02E-07	7.0	1.16E-07	6.9
14.0	2.43E-09	8.6	2.08E-09	8.7	5.48E-08	7.3	3.90E-08	7.4	3.95E-09	8.4	3.36E-09	8.5	7.31E-08	7.1	6.15E-08	7.2
28.0	3.06E-12	11.5	2.17E-12	11.7	1.14E-08	7.9	7.18E-09	8.1	9.98E-10	9.0	7.96E-10	9.1	2.25E-08	7.6	1.66E-08	7.8
42.0	8.91E-13	12.1	1.24E-12	11.9	2.88E-09	8.5	2.29E-09	8.6	3.52E-10	9.5	3.69E-10	9.4	9.64E-09	8.0	6.39E-09	8.2
49.0	2.36E-12	11.6	1.42E-12	11.8	3.31E-09	8.5	8.62E-10	9.1	6.14E-10	9.2	2.70E-10	9.6	1.03E-08	8.0	2.12E-09	8.7
63.0	1.26E-12	11.9	1.17E-12	11.9	1.46E-09	8.8	7.78E-10	9.1	3.22E-10	9.5	2.09E-10	9.7	4.30E-09	8.4	1.61E-09	8.8
100.0	6.69E-13	12.2	1.79E-12	11.7	5.28E-10	9.3	5.20E-10	9.3	1.17E-10	9.9	1.35E-10	9.9	1.11E-09	9.0	1.03E-09	9.0

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.2. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in DIW Leaching Solution after 28-Day Curing (Cont.)

Cumulative Leach Time (day)	T6-1 for ^{99}Tc		T6-2 for ^{99}Tc		T6-1 for ^{127}I		T6-2 for ^{127}I		T6-1 for NO_3^-		T6-2 for NO_3^-		T6-1 for Na^+		T6-2 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.20E-09	8.9	9.63E-10	9.0	1.00E-08	8.0	5.69E-09	8.2	1.02E-09	9.0	6.46E-10	9.2	1.87E-08	7.7	1.37E-08	7.9
1.0	1.50E-08	7.8	1.40E-08	7.9	8.62E-08	7.1	6.97E-08	7.2	8.33E-09	8.1	6.59E-09	8.2	8.16E-08	7.1	6.74E-08	7.2
2.0	1.81E-08	7.7	2.63E-08	7.6	1.03E-07	7.0	1.20E-07	6.9	9.63E-09	8.0	1.15E-08	7.9	1.08E-07	7.0	1.34E-07	6.9
7.0	2.09E-08	7.7	2.99E-08	7.5	1.45E-07	6.8	1.53E-07	6.8	1.27E-08	7.9	1.38E-08	7.9	1.36E-07	6.9	1.52E-07	6.8
14.0	1.36E-09	8.9	2.64E-09	8.6	7.95E-08	7.1	9.76E-08	7.0	6.75E-09	8.2	8.02E-09	8.1	8.76E-08	7.1	1.03E-07	7.0
28.0	2.23E-11	10.7	2.36E-11	10.6	3.91E-08	7.4	3.58E-08	7.4	3.04E-09	8.5	2.76E-09	8.6	7.43E-08	7.1	6.71E-08	7.2
42.0	8.02E-12	11.1	7.15E-12	11.1	1.36E-08	7.9	1.31E-08	7.9	1.10E-09	9.0	1.20E-09	8.9	5.19E-08	7.3	5.11E-08	7.3
49.0	1.21E-11	10.9	5.65E-12	11.2	1.10E-08	8.0	5.83E-09	8.2	1.06E-09	9.0	5.84E-10	9.2	2.34E-08	7.6	2.00E-08	7.7
63.0	7.48E-12	11.1	8.20E-12	11.1	4.77E-09	8.3	4.46E-09	8.4	5.00E-10	9.3	4.81E-10	9.3	1.99E-08	7.7	1.76E-08	7.8
100.0	1.09E-11	11.0	1.37E-11	10.9	2.41E-09	8.6	2.24E-09	8.7	3.24E-10	9.5	3.13E-10	9.5	3.74E-09	8.4	2.79E-09	8.6

Table 6.3. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in DIW Leaching Solution after 60-Day Curing

Cumulative Leach Time (day)	T1-6 for ^{99}Tc		T1-7 for ^{99}Tc		T1-6 for ^{127}I		T1-7 for ^{127}I		T1-6 for NO_3^-		T1-7 for NO_3^-		T1-6 for Na^+		T1-7 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.10E-09	9.0	1.39E-09	8.9	1.66E-09	8.8	2.10E-09	8.7	2.76E-10	9.6	4.13E-10	9.4	7.53E-09	8.1	9.64E-09	8.0
1.0	9.53E-09	8.0	1.22E-08	7.9	1.12E-08	8.0	1.61E-08	7.8	1.50E-09	8.8	2.50E-09	8.6	2.56E-08	7.6	3.40E-08	7.5
2.0	1.39E-08	7.9	1.19E-08	7.9	1.66E-08	7.8	1.51E-08	7.8	2.22E-09	8.7	2.23E-09	8.7	3.57E-08	7.4	3.23E-08	7.5
7.0	3.26E-08	7.5	3.31E-08	7.5	2.58E-08	7.6	3.13E-08	7.5	3.26E-09	8.5	4.39E-09	8.4	6.37E-08	7.2	7.23E-08	7.1
14.0	2.21E-08	7.7	1.93E-08	7.7	2.26E-08	7.6	2.30E-08	7.6	2.92E-09	8.5	3.36E-09	8.5	6.23E-08	7.2	6.63E-08	7.2
28.0	3.02E-09	8.5	2.79E-09	8.6	1.25E-08	7.9	1.54E-08	7.8	1.60E-09	8.8	2.00E-09	8.7	4.36E-08	7.4	5.45E-08	7.3
42.0	1.95E-12	11.7	1.75E-12	11.8	7.63E-09	8.1	9.37E-09	8.0	8.92E-10	9.0	1.14E-09	8.9	3.02E-08	7.5	3.81E-08	7.4
49.0	1.25E-12	11.9	1.41E-13	12.9	3.86E-09	8.4	3.87E-09	8.4	6.19E-10	9.2	5.14E-10	9.3	1.58E-08	7.8	2.40E-08	7.6
63.0	1.45E-13	12.8	9.06E-14	13.0	4.03E-09	8.4	4.06E-09	8.4	4.35E-10	9.4	4.61E-10	9.3	2.05E-08	7.7	2.02E-08	7.7
100.0	4.78E-14	13.3	7.79E-14	13.1	3.44E-09	8.5	4.19E-09	8.4	3.67E-10	9.4	5.37E-10	9.3	1.83E-08	7.7	1.90E-08	7.7
Cumulative Leach Time (day)	T2-5 for ^{99}Tc		T2-6 for ^{99}Tc		T2-5 for ^{127}I		T2-6 for ^{127}I		T2-5 for NO_3^-		T2-6 for NO_3^-		T2-5 for Na^+		T2-6 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	8.10E-09	8.1	1.35E-09	8.9	1.24E-08	7.9	1.86E-08	7.7	3.36E-09	8.5	4.89E-09	8.3	4.07E-08	7.4	5.24E-08	7.3
1.0	3.45E-08	7.5	6.76E-09	8.2	4.67E-08	7.3	6.15E-08	7.2	1.09E-08	8.0	1.64E-08	7.8	8.88E-08	7.1	9.26E-08	7.0
2.0	2.55E-08	7.6	6.15E-09	8.2	3.73E-08	7.4	6.16E-08	7.2	9.53E-09	8.0	1.65E-08	7.8	8.04E-08	7.1	1.03E-07	7.0
7.0	3.70E-08	7.4	4.93E-09	8.3	4.70E-08	7.3	6.08E-08	7.2	1.17E-08	7.9	1.68E-08	7.8	1.16E-07	6.9	1.18E-07	6.9
14.0	1.20E-08	7.9	3.88E-10	9.4	2.59E-08	7.6	3.94E-08	7.4	6.79E-09	8.2	1.11E-08	8.0	8.89E-08	7.1	1.25E-07	6.9
28.0	1.52E-09	8.8	2.81E-11	10.6	1.10E-08	8.0	1.64E-08	7.8	2.90E-09	8.5	4.39E-09	8.4	4.37E-08	7.4	7.79E-08	7.1
42.0	8.69E-12	11.1	1.19E-12	11.9	4.67E-09	8.3	5.32E-09	8.3	1.31E-09	8.9	1.26E-09	8.9	1.77E-08	7.8	4.35E-08	7.4
49.0	1.25E-11	10.9	1.23E-13	12.9	7.84E-09	8.1	2.15E-09	8.7	2.25E-09	8.6	5.60E-10	9.3	2.33E-08	7.6	3.75E-08	7.4
63.0	2.74E-12	11.6	8.39E-14	13.1	2.02E-09	8.7	1.08E-09	9.0	4.98E-10	9.3	2.62E-10	9.6	4.57E-09	8.3	1.39E-08	7.9
100.0	2.20E-13	12.7	2.40E-14	13.6	1.21E-09	8.9	2.86E-10	9.5	2.42E-10	9.6	6.60E-11	10.2	1.29E-09	8.9	3.13E-09	8.5

Table 6.3. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in DIW Leaching Solution after 60-Day Curing (Cont.)

Cumulative Leach Time (day)	T3-5 for ^{99}Tc		T3-6 for ^{99}Tc		T3-5 for ^{127}I		T3-6 for ^{127}I		T3-5 for NO_3^-		T3-6 for NO_3^-		T3-5 for Na^+		T3-6 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	3.95E-09	8.4	6.85E-09	8.2	1.83E-14	13.7	1.87E-14	13.7	4.30E-10	9.4	5.99E-10	9.2	9.64E-09	8.0	1.44E-08	7.8
1.0	4.33E-08	7.4	3.83E-08	7.4	3.02E-13	12.5	3.08E-13	12.5	3.44E-09	8.5	2.74E-09	8.6	4.36E-08	7.4	4.50E-08	7.3
2.0	5.52E-08	7.3	7.35E-08	7.1	8.90E-13	12.1	9.08E-13	12.0	4.79E-09	8.3	5.17E-09	8.3	5.85E-08	7.2	7.26E-08	7.1
7.0	1.14E-07	6.9	8.85E-08	7.1	4.03E-13	12.4	4.11E-13	12.4	6.91E-09	8.2	5.62E-09	8.2	9.40E-08	7.0	8.36E-08	7.1
14.0	8.14E-08	7.1	6.31E-08	7.2	5.09E-13	12.3	5.19E-13	12.3	5.74E-09	8.2	4.31E-09	8.4	1.03E-07	7.0	8.84E-08	7.1
28.0	4.30E-08	7.4	3.39E-08	7.5	2.54E-13	12.6	2.59E-13	12.6	2.40E-09	8.6	2.04E-09	8.7	6.43E-08	7.2	6.48E-08	7.2
42.0	3.20E-08	7.5	1.63E-08	7.8	4.32E-13	12.4	4.41E-13	12.4	1.33E-09	8.9	1.07E-09	9.0	3.87E-08	7.4	2.97E-08	7.5
49.0	2.02E-08	7.7	5.31E-09	8.3	2.27E-12	11.6	2.31E-12	11.6	1.20E-09	8.9	6.75E-10	9.2	3.95E-08	7.4	1.93E-08	7.7
63.0	3.69E-09	8.4	1.87E-09	8.7	6.95E-13	12.2	7.09E-13	12.1	5.36E-10	9.3	4.95E-10	9.3	1.84E-08	7.7	1.59E-08	7.8
100.0	5.64E-12	11.2	1.38E-11	10.9	1.44E-13	12.8	1.47E-13	12.8	4.26E-10	9.4	4.57E-10	9.3	1.07E-08	8.0	7.46E-09	8.1
Cumulative Leach Time (day)	T4-5 for ^{99}Tc		T4-6 for ^{99}Tc		T4-5 for ^{127}I		T4-6 for ^{127}I		T4-5 for NO_3^-		T4-6 for NO_3^-		T4-5 for Na^+		T4-6 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	4.85E-09	8.3	2.43E-09	8.6	1.04E-08	8.0	5.96E-09	8.2	9.14E-10	9.0	5.63E-10	9.2	1.40E-08	7.9	9.76E-09	8.0
1.0	4.63E-08	7.3	2.55E-08	7.6	1.06E-07	7.0	6.20E-08	7.2	7.45E-09	8.1	4.77E-09	8.3	9.33E-08	7.0	5.40E-08	7.3
2.0	3.89E-08	7.4	3.23E-08	7.5	9.71E-08	7.0	8.12E-08	7.1	7.17E-09	8.1	6.13E-09	8.2	9.68E-08	7.0	8.59E-08	7.1
7.0	3.79E-08	7.4	2.86E-08	7.5	8.31E-08	7.1	7.72E-08	7.1	6.56E-09	8.2	5.60E-09	8.3	1.06E-07	7.0	9.19E-08	7.0
14.0	8.14E-09	8.1	1.26E-08	7.9	3.64E-08	7.4	4.59E-08	7.3	3.23E-09	8.5	3.98E-09	8.4	6.54E-08	7.2	8.87E-08	7.1
28.0	6.34E-11	10.2	1.54E-10	9.8	1.15E-08	7.9	1.25E-08	7.9	1.13E-09	8.9	1.24E-09	8.9	2.49E-08	7.6	2.96E-08	7.5
42.0	1.41E-12	11.9	1.39E-12	11.9	4.53E-09	8.3	3.04E-09	8.5	5.83E-10	9.2	4.58E-10	9.3	9.14E-09	8.0	6.59E-09	8.2
49.0	1.69E-12	11.8	1.40E-12	11.9	1.95E-09	8.7	1.37E-09	8.9	5.01E-10	9.3	3.95E-10	9.4	4.00E-09	8.4	2.29E-09	8.6
63.0	1.52E-12	11.8	1.10E-12	12.0	1.17E-09	8.9	8.46E-10	9.1	3.10E-10	9.5	2.47E-10	9.6	2.38E-09	8.6	1.32E-09	8.9
100.0	8.77E-13	12.1	2.72E-13	12.6	7.08E-10	9.1	4.34E-10	9.4	1.74E-10	9.8	1.17E-10	9.9	6.21E-10	9.2	2.74E-10	9.6

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.3. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in DIW Leaching Solution after 60-day Curing (Cont.)

Cumulative Leach Time (day)	T6-5 for ^{99}Tc		T6-6 for ^{99}Tc		T6-5 for ^{127}I		T6-6 for ^{127}I		T6-5 for NO_3^-		T6-6 for NO_3^-		T6-5 for Na^+		T6-6 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	7.59E-09	8.1	1.65E-08	7.8	3.20E-08	7.5	3.98E-08	7.4	2.86E-09	8.5	3.56E-09	8.4	5.06E-08	7.3	7.49E-08	7.1
1.0	3.16E-08	7.5	6.70E-08	7.2	1.10E-07	7.0	1.60E-07	6.8	8.88E-09	8.1	1.35E-08	7.9	1.03E-07	7.0	1.84E-07	6.7
2.0	3.15E-08	7.5	3.18E-08	7.5	1.18E-07	6.9	8.81E-08	7.1	1.01E-08	8.0	9.15E-09	8.0	1.25E-07	6.9	1.15E-07	6.9
7.0	2.60E-08	7.6	1.22E-08	7.9	8.57E-08	7.1	4.11E-08	7.4	7.46E-09	8.1	4.46E-09	8.4	1.10E-07	7.0	6.56E-08	7.2
14.0	4.86E-09	8.3	1.18E-09	8.9	4.49E-08	7.3	2.14E-08	7.7	4.47E-09	8.3	3.13E-09	8.5	9.39E-08	7.0	3.37E-08	7.5
28.0	4.09E-11	10.4	5.43E-11	10.3	1.38E-08	7.9	7.73E-09	8.1	1.62E-09	8.8	1.39E-09	8.9	4.05E-08	7.4	1.43E-08	7.8
42.0	1.60E-11	10.8	2.27E-11	10.6	5.90E-09	8.2	4.80E-09	8.3	9.39E-10	9.0	1.05E-09	9.0	1.07E-08	8.0	7.22E-09	8.1
49.0	3.22E-11	10.5	1.23E-11	10.9	4.17E-09	8.4	2.58E-09	8.6	1.15E-09	8.9	9.83E-10	9.0	5.00E-09	8.3	2.81E-09	8.6
63.0	2.12E-11	10.7	8.51E-12	11.1	1.86E-09	8.7	1.53E-09	8.8	5.76E-10	9.2	4.96E-10	9.3	1.12E-09	9.0	6.32E-10	9.2
100.0	3.81E-12	11.4	1.28E-12	11.9	1.09E-09	9.0	1.10E-09	9.0	2.91E-10	9.5	2.97E-10	9.5	4.40E-10	9.4	4.43E-10	9.4

Table 6.4. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in VZPW Leaching Solution after 28-Day Curing

Cumulative Leach Time (day)	T1-3 for ^{99}Tc		T1-4 for ^{99}Tc		T1-3 for ^{127}I		T1-4 for ^{127}I		T1-3 for NO_3^-		T1-4 for NO_3^-		T1-3 for Na^+		T1-4 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	3.83E-09	8.4	2.63E-09	8.6	7.20E-09	8.1	5.28E-09	8.3	2.40E-10	9.6	5.25E-10	9.3	2.81E-08	7.6	2.43E-08	7.6
1.0	1.22E-08	7.9	1.12E-08	7.9	2.19E-08	7.7	1.54E-08	7.8	1.20E-09	8.9	1.63E-09	8.8	4.32E-08	7.4	4.36E-08	7.4
2.0	2.15E-08	7.7	3.31E-08	7.5	3.58E-08	7.4	4.89E-08	7.3	7.29E-10	9.1	3.43E-09	8.5	7.71E-08	7.1	9.80E-08	7.0
7.0	2.47E-08	7.6	3.29E-08	7.5	3.89E-08	7.4	4.97E-08	7.3	1.32E-09	8.9	1.85E-09	8.7	6.13E-08	7.2	8.17E-08	7.1
14.0	9.21E-09	8.0	1.15E-08	7.9	2.77E-08	7.6	3.73E-08	7.4	6.66E-11	10.2	4.05E-10	9.4	4.30E-08	7.4	5.44E-08	7.3
28.0	4.55E-11	10.3	5.00E-11	10.3	2.26E-08	7.6	1.97E-08	7.7	8.33E-12	11.1	8.10E-12	11.1	3.82E-08	7.4	3.54E-08	7.5
42.0	2.01E-12	11.7	2.28E-12	11.6	1.47E-08	7.8	1.50E-08	7.8	1.86E-10	9.7	1.81E-10	9.7	4.20E-08	7.4	4.03E-08	7.4
49.0	4.48E-13	12.3	6.35E-13	12.2	1.37E-08	7.9	1.32E-08	7.9	2.90E-09	8.5	2.82E-09	8.5	3.67E-08	7.4	3.70E-08	7.4
63.0	3.26E-13	12.5	3.36E-13	12.5	9.67E-09	8.0	9.01E-09	8.0	8.89E-10	9.1	8.65E-10	9.1	3.18E-08	7.5	2.83E-08	7.5
100.0	3.17E-13	12.5	7.64E-13	12.1	6.06E-09	8.2	7.44E-09	8.1	1.84E-10	9.7	1.79E-10	9.7	2.13E-08	7.7	2.31E-08	7.6
Cumulative Leach Time (day)	T2-3 for ^{99}Tc		T2-4 for ^{99}Tc		T2-3 for ^{127}I		T2-4 for ^{127}I		T2-3 for NO_3^-		T2-4 for NO_3^-		T2-3 for Na^+		T2-4 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.67E-09	8.8	1.26E-09	8.9	5.73E-09	8.2	7.10E-09	8.1	1.31E-09	8.9	8.36E-10	9.1	6.77E-08	7.2	3.79E-08	7.4
1.0	1.63E-08	7.8	8.16E-09	8.1	4.17E-08	7.4	3.67E-08	7.4	8.85E-09	8.1	7.23E-09	8.1	9.22E-08	7.0	8.60E-08	7.1
2.0	2.71E-08	7.6	1.15E-08	7.9	7.64E-08	7.1	5.49E-08	7.3	1.47E-08	7.8	7.33E-09	8.1	1.73E-07	6.8	1.14E-07	6.9
7.0	2.21E-08	7.7	1.28E-08	7.9	9.06E-08	7.0	6.05E-08	7.2	1.14E-08	7.9	8.68E-09	8.1	1.44E-07	6.8	1.27E-07	6.9
14.0	6.17E-09	8.2	2.93E-09	8.5	6.97E-08	7.2	5.86E-08	7.2	5.54E-09	8.3	1.63E-08	7.8	1.38E-07	6.9	1.23E-07	6.9
28.0	1.66E-11	10.8	1.15E-11	10.9	2.69E-08	7.6	2.28E-08	7.6	8.03E-10	9.1	7.25E-10	9.1	7.52E-08	7.1	6.56E-08	7.2
42.0	2.36E-12	11.6	1.66E-12	11.8	1.36E-08	7.9	1.20E-08	7.9	8.67E-10	9.1	8.13E-10	9.1	5.48E-08	7.3	5.76E-08	7.2
49.0	5.05E-13	12.3	1.11E-12	12.0	8.91E-09	8.1	9.29E-09	8.0	2.53E-09	8.6	2.52E-09	8.6	2.76E-08	7.6	3.81E-08	7.4
63.0	4.08E-13	12.4	1.67E-13	12.8	5.22E-09	8.3	4.29E-09	8.4	7.78E-10	9.1	7.74E-10	9.1	8.97E-09	8.0	1.25E-08	7.9
100.0	7.01E-13	12.2	9.88E-14	13.0	2.11E-09	8.7	1.66E-09	8.8	1.61E-10	9.8	1.60E-10	9.8	1.75E-09	8.8	2.75E-09	8.6

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.4. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in VZPW Leaching Solution after 28-Day Curing (Cont.)

Cumulative Leach Time (day)	T3-3 for ^{99}Tc		T3-4 for ^{99}Tc		T3-3 for ^{127}I		T3-4 for ^{127}I		T3-3 for NO_3^-		T3-4 for NO_3^-		T3-3 for Na^+		T3-4 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.07E-08	8.0	6.89E-09	8.2	1.81E-14	13.7	1.84E-14	13.7	1.32E-09	8.9	1.34E-09	8.9	2.28E-08	7.6	2.14E-08	7.7
1.0	7.86E-08	7.1	6.57E-08	7.2	2.98E-15	14.5	3.04E-15	14.5	5.86E-09	8.2	3.89E-09	8.4	7.71E-08	7.1	7.12E-08	7.1
2.0	1.22E-07	6.9	1.09E-07	7.0	8.80E-15	14.1	8.96E-15	14.0	8.29E-09	8.1	5.86E-09	8.2	1.28E-07	6.9	1.11E-07	7.0
7.0	1.26E-07	6.9	9.76E-08	7.0	3.98E-15	14.4	1.62E-12	11.8	6.12E-09	8.2	3.61E-09	8.4	1.06E-07	7.0	9.16E-08	7.0
14.0	1.42E-07	6.8	1.03E-07	7.0	5.03E-13	12.3	5.12E-13	12.3	3.74E-09	8.4	2.32E-09	8.6	1.13E-07	6.9	1.05E-07	7.0
28.0	5.96E-08	7.2	4.25E-08	7.4	6.28E-14	13.2	6.40E-14	13.2	6.59E-10	9.2	9.11E-11	10.0	5.89E-08	7.2	5.60E-08	7.3
42.0	3.27E-08	7.5	1.71E-08	7.8	4.27E-13	12.4	4.35E-13	12.4	7.70E-10	9.1	3.00E-10	9.5	5.46E-08	7.3	3.70E-08	7.4
49.0	2.33E-08	7.6	6.01E-09	8.2	2.24E-12	11.6	2.28E-12	11.6	2.54E-09	8.6	2.59E-09	8.6	6.02E-08	7.2	2.99E-08	7.5
63.0	2.96E-09	8.5	1.02E-09	9.0	6.87E-13	12.2	7.00E-13	12.2	7.80E-10	9.1	7.95E-10	9.1	3.78E-08	7.4	1.54E-08	7.8
100.0	3.96E-12	11.4	6.43E-13	12.2	1.42E-13	12.8	1.44E-13	12.8	1.61E-10	9.8	1.64E-10	9.8	1.93E-08	7.7	5.18E-09	8.3
Cumulative Leach Time (day)	T4-3 for ^{99}Tc		T4-4 for ^{99}Tc		T4-3 for ^{127}I		T4-4 for ^{127}I		T4-3 for NO_3^-		T4-4 for NO_3^-		T4-3 for Na^+		T4-4 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	2.24E-09	8.6	6.51E-09	8.2	8.38E-09	8.1	2.16E-08	7.7	8.68E-10	9.1	1.95E-09	8.7	1.11E-08	8.0	3.24E-08	7.5
1.0	3.61E-08	7.4	3.76E-08	7.4	1.20E-07	6.9	1.02E-07	7.0	5.59E-09	8.3	6.49E-09	8.2	9.76E-08	7.0	1.14E-07	6.9
2.0	4.53E-08	7.3	6.71E-08	7.2	1.42E-07	6.8	1.90E-07	6.7	5.93E-09	8.2	8.51E-09	8.1	1.41E-07	6.9	1.84E-07	6.7
7.0	4.05E-08	7.4	1.09E-07	7.0	1.06E-07	7.0	3.35E-07	6.5	2.68E-09	8.6	1.33E-08	7.9	1.09E-07	7.0	3.32E-07	6.5
14.0	1.47E-09	8.8	2.77E-09	8.6	3.36E-08	7.5	6.79E-08	7.2	1.70E-09	8.8	5.40E-10	9.3	4.44E-08	7.4	9.90E-08	7.0
28.0	4.07E-12	11.4	3.05E-12	11.5	1.09E-08	8.0	1.51E-08	7.8	2.94E-10	9.5	2.81E-10	9.6	2.25E-08	7.6	2.42E-08	7.6
42.0	2.53E-12	11.6	2.26E-12	11.6	6.74E-09	8.2	6.46E-09	8.2	5.00E-10	9.3	4.98E-10	9.3	1.33E-08	7.9	1.07E-08	8.0
49.0	5.72E-12	11.2	6.17E-12	11.2	4.96E-09	8.3	5.20E-09	8.3	2.62E-09	8.6	2.61E-09	8.6	9.08E-09	8.0	8.12E-09	8.1
63.0	8.67E-12	11.1	5.64E-12	11.2	3.01E-09	8.5	2.43E-09	8.6	8.04E-10	9.1	8.01E-10	9.1	3.40E-09	8.5	2.31E-09	8.6
100.0	8.75E-12	11.1	8.14E-12	11.1	1.11E-09	9.0	1.05E-09	9.0	1.66E-10	9.8	1.65E-10	9.8	1.28E-09	8.9	7.69E-10	9.1

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.4. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in VZPW Leaching Solution after 28-Day Curing (Cont.)

Cumulative Leach Time (day)	T6-3 for ^{99}Tc		T6-4 for ^{99}Tc		T6-3 for ^{127}I		T6-4 for ^{127}I		T6-3 for NO_3^-		T6-4 for NO_3^-		T6-3 for Na^+		T6-4 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	1.12E-09	9.0	2.21E-09	8.7	2.34E-08	7.6	1.30E-08	7.9	2.52E-09	8.6	8.24E-10	9.1	3.40E-08	7.5	2.50E-08	7.6
1.0	7.19E-09	8.1	2.21E-08	7.7	1.31E-07	6.9	6.93E-08	7.2	1.16E-08	7.9	7.63E-09	8.1	1.09E-07	7.0	9.77E-08	7.0
2.0	7.41E-09	8.1	3.24E-08	7.5	1.51E-07	6.8	1.34E-07	6.9	1.21E-08	7.9	9.03E-09	8.0	1.63E-07	6.8	1.47E-07	6.8
7.0	2.63E-09	8.6	2.89E-08	7.5	1.47E-07	6.8	1.42E-07	6.8	1.05E-08	8.0	7.65E-09	8.1	1.34E-07	6.9	1.31E-07	6.9
14.0	9.69E-11	10.0	4.00E-09	8.4	1.08E-07	7.0	1.42E-07	6.8	4.63E-09	8.3	5.72E-09	8.2	1.09E-07	7.0	1.37E-07	6.9
28.0	2.55E-11	10.6	4.24E-11	10.4	4.14E-08	7.4	4.17E-08	7.4	5.16E-10	9.3	5.16E-10	9.3	6.71E-08	7.2	7.18E-08	7.1
42.0	1.66E-11	10.8	2.08E-11	10.7	2.13E-08	7.7	2.86E-08	7.5	6.60E-10	9.2	6.60E-10	9.2	6.05E-08	7.2	8.13E-08	7.1
49.0	2.76E-11	10.6	2.42E-11	10.6	1.38E-08	7.9	2.05E-08	7.7	2.49E-09	8.6	2.49E-09	8.6	3.33E-08	7.5	5.20E-08	7.3
63.0	3.03E-11	10.5	1.93E-11	10.7	7.49E-09	8.1	1.07E-08	8.0	7.63E-10	9.1	7.63E-10	9.1	1.15E-08	7.9	2.76E-08	7.6
100.0	2.14E-10	9.7	1.17E-10	9.9	3.53E-09	8.5	4.62E-09	8.3	1.58E-10	9.8	1.58E-10	9.8	1.16E-09	8.9	2.07E-09	8.7

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.5. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in VZPW Leaching Solution after 60-Day Curing

Cumulative Leach Time (day)	T1-8 for ^{99}Tc		T1-9 for ^{99}Tc		T1-8 for ^{127}I		T1-9 for ^{127}I		T1-8 for NO_3^-		T1-9 for NO_3^-		T1-8 for Na^+		T1-9 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	3.59E-09	8.4	4.66E-09	8.3	4.93E-09	8.3	1.59E-08	7.8	9.68E-09	8.0	5.32E-10	9.3	1.49E-08	7.8	5.85E-08	7.2
1.0	1.28E-08	7.9	2.02E-08	7.7	1.61E-08	7.8	5.03E-08	7.3	8.27E-10	9.1	3.16E-09	8.5	3.29E-08	7.5	1.17E-07	6.9
2.0	1.53E-08	7.8	2.46E-08	7.6	1.97E-08	7.7	6.70E-08	7.2	1.08E-09	9.0	3.48E-09	8.5	3.54E-08	7.5	1.26E-07	6.9
7.0	3.00E-08	7.5	2.01E-08	7.7	3.14E-08	7.5	6.14E-08	7.2	1.65E-09	8.8	3.54E-09	8.5	5.99E-08	7.2	1.26E-07	6.9
14.0	2.17E-08	7.7	6.31E-09	8.2	2.70E-08	7.6	4.16E-08	7.4	4.30E-10	9.4	8.05E-10	9.1	5.30E-08	7.3	8.43E-08	7.1
28.0	4.42E-09	8.4	4.96E-10	9.3	2.43E-08	7.6	2.25E-08	7.6	3.63E-10	9.4	1.66E-10	9.8	5.85E-08	7.2	3.82E-08	7.4
42.0	5.00E-12	11.3	7.53E-12	11.1	1.82E-08	7.7	1.26E-08	7.9	5.94E-10	9.2	4.03E-10	9.4	4.08E-08	7.4	1.86E-08	7.7
49.0	9.02E-13	12.0	2.26E-12	11.6	1.47E-08	7.8	9.47E-09	8.0	2.99E-09	8.5	2.86E-09	8.5	4.00E-08	7.4	1.49E-08	7.8
63.0	4.47E-13	12.3	1.11E-12	12.0	1.01E-08	8.0	7.24E-09	8.1	9.18E-10	9.0	8.77E-10	9.1	2.32E-08	7.6	6.60E-09	8.2
100.0	2.41E-13	12.6	5.80E-13	12.2	7.90E-09	8.1	3.44E-09	8.5	1.90E-10	9.7	1.81E-10	9.7	2.22E-08	7.7	4.01E-09	8.4
Cumulative Leach Time (day)	T2-7 for ^{99}Tc		T2-8 for ^{99}Tc		T2-7 for ^{127}I		T2-8 for ^{127}I		T2-7 for NO_3^-		T2-8 for NO_3^-		T2-7 for Na^+		T2-8 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	2.05E-09	8.7	4.48E-09	8.3	8.78E-09	8.1	1.70E-08	7.8	4.75E-10	9.3	8.27E-10	9.1	1.78E-08	7.7	3.64E-08	7.4
1.0	1.70E-08	7.8	2.09E-08	7.7	6.47E-08	7.2	6.42E-08	7.2	1.19E-08	7.9	9.84E-09	8.0	9.06E-08	7.0	8.86E-08	7.1
2.0	2.20E-08	7.7	3.00E-08	7.5	9.89E-08	7.0	8.79E-08	7.1	1.87E-08	7.7	1.57E-08	7.8	1.51E-07	6.8	1.34E-07	6.9
7.0	2.54E-08	7.6	2.99E-08	7.5	8.23E-08	7.1	8.51E-08	7.1	1.50E-08	7.8	1.43E-08	7.8	1.33E-07	6.9	1.47E-07	6.8
14.0	1.17E-08	7.9	1.83E-08	7.7	6.03E-08	7.2	5.88E-08	7.2	7.75E-09	8.1	6.94E-09	8.2	1.38E-07	6.9	1.56E-07	6.8
28.0	1.58E-09	8.8	3.67E-09	8.4	4.03E-08	7.4	3.68E-08	7.4	3.71E-09	8.4	2.73E-09	8.6	1.39E-07	6.9	1.20E-07	6.9
42.0	6.04E-12	11.2	4.81E-12	11.3	1.91E-08	7.7	1.73E-08	7.8	4.98E-11	10.3	1.22E-11	10.9	5.61E-08	7.3	6.11E-08	7.2
49.0	7.88E-13	12.1	9.70E-13	12.0	9.77E-09	8.0	1.17E-08	7.9	1.11E-09	9.0	8.39E-10	9.1	4.05E-08	7.4	4.09E-08	7.4
63.0	4.13E-13	12.4	6.85E-13	12.2	5.74E-09	8.2	7.86E-09	8.1	7.83E-10	9.1	7.66E-10	9.1	1.59E-08	7.8	1.96E-08	7.7
100.0	1.53E-13	12.8	2.85E-13	12.5	2.16E-09	8.7	3.44E-09	8.5	1.62E-10	9.8	1.58E-10	9.8	3.00E-09	8.5	3.80E-09	8.4

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.5. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in VZPW Leaching Solution after 60-Day Curing (Cont.)

Cumulative Leach Time (day)	T3-7 for ^{99}Tc		T3-8 for ^{99}Tc		T3-7 for ^{127}I		T3-8 for ^{127}I		T3-7 for NO_3^-		T3-8 for NO_3^-		T3-7 for Na^+		T3-8 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	3.59E-08	7.4	1.39E-08	7.9	1.90E-14	13.7	1.82E-14	13.7	4.97E-10	9.3	5.28E-11	10.3	4.51E-08	7.3	1.70E-08	7.8
1.0	1.23E-07	6.9	7.27E-08	7.1	3.13E-13	12.5	2.99E-13	12.5	5.24E-09	8.3	3.48E-09	8.5	1.07E-07	7.0	5.68E-08	7.2
2.0	1.28E-07	6.9	1.33E-07	6.9	9.23E-13	12.0	8.82E-13	12.1	1.31E-09	8.9	8.31E-09	8.1	1.01E-07	7.0	1.32E-07	6.9
7.0	6.88E-08	7.2	1.05E-07	7.0	4.18E-13	12.4	3.99E-13	12.4	1.61E-09	8.8	4.64E-09	8.3	8.46E-08	7.1	9.83E-08	7.0
14.0	2.19E-08	7.7	5.57E-08	7.3	5.27E-13	12.3	5.04E-13	12.3	1.21E-09	8.9	1.47E-09	8.8	4.02E-08	7.4	7.87E-08	7.1
28.0	5.40E-09	8.3	3.81E-08	7.4	2.64E-13	12.6	2.52E-13	12.6	2.99E-10	9.5	1.83E-10	9.7	1.75E-08	7.8	5.80E-08	7.2
42.0	1.11E-09	9.0	1.82E-08	7.7	4.48E-13	12.3	4.28E-13	12.4	5.09E-10	9.3	3.94E-10	9.4	5.53E-09	8.3	2.82E-08	7.6
49.0	1.15E-10	9.9	1.95E-08	7.7	2.35E-12	11.6	2.25E-12	11.6	2.67E-09	8.6	2.55E-09	8.6	2.39E-09	8.6	3.72E-08	7.4
63.0	4.45E-12	11.4	4.33E-09	8.4	7.21E-13	12.1	6.89E-13	12.2	8.19E-10	9.1	7.83E-10	9.1	1.93E-09	8.7	3.24E-08	7.5
100.0	2.48E-14	13.6	1.36E-11	10.9	1.49E-13	12.8	1.42E-13	12.8	1.69E-10	9.8	1.62E-10	9.8	1.85E-10	9.7	9.61E-09	8.0
Cumulative Leach Time (day)	T4-7 for ^{99}Tc		T4-8 for ^{99}Tc		T4-7 for ^{127}I		T4-8 for ^{127}I		T4-7 for NO_3^-		T4-8 for NO_3^-		T4-7 for Na^+		T4-8 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	5.83E-09	8.2	1.14E-08	7.9	1.37E-08	7.9	2.17E-08	7.7	9.82E-10	9.0	1.52E-09	8.8	1.55E-08	7.8	2.43E-08	7.6
1.0	4.46E-08	7.4	6.15E-08	7.2	1.10E-07	7.0	1.19E-07	6.9	4.89E-09	8.3	5.29E-09	8.3	8.08E-08	7.1	9.68E-08	7.0
2.0	6.71E-08	7.2	8.17E-08	7.1	1.64E-07	6.8	1.62E-07	6.8	9.66E-09	8.0	8.53E-09	8.1	1.34E-07	6.9	1.77E-07	6.8
7.0	4.22E-08	7.4	6.05E-08	7.2	8.71E-08	7.1	1.21E-07	6.9	3.90E-09	8.4	4.57E-09	8.3	1.05E-07	7.0	1.56E-07	6.8
14.0	1.03E-08	8.0	5.76E-09	8.2	4.39E-08	7.4	2.66E-08	7.6	2.09E-10	9.7	2.58E-09	8.6	8.01E-08	7.1	4.64E-08	7.3
28.0	6.22E-11	10.2	1.70E-11	10.8	1.61E-08	7.8	1.31E-08	7.9	2.02E-10	9.7	3.29E-10	9.5	2.38E-08	7.6	1.53E-08	7.8
42.0	5.51E-12	11.3	2.30E-12	11.6	6.59E-09	8.2	6.17E-09	8.2	5.65E-10	9.2	5.59E-10	9.3	8.97E-09	8.0	6.20E-09	8.2
49.0	8.24E-12	11.1	3.81E-12	11.4	6.61E-09	8.2	6.73E-09	8.2	2.96E-09	8.5	2.93E-09	8.5	8.54E-09	8.1	8.14E-09	8.1
63.0	1.31E-11	10.9	5.12E-12	11.3	4.09E-09	8.4	3.50E-09	8.5	9.09E-10	9.0	9.00E-10	9.0	5.90E-09	8.2	7.44E-09	8.1
100.0	7.81E-12	11.1	3.76E-12	11.4	1.24E-09	8.9	1.07E-09	9.0	1.88E-10	9.7	1.86E-10	9.7	2.89E-10	9.5	5.37E-10	9.3

Values in red use EQL or average calculated values to determine D_{eff} and LI.

Table 6.5. Diffusivity and LI Values of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in VZPW Leaching Solution after 60-Day Curing (Cont.)

Cumulative Leach Time (day)	T6-7 for ^{99}Tc		T6-8 for ^{99}Tc		T6-7 for ^{127}I		T6-8 for ^{127}I		T6-7 for NO_3^-		T6-8 for NO_3^-		T6-7 for Na^+		T6-8 for Na^+	
	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]	D_{eff} (cm ² /s)	LI [-]
0.08	3.33E-09	8.5	1.30E-09	8.9	2.05E-08	7.7	1.30E-08	7.9	1.84E-09	8.7	1.25E-09	8.9	2.31E-08	7.6	1.85E-08	7.7
1.0	1.75E-08	7.8	9.72E-09	8.0	1.05E-07	7.0	8.87E-08	7.1	6.15E-09	8.2	6.02E-09	8.2	7.63E-08	7.1	7.10E-08	7.1
2.0	2.19E-08	7.7	1.51E-08	7.8	1.22E-07	6.9	1.36E-07	6.9	8.06E-09	8.1	9.75E-09	8.0	1.20E-07	6.9	1.40E-07	6.9
7.0	2.06E-08	7.7	1.12E-08	8.0	1.12E-07	6.9	1.24E-07	6.9	7.04E-09	8.2	8.34E-09	8.1	1.11E-07	7.0	1.23E-07	6.9
14.0	3.91E-09	8.4	1.08E-09	9.0	8.92E-08	7.0	7.79E-08	7.1	2.40E-09	8.6	2.35E-09	8.6	1.25E-07	6.9	1.14E-07	6.9
28.0	6.35E-11	10.2	2.93E-11	10.5	4.26E-08	7.4	5.80E-08	7.2	2.56E-10	9.6	1.00E-09	9.0	8.51E-08	7.1	9.96E-08	7.0
42.0	2.32E-11	10.6	1.56E-11	10.8	1.78E-08	7.7	3.17E-08	7.5	4.53E-10	9.3	9.85E-10	9.0	3.45E-08	7.5	7.42E-08	7.1
49.0	2.48E-11	10.6	9.94E-12	11.0	1.57E-08	7.8	1.90E-08	7.7	2.47E-09	8.6	2.42E-09	8.6	3.37E-08	7.5	5.81E-08	7.2
63.0	3.51E-11	10.5	1.21E-11	10.9	1.09E-08	8.0	1.07E-08	8.0	7.59E-10	9.1	7.44E-10	9.1	1.43E-09	8.8	1.60E-08	7.8
100.0	9.21E-11	10.0	2.02E-11	10.7	4.10E-09	8.4	4.79E-09	8.3	1.57E-10	9.8	1.54E-10	9.8	2.17E-09	8.7	2.77E-09	8.6

Values in red use EQL or average calculated values to determine D_{eff} and LI.

A time-invariant average D_{eff} value was calculated for the four constituents of concern by averaging the D_{eff} values determined for leach samples between 28 and 100 days. Average D_{eff} values are provided in Table 6.6 for DIW and Table 6.7 for VZPW, in addition to the fraction of total constituent mass released after the 100-day cumulative leach period relative to the initial mass of constituent in the monolith before leaching. Because the fraction of total released mass of ^{99}Tc during early leach periods, 0.08 to 14 days, is less than 20% of the total initial mass of ^{99}Tc , the time-invariant ^{99}Tc D_{eff} value was determined from the later leach periods, between 28 and 100 days. This approach is supported by the less significant effect of early leaching on full-sized cementitious waste forms to be disposed of in the IDF. In addition, average ^{99}Tc D_{eff} values with their uncertainty ranges can cover the minor artifacts that might result from the early stages of leaching (e.g., surface wash off), if there are any. For consistency, this approach to calculating average D_{eff} values is used for all four constituents.

In general, early ^{99}Tc D_{eff} values, up to the cumulative 14 days, were at times five orders of magnitude higher than D_{eff} values measured during later leach periods because of the initial removal of surface-bound ^{99}Tc and fast release through cracks formed during monolith curing and/or during the early leach testing. Even though most of the monoliths, cured for either 28 or 60 days, showed some cracks before the leaching tests were started (Figure 6.1 and Figure 6.2), ^{99}Tc D_{eff} values decreased by at least two orders of magnitude between 14 and 28 days of cumulative leaching (Table 6.2 to Table 6.5). Because of the presence of cracks, these early stage D_{eff} values before 28-day leaching in Table 6.2 to Table 6.5 were overly conservative, although these values seemed to meet the acceptable diffusion limit for the EPA 1315 method (a slope of 0.5 ± 0.15).

Averaged ^{99}Tc D_{eff} values for individual monoliths after 28-day curing from the cumulative 28-day to 100-day leaching in DIW leaching solution ranged from $10^{-10.9}$ to $10^{-12.0}$ except for the T3 monolith showing a ^{99}Tc D_{eff} value of $\sim 10^{-7.9}$ (Table 6.6). Similar low average ^{99}Tc D_{eff} values from the cumulative 28-day to 100-day leaching were also found for most monoliths irrespective of different curing periods and leachant solutions used (Table 6.6 and Table 6.7). T3 monoliths prepared with iodine getter (Ag-zeolite) showed the highest average ^{99}Tc D_{eff} values compared to other monoliths, but also the lowest average ^{127}I D_{eff} values ($\sim 10^{-12.0}$) (Table 6.6 and Table 6.7). Interestingly, most of the average ^{99}Tc D_{eff} values for individual monoliths, except T3, showed lower D_{eff} values than other highly mobile nonreactive constituents (NO_3^- and Na^+), even though severe cracks were formed in most of the leached monoliths after 100-day leaching. Except for T2 monoliths, as shown in Figure 6.1, all of the monoliths leached for 100 days showed severe cracks and deformations (See Appendix A.1 for photographs of the leached monoliths after 100-day leaching).

Figure 6.1. Photographs of T2 Monoliths after the Cumulative 100-Day Leaching in DIW

If the total fraction of ^{99}Tc mass released from the monoliths is less than 20% over the course of EPA Method 1315 leach testing, then the D_{eff} values determined are valid and meet the semi-infinite source term assumption and effective diffusion coefficient calculations defined by Equation (6.1) and per discussion in ANSI/ANS-16.1 (ANSI/ANS 2003). Thus, D_{eff} corrections for inventory depletion is not necessary. For more than 50% of the LSWG monoliths (see Table 6.6 and Table 6.7) leached in DIW or VZPW, the average total fraction of ^{99}Tc mass leached from monoliths after 28 or 60 days curing did not exceed 20% of the initial ^{99}Tc mass over 100-day cumulative leaching. T6 monoliths released the least ^{99}Tc , regardless of leach solution and monolith cure time, due to the addition of ^{99}Tc getter, Sn-apatite. For iodine, less than 20% mass release after 100-day leaching was only achieved for T3 monoliths where iodine getter, Ag-zeolite, was added. However, T3 monoliths released the most ^{99}Tc .

The average total fraction of NO_3^- mass released from all but one monolith (T2, 60-day cured, DIW) for the cumulative 100-day leaching in DIW and VZPW solutions was also less than 20% (Table 6.6 and Table 6.7). However, for monoliths leached in VZPW, all the blank-corrected NO_3^- concentrations for 100 days cumulative leaching were zero or negative, so the IC EQL value for NO_3^- was used to calculate the total fraction of NO_3^- mass released, which can lead to very high uncertainty. Na^+ , on the other hand, exhibits highly leachable behavior and at least 45% Na^+ mass was released after 100 days for all monoliths regardless of leach solution. This is significantly higher than the mass release for ^{99}Tc , ^{127}I , and NO_3^- because of the highly soluble white precipitates formed on the surface of most monoliths, identified as thenardite (Na_2SO_4) or mirabilite (hydrated thenardite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) (Figure 4.2 and Figure 4.4). It is also possible that the dry blend ingredients contained readily leachable Na^+ that was not included in the $C(0)$ value used to calculate Na^+ D_{eff} values and thus cumulative Na^+ mass released during the 100-d leach test.

Some release of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ did not follow a pure diffusion trend, also found in previous work (Um et al. 2016), showing a low slope beyond the acceptable limit for the EPA 1315 method (a slope of 0.5 ± 0.15) and exceeding 20% of the initial mass. Therefore, the calculated diffusivity values in Table 6.2 to Table 6.7 should be used with care, and are provided only for comparison with previous results (Um et al. 2016). In addition, the cumulative releases of ^{99}Tc , ^{127}I , NO_3^- , and Na^+ as a function leaching time were also reported for qualitative understanding of release in Table A.1 to Table A.4.

Table 6.6. Calculated Dry Bulk Density of Each Monolith and Averaged D_{eff} Values of ^{99}Tc , I^- , NO_3^- , and Na^+ from the Cumulative 28-Day to 100-Day Leaching in DIW with Average Fraction of Released Mass in Duplicates of Individual Monolith Batch

Test Batch	Dry Bulk Density (g/cm ³)	DIW Leaching Solution							
		⁹⁹ Tc <i>D</i> _{eff} [cm ² /s]	F ^(a)	I ⁻ <i>D</i> _{eff} [cm ² /s]	F	NO ₃ ⁻ <i>D</i> _{eff} [cm ² /s]	F	Na ⁺ <i>D</i> _{eff} [cm ² /s]	F
After 28-day curing									
T1-1	1.17	10 ^{-11.0}	0.162	10 ^{-8.15}	0.373	10 ^{-9.14}	0.126	10 ^{-7.46}	0.675
T1-2	1.16	10 ^{-11.4}	0.122	10 ^{-8.43}	0.297	10 ^{-9.27}	0.110	10 ^{-7.84}	0.506
T2-1	1.05	10 ^{-12.0}	0.041	10 ^{-8.55}	0.329	10 ^{-9.16}	0.169	10 ^{-7.55}	0.641
T2-2	1.07	10 ^{-11.6}	0.091	10 ^{-8.35}	0.388	10 ^{-8.95}	0.197	10 ^{-7.45}	0.741
T3-1	1.06	10 ^{-7.88}	0.514	10 ^{-12.2}	0.001	10 ^{-9.02}	0.153	10 ^{-7.57}	0.661
T3-2	1.04	10 ^{-7.85}	0.559	10 ^{-12.2}	0.001	10 ^{-9.06}	0.163	10 ^{-7.55}	0.699
T4-1	1.00	10 ^{-11.8}	0.158	10 ^{-8.41}	0.437	10 ^{-9.32}	0.124	10 ^{-8.02}	0.513
T4-2	0.99	10 ^{-11.8}	0.174	10 ^{-8.63}	0.415	10 ^{-9.45}	0.123	10 ^{-8.26}	0.492
T6-1	1.05	10 ^{-10.9}	0.131	10 ^{-7.85}	0.603	10 ^{-8.92}	0.181	10 ^{-7.46}	0.728
T6-2	1.04	10 ^{-10.9}	0.150	10 ^{-7.91}	0.599	10 ^{-8.97}	0.181	10 ^{-7.50}	0.722
After 60-day curing									
T1-6	1.18	10 ^{-9.22}	0.200	10 ^{-8.20}	0.330	10 ^{-9.11}	0.117	10 ^{-7.59}	0.602
T1-7	1.18	10 ^{-9.25}	0.198	10 ^{-8.13}	0.356	10 ^{-9.03}	0.131	10 ^{-7.51}	0.644
T2-5	1.04	10 ^{-9.51}	0.214	10 ^{-8.27}	0.368	10 ^{-8.84}	0.185	10 ^{-7.74}	0.605
T2-6	1.10	10 ^{-11.2}	0.073	10 ^{-8.30}	0.405	10 ^{-8.88}	0.210	10 ^{-7.45}	0.745
T3-5	1.03	10 ^{-7.70}	0.546	10 ^{-12.1}	0.002	10 ^{-8.93}	0.152	10 ^{-7.46}	0.682
T3-6	1.02	10 ^{-7.94}	0.474	10 ^{-12.1}	0.002	10 ^{-9.02}	0.140	10 ^{-7.56}	0.640
T4-5	1.00	10 ^{-10.9}	0.198	10 ^{-8.40}	0.425	10 ^{-9.27}	0.131	10 ^{-8.09}	0.503
T4-6	0.97	10 ^{-10.5}	0.179	10 ^{-8.44}	0.392	10 ^{-9.31}	0.121	10 ^{-8.10}	0.472
T6-5	1.04	10 ^{-10.6}	0.174	10 ^{-8.27}	0.475	10 ^{-9.04}	0.158	10 ^{-7.94}	0.572
T6-6	1.00	10 ^{-10.7}	0.162	10 ^{-8.45}	0.403	10 ^{-9.07}	0.149	10 ^{-8.29}	0.468

a. F indicates fraction of total mass released for each constituent in DIW leaching solution compared to initial mass of constituent in each monolith after 100 days leaching. Bold italic numbers in red indicate that the average fraction of total mass released from the monolith was higher than 20% of the initial mass of the constituent.

Table 6.7. Calculated Dry Bulk Density of Each Monolith and Averaged D_{eff} Values of ^{99}Tc , I^- , NO_3^- , and Na^+ from the Cumulative 28-Day to 100-Day Leaching in VZPW with Average Fraction of Released Mass in Duplicates of Individual Monolith Batch

Test Batch	Dry Bulk Density (g/cm ³)	VZPW Leaching Solution							
		⁹⁹ Tc <i>D</i> _{eff} [cm ² /s]	F ^(a)	I ⁻ <i>D</i> _{eff} [cm ² /s]	F	NO ₃ ⁻ <i>D</i> _{eff} [cm ² /s]	F	Na ⁺ <i>D</i> _{eff} [cm ² /s]	F
After 28-day curing									
T1-3	1.16	10 ^{-11.0}	0.155	10 ^{-7.87}	0.438	10 ^{-9.08}	0.066	10 ^{-7.47}	0.647
T1-4	1.18	10 ^{-11.0}	0.174	10 ^{-7.89}	0.458	10 ^{-9.09}	0.079	10 ^{-7.48}	0.677
T2-3	1.04	10 ^{-11.4}	0.149	10 ^{-7.95}	0.512	10 ^{-8.99}	0.165	10 ^{-7.47}	0.763
T2-4	1.04	10 ^{-11.5}	0.109	10 ^{-8.00}	0.463	10 ^{-9.00}	0.171	10 ^{-7.45}	0.743
T3-3	1.04	10 ^{-7.63}	0.642	10 ^{-12.1}	0.001	10 ^{-9.01}	0.137	10 ^{-7.34}	0.791
T3-4	1.03	10 ^{-7.88}	0.536	10 ^{-12.1}	0.002	10 ^{-9.10}	0.108	10 ^{-7.54}	0.675
T4-3	1.01	10 ^{-11.2}	0.179	10 ^{-8.27}	0.478	10 ^{-9.06}	0.111	10 ^{-8.00}	0.527
T4-4	1.02	10 ^{-11.3}	0.246	10 ^{-8.22}	0.622	10 ^{-9.06}	0.135	10 ^{-8.04}	0.627
T6-3	1.05	10 ^{-10.2}	0.076	10 ^{-7.76}	0.675	10 ^{-9.04}	0.158	10 ^{-7.46}	0.734
T6-4	1.05	10 ^{-10.3}	0.172	10 ^{-7.67}	0.691	10 ^{-9.04}	0.148	10 ^{-7.33}	0.798
After 60-day curing									
T1-8	1.16	10 ^{-9.05}	0.208	10 ^{-7.82}	0.432	10 ^{-9.00}	0.092	10 ^{-7.43}	0.648
T1-9	1.18	10 ^{-10.0}	0.188	10 ^{-7.96}	0.559	10 ^{-9.05}	0.117	10 ^{-7.78}	0.753
T2-7	1.06	10 ^{-9.50}	0.182	10 ^{-7.81}	0.547	10 ^{-8.93}	0.186	10 ^{-7.29}	0.816
T2-8	1.07	10 ^{-9.13}	0.216	10 ^{-7.81}	0.556	10 ^{-9.05}	0.173	10 ^{-7.31}	0.833
T3-7	1.02	10 ^{-8.88}	0.360	10 ^{-12.1}	0.002	10 ^{-9.05}	0.096	10 ^{-8.26}	0.456
T3-8	1.04	10 ^{-7.79}	0.541	10 ^{-12.1}	0.002	10 ^{-9.09}	0.109	10 ^{-7.48}	0.692
T4-7	0.97	10 ^{-10.7}	0.215	10 ^{-8.16}	0.481	10 ^{-9.02}	0.105	10 ^{-8.02}	0.515
T4-8	0.97	10 ^{-11.2}	0.234	10 ^{-8.21}	0.483	10 ^{-9.01}	0.123	10 ^{-8.12}	0.523
T6-7	1.05	10 ^{-10.3}	0.154	10 ^{-7.74}	0.640	10 ^{-9.09}	0.129	10 ^{-7.50}	0.690
T6-8	1.06	10 ^{-10.8}	0.108	10 ^{-7.60}	0.675	10 ^{-8.97}	0.144	10 ^{-7.30}	0.780

a. F indicates fraction of total mass released for each constituent in VZPW leaching solution compared to initial mass of constituent in each monolith after 100 days leaching. Bold italic numbers in red indicate that the average fraction of total mass released from the monolith was higher than 20% of the initial mass of the constituent.

6.2.1 ^{99}Tc Leachability in DIW and VZPW Leaching Solution

The results for the cumulative 100-day leaching for ^{99}Tc in DIW are shown in Figure 6.2. Since T5 monoliths prepared from the current Cast Stone formulation (OPC, BFS, and FA) did not completely set after either 28 or 60 days (Figure 4.3), T5 monoliths were not used for EPA Method 1315 leach tests. In general, $^{99}\text{Tc } D_{eff}$ values for the LSWG monoliths showed an increasing trend during early leaching periods up to 7–14 days, followed by a gradual decrease in D_{eff} values through the remainder of the cumulative 100-day leach period. Although most of the monoliths showed severe cracks by the end of the 100-day leach period, $^{99}\text{Tc } D_{eff}$ values after 28-day leaching still show relatively low D_{eff} values, with a range of 10⁻⁹ to 10⁻¹⁴ cm²/s, which is much lower than average D_{eff} values for nonreactive NO_3^- , ~10⁻⁹ cm²/s (Table 6.7). Only T3 monoliths, cured 28 or 60 days, showed relatively high $^{99}\text{Tc } D_{eff}$ values up to 63 days leaching, likely due to severe cracks that formed after 7 days of leaching (See Appendix A.1). T3 monoliths were also prepared with iodine getter (Ag-zeolite), but showed the highest $^{99}\text{Tc } D_{eff}$ values compared to the other LSWG formulations. T1 and T2 monoliths showed the lowest $^{99}\text{Tc } D_{eff}$ values (Figure 6.2), because T1 monoliths were prepared with relatively lower w/dm ratio (0.6 vs. 0.75) and T2

monoliths were prepared with Xypex that worked as a filler for reducing bulk porosity. A similar effect of reducing porosity by adding Xypex was also reported by Alex et al. (2015). In addition, T2 monoliths cured 28 days (T2-1 and T2-2) did not show any significant cracks; however, one of the T2 monoliths cured 60 days (T2-5) formed severe cracks (See Appendix A.1), resulting in relatively higher ^{99}Tc D_{eff} values compared to its pair, the T2-6 monolith, which did not form cracks despite being prepared under the same formulation and curing conditions. Even though T6 monoliths were prepared with ^{99}Tc getter (Sn-apatite), ^{99}Tc D_{eff} values of T6 monoliths were not much lower than the ^{99}Tc D_{eff} for others, except T3 monoliths, because of the severe cracks formed. More cracks were found in monoliths cured 60 days than in 28-day cured monoliths. However, different curing times between 28 and 60 days did not significantly affect ^{99}Tc D_{eff} values and showed similar trends in D_{eff} values up to 100 days leaching.

Figure 6.2. Effective Diffusivity Values of ^{99}Tc from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in DIW (left: 28 days; right: 60 days)

Although the release of ^{99}Tc from most of the HL-based monoliths here is not considered to follow a pure diffusion trend due to the presence of cracks, the ^{99}Tc release at later stages of leaching (>28 days) are much lower and likely caused by chemical reactions. Potential chemical reactions that slow release of ^{99}Tc were also suggested in previous HL-based grout leach testing by Um et al. (2016). Um et al. (2016) hypothesized that the chemical reactions could be (1) ^{99}Tc incorporation into ettringite in either the pre-leached cured grout or incorporation into newly formed ettringite from transformation of portlandite during the active leaching stage, (2) ion exchange between ^{99}Tc and sulfate in ettringite, (3) ^{99}Tc removal by continuous and slow hydration reactions in the HL-based grouts, or (4) continuous, slow ^{99}Tc reduction (or incorporation into mineral phase) by slow dissolution of BFS. Recent independent batch test results for ^{99}Tc removal using co-precipitation with formation of ettringite showed much higher ^{99}Tc removal from solution was possible under reducing conditions than under oxidizing conditions (Um et al. 2017). No other mineral, other than ettringite, was found in the filtered co-precipitate. Continuous immobilization of ^{99}Tc by co-precipitation with ettringite is considered to occur as long as reducing conditions exist. It appears that slow dissolution of BFS, even in the presence of cracks, is occurring that reduces $^{99}\text{Tc(VII)}$ to insoluble Tc(IV) solids.

In addition, the extended leaching test and analysis were conducted for the monoliths prepared for EPA Method 1315 leaching in FY 2015 up to 406 days leaching. However, no severe cracks were found in any monoliths prepared with HL grout formulations when the liquid waste was WTP simulant (See Appendix A.1). Because the measured sulfate concentrations were 122 g/L and 240 g/L for WTP and EMF/CS simulants, respectively, a 20% HL addition to prepare monoliths in FY 2015 was enough to form adequate early stage ettringite such that no cracks were formed even after 406 days leaching. More

details on these extended EPA Method 1315 leaching tests and subsequent solids characterization are found in Appendix A.5.

The results for the cumulative 100-day leaching for ^{99}Tc in VZPW are shown in Figure 6.3. Even though lower ^{99}Tc D_{eff} values were reported for VZPW compared to DIW in previous work (Serne et al. 2015; Um et al. 2016), similar ^{99}Tc D_{eff} values were found here between DIW and VZPW leaching solutions due to the severe cracks formed. White secondary precipitates were also found on the surface of monoliths after 100 days leaching (See Appendix A.1), but the sealing effect of these secondary precipitates was likely overcome by the presence of severe cracks.

Figure 6.3. Effective Diffusivity Values of ^{99}Tc from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in VZPW (left: 28 days; right: 60 days)

6.2.2 ^{127}I Leachability in DIW or VZPW Leaching Solutions

The results for the cumulative 100-day leaching for ^{127}I in DIW or VZPW are shown in Figure 6.4. Except for T3 monoliths, ^{127}I D_{eff} values for LSWG monoliths showed a very similar leaching trend in both DIW and VZPW leachants and for both cure times, 28 and 60 days. Because I getter (Ag-zeolite) was present in the T3 monoliths, ^{127}I D_{eff} values for T3 monoliths were 3–4 orders of magnitude lower than those of the other LSWGs in later stages of DIW leaching (>28 days). Ag-zeolite worked well to immobilize ^{127}I in T3 monoliths even though some cracks were formed during the cumulative 100-day leaching period (See Appendix A.1). In addition, the fraction of total ^{127}I mass released in DIW and VZPW leaching solution was much higher than 20% in most of monoliths tested here except for the T3 monoliths (Table 6.6 and Table 6.7). Therefore, the calculated ^{127}I D_{eff} values should be used only for qualitative understanding of ^{127}I diffusion from LSWG monoliths that do not contain the I-getter.

Figure 6.4. Effective Diffusivity Values of ^{127}I from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in DIW or VZPW

6.2.3 Leachability of NO_3^- in DIW or VZPW Leaching Solutions

The results for the cumulative 100-day leaching for NO_3^- in DIW or VZPW are shown in Figure 6.5. Calculated D_{eff} values for NO_3^- for each leaching interval up to 100-day leaching and averaged D_{eff} values from 28 days to 100 days in both DIW and VZPW leaching solutions are shown in Table 6.2–Table 6.7. In general, average D_{eff} values for NO_3^- in DIW showed a very similar trend for the 28- and 60-day cured monoliths (Figure 6.5 and Table 6.6), with D_{eff} values ranging from $10^{-9.5}$ – $10^{-8.8}$ cm^2/s . These NO_3^- D_{eff} values are higher-than-average ^{99}Tc D_{eff} values ($10^{-12.0}$ – $10^{-9.2}$ cm^2/s) for most monoliths because NO_3^- is highly mobile and serves as a nonreactive tracer. In VZPW leaching solution, the average NO_3^- D_{eff} values fluctuated more and were slightly lower than the DIW NO_3^- D_{eff} values, which is attributed to some NaNO_3 salt precipitate formation upon reaction with VZPW. However, low uncertainty in the calculated D_{eff} values for NO_3^- is supported by the fact that less than 20% of total NO_3^- mass released in both DIW and VZPW leaching solutions, as shown in Table 6.6 and Table 6.7, respectively.

Figure 6.5. Effective Diffusivity Values of Nitrate from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in DIW or VZPW

6.2.4 Leachability of Na^+ and Other Measurements in DIW or VZPW Leachates

Average Na^+ D_{eff} values in both DIW and VZPW leaching solutions for the cumulative 100-day leaching are much higher than average D_{eff} values of other constituents of interest, ^{99}Tc , ^{127}I , and NO_3^- . In all the LSWG monoliths, the fraction of total Na^+ mass released from 28-day to 100-day leaching is much higher than 20% (Table 6.6 and Table 6.7). This is likely due to the formation of soluble white precipitates, thenardite (Na_2SO_4) or mirabilite (hydrated thenardite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$), on the surface of monoliths (Figure 4.2 and Figure 4.4), which contribute to the high uncertainty values of D_{eff} for Na^+ in both DIW and VZPW. Increasing sulfate concentrations in the leachates were also found up to 14 days or 28 days in the early leaching period (See Appendix A.2). A second possibility for the high fraction release of the assumed starting mass of the Na^+ is the dry blend ingredients likely contain leachable Na^+ that is not considered in the Na^+ $C(0)$ value used in the calculations of effective/observed diffusivity and Na^+ mass released. Therefore, the calculated Na^+ D_{eff} values in DIW and VZPW leaching solution may be lower than calculated or if the leachable Na^+ content of the dry blend is small then the calculated Na^+ D_{eff} values should be corrected for inventory depletion. In either case the reported Na^+ D_{eff} values should be used only for qualitative comparison. Additional cations and anions measured in EPA 1315 Method leaching tests can be found in Appendix A.2.

Other measurements, including pH, EC, and alkalinity, were made for each leachate and individual monolith at each leaching interval. The measured pH in the DIW and VZPW leachates showed a range between 10.4 and 12.5. Initial leachate pH values were relatively low, but the measured pH levels after 7 days leaching stabilized close to pH 12–12.5 in both leachants. The measured ECs in DIW and VZPW leaching solutions were initially low, 0.9 and 3.0 mS/cm, respectively, increasing up to 4–5 mS/cm in DIW and 6–7 mS/cm in VZPW as the leaching time increased, indicating that there were some broken pieces and significant dissolution occurring for most monoliths during the 100-day cumulative leaching period. Alkalinity (measured as CaCO_3) values were already as high as 50–100 mg/L at the 2 h interval in both DIW and VZPW leaching solutions, and continuously increased with cumulative leaching time up to 28 days because of loose carbonate-containing solids that continuously leach hydroxyl and carbonate ions. However, alkalinity values in both leachates showed a decreasing trend after 28-day leaching through 100-day leaching. This decrease in alkalinity is attributed to precipitation of carbonate minerals (aragonite and calcite) and/or gypsum. Similar decreasing trends of Ca^{2+} and SO_4^{2-} concentrations were also observed in both leaching solutions after the 28-day or 42-day leaching period. Additional pH values and other measurements are found in Appendix A.4.

6.2.5 Post Characterization for Mineralogy after 100 Days Leaching

The XRD patterns of 28-day and 60-day cured monoliths after 100-day leach testing are shown in Figure 6.6 along with the reference pattern for TiO_2 (rutile). Quantitative analysis of XRD patterns collected from samples with added TiO_2 reference material is provided in Table 6.8. All leached LSWGs showed ettringite [$\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26\text{H}_2\text{O}$] as the primary crystalline phase, with a range of content from 27 to 39 wt% in both 28- and 60-day cured monoliths. Compared to the mineral content of initial monoliths before leaching (Table 4.2), all leached LSWG monoliths showed an increase in ettringite and calcite content and a decrease in portlandite and gypsum content after 100 days leaching (Table 6.8). Portlandite content was significantly reduced to 0–2 wt% after 100 days leaching, indicating continuous formation of ettringite from portlandite transformation after reaction with sulfate. Late and continuous formation of ettringite can be considered as a major contributor to crack growth and additional immobilization of ^{99}Tc . Similar results of increasing ettringite content with decreasing portlandite content were also found in the 406-day leached FY 2015 monoliths. Additional post-test characterization of these FY 2015 monoliths after 406-day leaching are found in Appendix A.5.

Table 6.8. XRD Analysis for Mineral Content of 100-Day Leached Monoliths

Test #	Curing Time (day)	XRD Analysis (wt%)(a)								
		Ettringite	Portlandite	Calcite	Larnite	Brucite	Hydrocalumite	Dolomite	Gypsum	CSH(b)
T1-1	28	27	1.6	9.2	3.4	-	0.4	-	-	58.4
T1-3	28	27	0.4	11.0	3.0	3.4	-	-	5.1	50.1
T2-1	28	29	0.6	14.0	3.3	-	-	-	4.1	49.0
T2-3	28	29	-	10.0	3.8	1.6	-	-	6.8	48.8
T3-1	28	31	0.4	12.0	3.4	-	-	-	-	53.2
T3-3	28	35	0.6	10.0	4.2	-	-	-	-	50.2
T4-1	28	33	-	6.3	3.7	-	-	-	-	57.0
T4-3	28	35	-	7.1	3.2	-	-	-	2.6	52.1
T6-1	28	38	-	13.0	5.2	-	-	-	1.1	42.7
T6-3	28	29	0.6	9.8	4.9	1.6	-	-	6.5	47.6
T1-6	60	31	2.3	9.5	5.1	-	-	-	-	52.1
T1-8	60	32	1.2	8.6	4.8	1.2	-	-	3.4	48.8
T2-5	60	30	-	7.7	3.5	-	-	1.1	-	57.7
T2-7	60	32	0.8	7.4	3.2	2.2	-	-	7.5	46.9
T3-5	60	33	-	6.5	2.5	-	-	-	-	58.0
T3-7	60	34	-	5.6	2.1	1.8	-	-	3.6	52.9
T4-5	60	30	-	6.7	2.6	-	-	-	-	60.7
T4-7	60	34	-	6.7	3.5	1.3	-	-	3.0	51.5
T6-5	60	32	0.5	7.3	4.9	-	-	-	-	55.3
T6-7	60	39	-	7.8	4.9	1.9	-	-	3.4	43.0

(a) Chemical formulas of minerals: ettringite $[\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26\text{H}_2\text{O}]$, portlandite $[\text{Ca}(\text{OH})_2]$, calcite $[\text{CaCO}_3]$, larnite $[\text{Ca}_2\text{SiO}_4]$, brucite $[\text{Mg}(\text{OH})_2]$, hydrocalumite $[\text{Ca}_4\text{Al}_2(\text{OH})_{12}(\text{OH})_2\cdot 6\text{H}_2\text{O}]$, dolomite $[\text{CaMg}(\text{CO}_3)_2]$, gypsum $[\text{CaSO}_4\cdot 2\text{H}_2\text{O}]$, and quartz $[\text{SiO}_2]$

(b) CSH: calcium silicon hydrated amorphous phase

(-) not detected

Figure 6.6. XRD Patterns of 100-Day Leached White Precipitates Formed on the 28-Day Cured (left) and 60-Day Cured (right) Monoliths after 100-Day Leaching

7.0 ⁹⁹Tc Desorption K_d Measurements

This section presents time dependent ⁹⁹Tc desorption K_d measurements performed after an initial 30-day sorption phase. Preliminary ⁹⁹Tc sorption tests were conducted using non-⁹⁹Tc-spiked T7 monolith crushed material. After the initial 30-day adsorption phase, the ⁹⁹Tc-laden T7 material was used to perform ⁹⁹Tc desorption K_d tests. Sorption testing was performed under reducing conditions to maximize ⁹⁹Tc sorption, whereas desorption tests were performed under oxidizing conditions.

7.1 Methods and Materials

For all ⁹⁹Tc sorption and desorption tests, non-⁹⁹Tc-spiked monolith T7 material was used. Monolith T7 was prepared with 20% HL, 35% OPC, and 45% BFS at a w/dm ratio of 0.6 using EMF/CS simulant.

7.1.1 ⁹⁹Tc Sorption and Desorption K_d using Three Aliquots of Non-⁹⁹Tc-Spiked Cementitious Material

7.1.1.1 Material Preparation

After 28 days of curing, one T7 monolith was removed from its form and transferred to an anoxic chamber filled with a mixture of N₂ (98%) and H₂ (2%) gases and with a palladium catalyst to maintain an O₂-free environment (<20 ppm O₂). Once in the chamber, the most internal solid portion of the T7 monolith was reduced to a size fraction of 0.3–2 mm using a mortar and pestle. The crushed material was then size fractionated by dry sieving. Effort was made to avoid near-surface material, which may have oxidized during the curing or crushing process. A portion of this ground material was used to determine the MC of the size-reduced powders, determined to be 28.3% by weight (Eq. 4.1). Size-reduced material was stored in a sealed container in the anoxic chamber until needed.

7.1.1.2 ⁹⁹Tc Sorption Phase Using non-⁹⁹Tc-Spiked Cementitious Material

A Ca(OH)₂-saturated solution pre-equilibrated with 0.3–2 mm size-reduced T7 monolith material was used for all ⁹⁹Tc sorption and desorption experiments. The pre-equilibration step was used to prevent large changes in pH and aqueous chemistry composition during the sorption phase in hopes of minimizing other processes, such as ⁹⁹Tc precipitation, that could affect the desorption behavior and change the pH of the Ca(OH)₂-saturated solution (Almond et al. 2012, Kaplan 2010). The Ca(OH)₂-saturated solution simulates young/moderately aged cement pore solution and was prepared by adding approximately 15 g of reagent grade Ca(OH)₂(s) to 1.5 liters of DIW that had been purged with N₂ (98%) and H₂ (2%) gases. After stirring for at least 7 days in the anoxic chamber, the Ca(OH)₂-saturated solution was filtered using a 0.45 μm filter into a separate container. To the filtered Ca(OH)₂-saturated solution, 0.3–2 mm size-reduced T7 monolith was added at a 1 g/ 40 mL ratio inside the anoxic chamber. Over the course of at least 5 days, the solid material was allowed to react in solution, shaken periodically to promote mixing. After 5 days of reaction, the pH and E_h of the solution were measured. If the E_h was below –400 mV (SHE corrected) no more reaction time was required; however, if above –400 mV, the reaction time was extended until the target E_h (<–400 mV) was reached. Once the desired low E_h was reached, 1 L of equilibrated Ca(OH)₂-saturated solution was transferred to a separate container and spiked with 0.1 μL–0.1 mL of 10–10,000 ppm ⁹⁹Tc using NaTcO₄ (or NH₄TcO₄) stock solution to achieve a final concentration of 1 ppb ⁹⁹Tc.

All ^{99}Tc sorption phase of the batch experiments were performed inside the anoxic chamber. About 21 mL of the ^{99}Tc (1.0 ppb)-spiked $\text{Ca}(\text{OH})_2$ solution was added to a 50 mL centrifuge tube containing ~3 g of 0.3–2 mm size-reduced T7 monolith powder to achieve a solid-to-solution ratio of 3 g/21 mL. In total, twelve 50 mL centrifuge tubes were prepared for the sorption phase testing that is followed by the desorption phase, which requires triplicate samples for four different reaction times (30, 54, 90, and 120 days). Triplicate control samples, containing 21 mL of the ^{99}Tc (1.0 ppb)-spiked $\text{Ca}(\text{OH})_2$ solution in 50 mL centrifuge tubes without solids, were also prepared. The total sorption reaction time was 30 days, which was previously determined to be enough time for ^{99}Tc in this size fraction to reach steady state (Um et al. 2016). Over the course of the sorption phase, the centrifuge tubes were shaken within the anoxic chamber by hand for ~15 seconds once a day between days 0 and 7 and twice a week between days 7 and 29.

After reacting for 30 days, capped sorption samples were briefly transferred outside the anoxic chamber to be centrifuged for 15 minutes at 5,000 rpm in order to separate the supernatant and solid material. Then, the centrifuged tubes were carefully moved back inside the anoxic chamber without disturbing the settled solids and a ~15 mL aliquot of supernatant was filtered using a 0.45 μm syringe filter. A 2 mL subsample of filtered supernatant was then transferred to a 20 mL plastic vial and spiked with 0.02 mL of ultrapure nitric acid before it was submitted for ^{99}Tc analysis by ICP-MS. These acidified samples were stored in the refrigerator (outside the chamber) until ICP-MS analysis. Inside the anoxic chamber, a second filtered aliquot was used to measure the E_h and pH. The measured E_h values, using a Hanna E_h probe, were SHE corrected by adding +208 mV to the recorded value. The remainder of the filtered subsample was archived inside the anoxic chamber.

The ^{99}Tc sorption coefficient, K_d , was calculated according to Equation (7.1) below:

$$K_d = \frac{(C_i - C_t)V}{C_t m_{\text{solid}}} \quad (7.1)$$

where C_i is the initial aqueous total ^{99}Tc concentration ($\mu\text{g/mL}$) in the supernatant determined from the control samples, C_t is the final aqueous equilibrated ^{99}Tc concentration ($\mu\text{g/mL}$), V is the solution volume in the final equilibrated suspension (mL), and m_{solid} is the dry solid mass of the sample (g). The dry solid mass was corrected by the determined MC for this size fraction (Section 7.1.1.1).

7.1.1.3 Desorption ^{99}Tc K_d Measurements using ^{99}Tc -Sorbed Cementitious Material

The same crushed T7 monolith material samples used to measure sorption K_d values were used for ^{99}Tc desorption tests. Four different desorption reaction times (30, 54, 90, and 120 days) were used under oxidizing conditions in air; tubes were on the bench top and no longer in the anoxic chamber. An equilibrated $\text{Ca}(\text{OH})_2$ -saturated solution was prepared according to the procedure described in Section 7.1.1.2, but under oxidizing conditions (outside the anoxic chamber) in air with a target E_h value greater than +250 mV (SHE corrected). After removing as much solution as possible from the centrifuge tubes used for the 30-day ^{99}Tc sorption phase of testing, the weight of the wet slurry remaining in each 50 mL centrifuge tube was recorded before the ^{99}Tc desorption process was started. Desorption testing was started by adding 21 mL of equilibrated $\text{Ca}(\text{OH})_2$ -saturated solution (prepared under oxidizing conditions) into the centrifuge tube containing the ^{99}Tc -laden crushed T7 monolith material. The desorption vials were also shaken by hand for ~15 seconds daily for the first week, after which they were shaken one to two times per week. In addition, once a week the samples were sparged with air for one hour and then weighed. Mass lost due to evaporation or entrainment in escaping air bubbles during the air sparging was replenished with fresh equilibrated $\text{Ca}(\text{OH})_2$ -saturated solution to maintain a constant sample weight for a constant solid-to-solution ratio. Four desorption reaction times (30, 54, 90, and 120 days) were tested, with triplicate samples prepared for each reaction time. After the target desorption reaction period was

reached, the desorption tubes were centrifuged and ~15 mL of supernatant was removed from each tube using a pipette and then filtered using a 0.45 µm syringe filter. A 2 mL filtered subsample was spiked with 0.02 mL of ultrapure nitric acid and stored in a refrigerator before ⁹⁹Tc concentration analysis by ICP-MS. The remaining filtered aliquot was divided between two separate containers: one for pH and E_h analysis and one as an archive. For E_h analysis, a YSI E_h probe was used, requiring +211 mV be added to the recorded E_h value for SHE correction, according to the YSI probe manual.

The desorption ⁹⁹Tc K_d was calculated using Equation (7.2),

$$K_d = \frac{C_s}{C_t} = \frac{\left(\frac{m_r}{V} - C_t\right)V}{m_{solid}C_t} \quad (7.2)$$

where C_s is the final ⁹⁹Tc concentration (µg/g) on the solid after the desorption test. C_s is determined by taking the difference between the initially sorbed ⁹⁹Tc mass on the solids after the sorption phase of the test and the final ⁹⁹Tc mass in the desorption solution at steady state. C_t is the final aqueous ⁹⁹Tc concentration for the desorption test (µg/mL), and m_r is the remaining ⁹⁹Tc mass (µg) in the sorption tube before starting the desorption experiment. m_r was calculated by multiplying the desorption aqueous total ⁹⁹Tc concentration by the remaining solution (mL) in the sorption phase, based on the weight of slurry before starting desorption, and subtracting this value from the total ⁹⁹Tc mass on the solid at the start of the desorption experiment. To determine the total ⁹⁹Tc mass on the solid at the start of the desorption experiment, the average total ⁹⁹Tc concentration determined from the sorption control samples was multiplied by the starting sorption supernatant volume, and any ⁹⁹Tc mass removed through supernatant removal at the start of the desorption tests was subtracted. Finally, V is the total solution volume in the final equilibrated desorption suspension (including the residual volume of sorption liquid plus the ~21 mL of fresh desorption solution added) (mL) and m_{solid} is the dry solid mass (g) of the crushed cementitious material. We assume no cementitious mass is lost during all the tube manipulations (centrifuging, and removing supernatant solutions for filtering).

7.2 Results and Discussion

7.2.1 ⁹⁹Tc Sorption on Non-⁹⁹Tc-Spiked Monolith Crushed Material

All ⁹⁹Tc sorption tests were conducted inside an anoxic chamber to maintain reducing conditions. The pH and E_h values of the initial ⁹⁹Tc (1.0 ppb)-spiked Ca(OH)₂ solution were determined to be 12.36 and -593.6 mV (SHE corrected), respectively. At the end of the sorption test, pH and E_h measurements were collected for each supernatant and the E_h measurements SHE corrected by adding +208 mV to the measured value. These pH and SHE-corrected E_h values are tabulated in Table 7.1. For all samples containing crushed monolith, the measured pH values for supernatants were ~12.6 and E_h (SHE corrected) values fell in the range of -431 to -452 mV. Control samples, with no solid powders added, were similar, with pH ~12.5 and slightly elevated E_h values between -493 and -518 mV. When compared to the initial conditions recorded for the ⁹⁹Tc (1.0 ppb)-spiked Ca(OH)₂ solution, these values indicate that no significant chemical changes occurred during sorption testing and constant reducing conditions ($E_h < -400$ mV[(SHE)]) were maintained.

The ⁹⁹Tc concentrations measured in the supernatant collected from sorption supernatants after 30 days of testing are presented in Figure 7.1. The initial concentration of ⁹⁹Tc present in solution, 1.19 µg/L, is the average concentration calculated from the measured ⁹⁹Tc concentrations for the three control samples and is close to the target ⁹⁹Tc concentration of 1.0 µg/L. Furthermore, this concentration and the absence of visible precipitates, e.g., black TcO₂(s), suggests that ⁹⁹Tc remains soluble in the control samples and that the reducing conditions used are not low enough to facilitate TcO₂(s) precipitation. For all sorption

samples containing T7 monolith powders, the measured ^{99}Tc concentration in the supernatant was below $0.066\ \mu\text{g/L}$, the EQL for ICP-MS ^{99}Tc analysis. That is all ^{99}Tc concentrations in the adsorption phase supernatants were below the limit of detection for ^{99}Tc . This implies that ^{99}Tc was completely removed from solution by sorption after the 30-day reaction period, consistent with sorption testing results for identical dry mix and w/dm ratio conditions using WTP off-gas condensate simulant in FY 2015 (Um et al. 2016). The calculated ^{99}Tc sorption K_d values for individual samples are provided in Table 7.1 and the average of these ^{99}Tc sorption K_d values is $165 \pm 1\ \text{mL/g}$. It is important to note that the ICP-MS EQL has an approximately inverse linear impact on the calculated sorption K_d ; thus, by improving the EQL to $0.033\ \mu\text{g/L}$, the sorption K_d value for non-detectable ^{99}Tc samples would nearly double. This EQL impact is marginal and within experimental error with desorption K_d measurements; therefore, reducing the EQL value for ND sorption samples was not a concern for this work.

Table 7.1. K_d , pH, and E_h Results from ^{99}Tc Sorption and Desorption Tests^(a)

^{99}Tc Sorption Tests				^{99}Tc Desorption Tests				
Sample Name	pH	SHE Corrected E_h (mV)	K_d (mL/g)	Sample Name	pH	SHE Corrected E_h (mV)	K_d (mL/g)	Average K_d (mL/g)
KS-S1-D30	12.6	-432	165	KD-S1-D30	12.5	147.0	21.3	21.7 ± 0.6
KS-S2-D30	12.6	-431	166	KD-S2-D30	12.5	146.2	21.4	
KS-S3-D30	12.6	-432	166	KD-S3-D30	12.5	146.3	22.4	
KS-S1-D60	12.6	-441	165	KD-S1-D60	12.5	154.6	22.8	22.1 ± 0.8
KS-S2-D60	12.6	-440	166	KD-S2-D60	12.4	156.9	22.3	
KS-S3-D60	12.6	-443	166	KD-S3-D60	12.4	156.4	21.3	
KS-S1-D120	12.6	-451	165	KD-S1-D120	12.2	160.3	21.4	24.0 ± 3.6
KS-S2-D120	12.7	-436	166	KD-S2-D120	12.2	159.2	28.1	
KS-S3-D120	12.6	-449	165	KD-S3-D120	12.2	157.2	22.4	
KS-S1-D150	12.6	-448	165	KD-S1-D150	12.2	163.3	35.4	35.0 ± 0.9
KS-S2-D150	12.6	-425	166	KD-S2-D150	12.2	162.9	35.7	
KS-S3-D150	12.6	-452	165	KD-S3-D150	12.2	159.4	33.9	
KS-C1	12.5	-493	N/A					
KS-C2	12.5	-498	N/A					
KS-C3	12.5	-518	N/A					

a. Label format for ^{99}Tc sorption samples: KS-S#(for different samples)-D#(for different desorption reaction times). Label format for ^{99}Tc desorption test: KD-S1/2/3(for different samples)-D30/60/120/150(for different target desorption reaction times). "C" indicates the control sample for ^{99}Tc K_d sorption tests. Actual reaction times are 30, 54, 90, and 120 days for samples labeled as 30, 60, 120, and 150 respectively. NA = not applicable; no sorbing solids in control tubes.

Figure 7.1. ⁹⁹Tc Concentrations in the Supernatants after 30-Day Sorption Testing. The black dashed line indicates the average initial ⁹⁹Tc concentration [µg/L] in the supernatant at the start of sorption testing determined from the average concentration values for control samples (KS-C1, KS-C2, and KS-C3). The red dashed line represents the EQL for ⁹⁹Tc analysis by ICP-MS, 0.066 µg/L.

7.2.2 ⁹⁹Tc Desorption K_d s using ⁹⁹Tc Sorbed Monolith Powders

The wet slurry remaining from the ⁹⁹Tc sorption phase of testing was used for ⁹⁹Tc desorption testing by refilling the sorption sample vials with 21 mL of equilibrated, saturated Ca(OH)₂ solution under oxidizing conditions for four reaction times (30, 54, 90, and 120 days). Before starting the desorption phase of testing, the pH and E_h of the oxidized and equilibrated, saturated Ca(OH)₂ solution were measured and determined to be 12.5 and +264 mV (SHE corrected), respectively. At the end of each desorption reaction period, the pH and SHE-corrected E_h of each respective filtered supernatant solution were determined (Table 7.1). The final pH values measured following desorption testing ranged from 12.2 to 12.5 and SHE-corrected E_h values ranged from 146 to 163 mV. Despite the 100 mV decrease in E_h measured at the end of the desorption test relative to the start, oxidizing conditions ($E_h > 100$ mV, SHE corrected) and consistent pH conditions were maintained in all samples throughout desorption testing.

For all desorption samples, ⁹⁹Tc concentrations above the EQL level were measured and are shown in Figure 7.2. These values were used to determine individual sample ⁹⁹Tc desorption K_d values and average K_d values for each desorption testing period, which are reported in Table 7.1. Interestingly, the average ⁹⁹Tc desorption K_d value increased slightly to 35.0 mL/g after 120 days, whereas average K_d values for shorter reaction periods, up to 90 days, ranged from 21.7 ± 6 to 24.0 ± 3.6 mL/g, but remain within error of each other. This increase in ⁹⁹Tc desorption K_d after 120 days implies that less ⁹⁹Tc partitions into the aqueous phase and that some ⁹⁹Tc presumably desorbed during early reaction periods resorbs to the solid monolith material at the later desorption times. We attribute this increase in sorption with time to the slow dissolution of residual BFS that reduces Tc(VII) in solution and promotes sorption or precipitation of Tc(IV) species. Unfortunately, this finding also indicates that ⁹⁹Tc desorption did not reach equilibrium in these long-term batch tests; therefore, additional desorption testing with longer reaction times perhaps over years is required to determine whether ⁹⁹Tc desorption, and possible resorption, reaches equilibrium. Finally, the average ⁹⁹Tc desorption K_d value (25.7 ± 5.9 mL/g), calculated from all 12 samples under

oxidizing conditions (+264 mV), is similar to that (24 ± 5.4 mL/g) found in previous tests published by Um et al. (2016). These values are likely higher than ^{99}Tc desorption K_d values (0–10 mL/g) reported by Kaplan (2010) for oxidizing cementitious solids because the added BFS in these 12 samples is still acting as strong ^{99}Tc reductant.

Figure 7.2. ^{99}Tc Concentrations ($\mu\text{g/L}$) Measured in the Filtered Supernatants Collected after Desorption Testing Periods. Sample names containing D60, D120, and D150 correspond with actual testing times equal to 54, 90, and 120 days, respectively.

8.0 ⁹⁹Tc Solubility Measurements

This section presents ⁹⁹Tc (mol/L) solubility measurements for size-reduced non-⁹⁹Tc-spiked (T7) and ⁹⁹Tc-spiked (T1) monolith material contacted with simulated pore water solutions spiked with various concentrations of ⁹⁹Tc. Measurements were determined using the test method recommended by Estes et al. (2012) under reducing conditions. The hypothesis of this method is as follows: if the equilibrium aqueous ⁹⁹Tc concentration is controlled by the solubility of a ⁹⁹Tc(IV)-bearing solid phase, then the ⁹⁹Tc equilibrium concentration should be independent of the initial ⁹⁹Tc concentration added to each LSWG batch system. In Estes et al. (2012) and Um et al. (2016), solubility tests were performed using only non-radiological crushed cementitious material; however, in this test both crushed non-⁹⁹Tc-spiked (T7) and crushed ⁹⁹Tc-spiked (T1) LSWG were used to provide a direct comparison between ⁹⁹Tc solubility in the presence and absence of ⁹⁹Tc within the cured LSWG. The aqueous ⁹⁹Tc concentrations in the supernatant collected from each batch test are expected to converge to a single ⁹⁹Tc concentration after achieving steady state, despite different starting aqueous ⁹⁹Tc concentrations, under reducing and fixed pH conditions (Estes et al. 2012).

8.1 Methods and Materials

8.1.1 Material Preparation

All ⁹⁹Tc batch solubility experiments were conducted in an anoxic chamber filled with a mixture of N₂ (98%) and H₂ (2%) gases, and with two palladium catalysts that convert O₂(g) to water via reaction with H₂(g). After curing for 28 days, LSWG monoliths T1 (⁹⁹Tc spiked) and T7 (non-⁹⁹Tc spiked) were removed from their forms and size reduced to 0.3–2 mm using chemically inert instruments to crush and grind the monoliths inside the anoxic chamber (Section 7.1.1.1). The ⁹⁹Tc-loading within T1 after curing for 28 days was determined to be 7.46 µg/g (Section 4). The average MCs of the two cured monoliths were determined to be 26.6 ± 1.2% and 28.3 ± 1.4 % for T1 and T7, respectively. The MC measurements were conducted using 0.3–2 mm size fraction. Solubility tests were performed using the pre-equilibrated Ca(OH)₂-saturated solution prepared under anoxic conditions as described in Section 7.1.1.2 and spiked with different concentrations of ⁹⁹Tc(VII). Specifically, three solutions were prepared with ⁹⁹Tc(VII) concentrations equal to 2.0, 20, and 200 µg/L (or ppb) by adding 25 µL, 250 µL and 2.5 mL of 100 ppm ⁹⁹Tc stock solution to 1,250 mL of pre-equilibrated saturated Ca(OH)₂ solutions, respectively.

8.1.2 ⁹⁹Tc Solubility Measurements

In 50 mL centrifuge tubes, 40 mL of ⁹⁹Tc(VII)-spiked saturated Ca(OH)₂ solution was combined with 1 g of size-reduced monolith material to achieve a solid-to-solution ratio of 1 g/40 mL for each ⁹⁹Tc-spiked solution prepared and each monolith, T1 and T7. Triplicate reaction tubes for each crushed LSWG, each starting ⁹⁹Tc concentration, and each reaction time were prepared. In addition, triplicate control samples (three for each of the three initial ⁹⁹Tc concentrations, for a total of nine) consisting of 40 mL of the 2.0, 20, and 200 ppb ⁹⁹Tc(VII)-spiked Ca(OH)₂ solution in a 50 mL centrifuge tube were also prepared and reacted in parallel. Four different solubility reaction times, 30, 60, 120, and 150 days, were initially chosen to provide data. All the tubes were hand shaken (inside the anoxic chamber) daily in the first week and then 1–2 times per week thereafter. After each reaction time was reached, the supernatant was removed from the slurry, after settling overnight, using a pipette and then filtered using a 0.45 µm syringe filter.

The filtered solution final pH and E_h , and the ^{99}Tc total concentration were determined using the same methods described in Section 2. By plotting total aqueous ^{99}Tc concentration vs. reaction time, the presence of an aqueous ^{99}Tc concentration plateau can be determined, which suggests a steady state with respect to ^{99}Tc partitioning has been reached. The initial 2.0, 20, and 200 ppb total ^{99}Tc concentrations in the final filtrates were expected to converge to a single concentration (steady state) value as contact time progressed, resulting in the solubility value of $^{99}\text{Tc(IV)}$ -bearing solid phase as (mol/L).

8.2 Results and Discussion

Solubility tests of ^{99}Tc in the two crushed LSWG monoliths (T1 and T7), with size fraction of 0.3–2 mm, was conducted for 30, 60, 120, and 150 days under reducing conditions inside the anoxic chamber. The measured average E_h and pH values for each LSWG filtrates were similar to those described in Section 7.2.1, with values ~ 12.5 for pH and ~ -450 mV for E_h (Appendix A.4), indicating that reducing conditions prevailed inside the chamber during the entire solubility test. Similar to Um et al. (2016), no precipitates or significant ^{99}Tc losses were observed in any of control samples prepared with initial spiked ^{99}Tc concentrations of 2.0, 20, and 200 $\mu\text{g/L}$ inside the chamber. This demonstrates that the ^{99}Tc remained soluble in control samples over the entire course of the solubility experiments and thus reductive precipitation of $^{99}\text{Tc(IV)}$ did not occur. This is likely due to the reducing conditions in the anoxic chamber being moderate and incapable of facilitating aqueous homogeneous reduction from $^{99}\text{Tc(VII)}$ to $^{99}\text{Tc(IV)}$ and precipitation, which could occur under more extreme reducing conditions.

The measured average aqueous ^{99}Tc concentrations in the filtrates collected from the crushed LSWG samples for each reaction time are shown in Figure 8.1 and Figure 8.2. Generally, the aqueous ^{99}Tc concentration in all filtrates isolated from T1 and T7 crushed LSWG slurries rapidly decreased with increasing reaction time during early reaction periods (up to 60-day reaction). Then, the filtrates showed a gradual decrease (up to 120-day reaction) and finally a concentration plateau for the remainder of the time (150 days). In addition, the difference in ^{99}Tc aqueous concentration between the three initial concentrations (2.0, 20, and 200 $\mu\text{g/L}$) also decreased with reaction time in the various filtrates.

For ^{99}Tc -spiked T1 batch slurries with starting ^{99}Tc aqueous concentrations of 2.0, 20, and 200 $\mu\text{g/L}$, the ^{99}Tc aqueous concentrations in the filtrates collected after 120 reaction days were 1.04, 1.24, and 1.23 $\mu\text{g/L}$, respectively, with an average value of 1.17 ± 0.11 $\mu\text{g/L}$. After increasing the reaction time to 150 days, the ^{99}Tc aqueous concentrations in filtrates decreased very gradually to 0.74, 1.12, and 1.17 $\mu\text{g/L}$, for respective starting ^{99}Tc aqueous concentrations 2.0, 20, and 200 $\mu\text{g/L}$, with an average value of 1.01 ± 0.24 $\mu\text{g/L}$. It is clear that, despite different initial ^{99}Tc concentrations, the aqueous ^{99}Tc concentration leveled off to an average ^{99}Tc concentration value of 1.01 ± 0.24 $\mu\text{g/L}$ after 150 days of reaction, which is equivalent to an overall average single aqueous ^{99}Tc concentration value of $1.1 \pm 0.12 \times 10^{-8}$ M.

In the case of non- ^{99}Tc -spiked LSWG sample T7, Figure 8.2 illustrates that for the batch solubility experiment that started with ^{99}Tc aqueous concentrations of 2.0 $\mu\text{g/L}$, all the ^{99}Tc aqueous concentrations in the filtrates were below the ^{99}Tc detection limit for ICP-MS (0.033 $\mu\text{g/L}$) except the first sampling after 30 reaction days. For the batch experiment with a starting ^{99}Tc aqueous concentration equal to 20 $\mu\text{g/L}$, nearly constant, low aqueous ^{99}Tc concentrations of 0.08–0.1 $\mu\text{g/L}$ were observed for all 60-, 120-, and 150-day sampling intervals. For the batch experiment that started with the highest ^{99}Tc aqueous concentration of 200 $\mu\text{g/L}$, a gradual decrease in ^{99}Tc aqueous concentration was observed throughout almost the entire reaction period, except for the samplings at 120 and 150 reaction days, where nearly constant ^{99}Tc aqueous concentrations of 0.76 and 0.67 $\mu\text{g/L}$, respectively, were measured.

In contrast with the experiments with LSWG T1, equilibrium aqueous ^{99}Tc concentrations in the T7 filtrates for the different initial ^{99}Tc concentrations (2.0, 20, and 200 $\mu\text{g/L}$) did not converge to a single concentration value for LSWG T7 experiments. Considering the identical grout recipe for T1 and T7 (20 wt% HL, 35 wt% OPC, and 45 wt% BFS dry ingredients), with the exception of ^{99}Tc spiking in the T1 simulant, the different experimental behaviors between the two LSWG monoliths could be explained by additional ^{99}Tc sorption processes. For the non- ^{99}Tc -spiked LSWG T7, the spiked ^{99}Tc amount likely did not exceed the monolith's sorption capacity; thus almost 100% of the spiked ^{99}Tc in the $\text{Ca}(\text{OH})_2$ contacting solution with initial ^{99}Tc aqueous concentrations of 2.0 and 20 $\mu\text{g/L}$ was taken up by the cementitious material during the initial 30 days, resulting in almost non-detectable ^{99}Tc concentrations in the filtrates collected at longer times. In such a scenario, the measured ^{99}Tc aqueous concentration in filtrates from the T7 tests may not represent the true ^{99}Tc solubility value because ^{99}Tc sorption sites within the crushed T7 material are not filled to saturation. For the experiment using crushed T7 material in contact with the highest initial ^{99}Tc aqueous concentration of 200 $\mu\text{g/L}$, a concentration plateau at the later stage (120–150 days) was observed, which may indicate a ^{99}Tc solubility with an average value of $0.71 \pm 0.07 \mu\text{g/L}$ ($7.1 \pm 0.65 \times 10^{-9} \text{ M}$). In contrast, for ^{99}Tc -spiked LSWG T1, the total amounts of ^{99}Tc in the reactors were probably sufficient compared to the cementitious sorption capacity due to initial ^{99}Tc loading in the T1 solid. However, uptake of additional ^{99}Tc from the contacting solutions to T1 cementitious material was still observed, leading to the observed slight decreases of the ^{99}Tc aqueous concentrations in the filtrates collected at 150 days.

Thus there may be continued interplay between ^{99}Tc sorption sites on the crushed LSWG solids and discrete Tc(IV) precipitates within these batch solubility tests performed in the anoxic chamber over 150-days. The system likely remains “dynamic” with slight changes in E_h , slow dissolution of un-reacted BFS, slight changes in the slurry aqueous chemistry etc. However, we conclude, for the experiments with LSWG T1, that the ^{99}Tc concentrations in all the supernatants leveled off to a similar single ^{99}Tc aqueous concentration of $\sim 1.1 \pm 0.12 \times 10^{-8} \text{ M}$, despite the different initial ^{99}Tc concentrations (2.0, 20, and 200 $\mu\text{g/L}$). For the experiments with LSWG T7, the average value of $7.1 \pm 0.65 \times 10^{-9} \text{ M}$ could also be considered to be controlled by the solubility of a $^{99}\text{Tc(IV)}$ -bearing solid phase. An overall average value range for solubility of $^{99}\text{Tc(IV)}$ can be reported as $7.1 \times 10^{-9} \text{ M}$ to $1.1 \times 10^{-8} \text{ M}$ based on the results of this study. This range agrees well with values reported by Estes et al. (2012) and Um et al. (2016), who respectively reported solubility values of 10^{-9} to 10^{-8} M and $4.8 \times 10^{-9} \text{ M}$ for empirical solubility experiments conducted under reducing conditions with several different cementitious formulations.

In addition to the ^{99}Tc solubility experiments with LSWG T1 and T7 described above, this report also includes additional extended data analysis on ^{99}Tc (mol/L) solubility measurements using crushed samples from monoliths T19, T20, and T21 (corresponding to monolith Tests #3, #6, and #11, respectively) from FY 2015 tests. These FY2015 solubility tests included three different initial ^{99}Tc concentrations (2.5, 10, and 25 $\mu\text{g/L}$) for three extended reaction times (121, 210, and 370 days). The data analysis on the three early-stage measurements (14, 30, and 51 days) has been reported in Um et al. (2016). Based on the additional data analysis up to 370 days on LSWG T19, T20, and T21, an overall average value for solubility of $^{99}\text{Tc(IV)}$ can be reported as $\sim 1.7 \pm 0.6 \times 10^{-9} \text{ M}$, which is lower than the $\sim 10^{-8} \text{ M}$ value from shorter-term reaction (<150 days). The details on the data analysis of extended ^{99}Tc solubility test for FY 2015 samples are presented in Appendix A6.

Figure 8.1. Average Aqueous ^{99}Tc Concentrations for Different Sorption Reaction Times using T1 (^{99}Tc spiked) LSWG Monolith Material. The blue, red, and green symbols indicate sorption reactions spiked with initial ^{99}Tc concentrations of 2.0, 20, and 200 $\mu\text{g/L}$, respectively. The error bars are the standard deviation of the average, calculated from triplicate sample measurements.

Figure 8.2. Average Aqueous ^{99}Tc Concentrations for Different Sorption Reaction Times using T7 (non- ^{99}Tc spiked) LSWG Monolith Material. The blue, red, and green symbols indicate sorption reactions spiked with initial ^{99}Tc concentrations of 2.0, 20, and 200 $\mu\text{g/L}$, respectively. The error bars are the standard deviation of the average, calculated from triplicate sample measurements.

9.0 Summary and Recommendations

This section summarizes the key conclusions from each activity performed during FY 2016 LSWG formulation and testing. The results obtained help fill existing data gaps, support final selection of a LSWG waste form, and improve the technical defensibility of long-term waste form performance estimates. Recommendations for further testing needed, to provide additional information for LSWG waste form development and to support 2017 IDF PA maintenance, are also addressed.

Subtasks of the LSWG formulation and testing project performed in FY 2016 included:

1. formulation of new LSWG waste forms for a high-sulfate waste simulant
2. detailed solid characterization of the cured LSWG waste forms
3. leach testing (EPA Method 1313) on select LSWG formulations to determine ^{99}Tc leachability as a function of pH, which will help account for variations in the waste form surroundings
4. determination of effective diffusivity (D_{eff}) values for ^{99}Tc , ^{127}I , NO_3^- , and Na^+ in both deionized water (DIW) and vadose zone pore water (VZPW) leach solutions using EPA Method 1315 to assess the long-term immobilization potential of the waste form under different leach environments
5. quantification of ^{99}Tc desorption K_d (distribution coefficient) values from the cementitious material under oxidizing conditions to support maintenance of the Hanford IDF PA predictions for ^{99}Tc transport
6. estimation of the empirical solubility of Tc from $^{99}\text{Tc(IV)}$ -bearing solids under reducing conditions, which are expected to persist in young cementitious materials, to support maintenance of the IDF PA model predictions for ^{99}Tc transport
7. report results from extended leach testing, ^{99}Tc solubility experiments, and solid-phase characterization analysis of LSWG monoliths carried over from Fiscal Year (FY) 2015 testing (Um et al. 2016).

9.1 Conclusions

New formulations for LSWG waste forms were developed using HL instead of FA and tested with one high-sulfate simulant, EMF/CS, developed based on projected compositions for EMF liquid waste streams. The HL was added to increase Ca^{2+} available to react with and sequester sulfate early in the curing phase by forming ettringite $[\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26(\text{H}_2\text{O})]$, avoiding late ettringite formation that can lead to undesired swelling and cracking of the waste form and subsequent risk of ^{99}Tc release. A total of seven LSWG formulations were tested: six spiked with ^{99}Tc and one without ^{99}Tc . Each formulation tested the effects of different w/dm ratios (0.6 vs. 0.75), different dry ingredients and relative compositions, the addition of admixture (Xypex), addition of a ^{99}Tc getter (Sn-treated apatite), and addition of an iodine getter (Ag-zeolite). In addition, the effect of cure time (28 days vs. 60 days) was evaluated for each formulation.

A dry blend of 20% HL, 35% OPC, and 45% BFS was tested at a w/dm ratio of 0.6 for comparison to tests performed in FY 2015 (Um et al. 2016) using a WTP-treated off-gas condensate simulant. This formulation was used, with and without ^{99}Tc , to perform EPA Method 1313 testing and ^{99}Tc solubility/sorption/desorption testing. The original Cast Stone recipe (8% OPC, 45% FA, and 47% BFS) was also tested for comparison, but did not set (properly harden) over the 28- and 60-day cure periods.

The EMF/CS simulant used contains the highest sulfate concentration tested to date, further demonstrating that the original Cast Stone recipe will likely be insufficient for handling expected high-sulfate waste streams sent to the ETF. All ^{99}Tc -containing formulations were used for EPA Method 1315 leach testing, except for the uncured original Cast Stone formulation.

For all formulations, most cured monoliths showed some cracks after both 28- and 60-day curing periods. White precipitates on the surfaces of 28- and 60-day cured LSWG monoliths made with the EMF/CS simulant were determined by XRD to be 60–98 wt% thenardite (Na_2SO_4) or mirabilite (hydrated thenardite, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$), suggesting that not all of the EMF/CS simulant sulfate reacted with the added HL. Since white precipitates and cracks were not observed in monoliths prepared with WTP-treated off-gas condensate simulant and the same 20 wt% HL addition in FY2015, the monoliths prepared with 20% HL herein are not considered to provide enough Ca^{2+} and Al^{3+} to react with the elevated levels of sulfate in the EMF/CS simulant to form ettringite in the early stages of curing. The XRD patterns of the powdered monolith all showed the presence of ettringite [$\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26\text{H}_2\text{O}$] as the primary crystalline phase (19 to 26 wt%), which increased slightly from 28- to 60-day cure times. Continual growth of ettringite with extended curing likely contributed to the severe cracks observed on the 60-day cured monoliths. Ettringite and gypsum formation were also greatest in formulations with HL and a w/dm ratio of 0.75, due to more sulfate present relative to the 0.6 w/dm ratio formulations. All cured monoliths were dominated by amorphous phases ranging from 52 to 63 wt%, which is attributed to calcium-silicate-hydrate (C-S-H) gel in the cementitious material. For the original Cast Stone formulation, when used to solidify EMF/CS simulant, gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) was the major mineral phase (~25 wt%) formed, followed by thenardite (Na_2SO_4), and neither ettringite nor portlandite were formed. This is due to the absence of HL as an additional Ca source needed for ettringite formation. This Cast Stone formulation with EMF/CS simulant failed to set (harden) into an acceptable waste form.

Results from EPA Method 1313 leach testing using crushed monolith material from T1 (20% HL, 35% OPC, and 45% BFS, 0.6 w/dm ratio), showed that with increasing pH between pH 5.33 and 10.60, ^{99}Tc is more readily released into solution. Since ^{99}Tc is expected to be released as pertechnetate (TcO_4^-), at elevated pH levels, release into solution at high pH is favored due to the repulsive force between pertechnetate anions and negatively charged LSWG surfaces. A slight decrease in ^{99}Tc release beyond pH 10.60 correlates with a decrease in Ca concentration. This could be indicative of calcite (CaCO_3) precipitation capable of blocking ^{99}Tc release as it forms on the monolith surface. Complete release of all the ^{99}Tc solidified in the T1 formulation was not achieved within the 24 hour reaction period under all pH conditions tested by EPA Method 1313 (pH 2.07–12.62); however, all the ^{127}I solidified within the T1 monolith is completely released within the testing period for all pH values except 2.07 and those beyond pH 10.60. At low pH conditions, the decrease in ^{127}I release is attributed to either the electrostatic attraction between anions and the positively charged surfaces that promote ^{127}I retention, or ^{127}I volatilization during supernatant filtration. At pH levels greater than 10.60, ^{127}I release is also thought to be limited due to calcite formation on the surfaces of the crushed monolith physically blocking release within the short 24 hour contact time.

EPA Method 1315 leach testing was performed on monoliths cured 28 and 60 days from all ^{99}Tc -spiked formulations, except the unhardened monoliths made with the original Cast Stone recipe. In general, more cracks were found in HL-containing monoliths made with the EMF/CS simulant that were cured 60 days than those cured for only 28 days; however, different curing times did not significantly affect ^{99}Tc , ^{127}I , NO_3^- , or Na^+ D_{eff} values measured in subsequent EPA Method 1315 leach tests. For ^{99}Tc , D_{eff} values for monoliths leached in DIW and VZPW increased during early leach periods, up to 7–14 days, but gradually decreased through the cumulative 100-day leach period. Despite severe monolith cracks, ^{99}Tc D_{eff} values after 28-day leaching still show relatively low values, with a range of 10^{-9} to 10^{-14} cm^2/s . Only T3 monoliths, cured 28 and 60 days and prepared with iodine getter (Ag-zeolite), showed relatively high ^{99}Tc D_{eff} values up to 63 days leaching, likely due to severe cracks in the leached monoliths. But the T3

monoliths (containing the iodine getter), were very effective at reducing ^{127}I D_{eff} values by 3–4 orders of magnitude during the later stages leaching (>28 days) relative to other monolith formulations. However, it is important to note that the fraction of total ^{127}I mass released in DIW and VZPW leaching solutions was much higher than 20% in most of the monoliths, except T3 monoliths; therefore, the calculated ^{127}I D_{eff} values should be used only for qualitative understanding of ^{127}I mass release from those monoliths.

T1 and T2 monoliths showed the lowest ^{99}Tc D_{eff} values because T1 monoliths were prepared with a lower w/dm ratio (0.6) and T2 monoliths were prepared with Xypex. Xypex works as a pore filler and prevented the formation of monolith cracks in all but one T2 monolith, cured 60 days, which resulted in a relatively higher ^{99}Tc D_{eff} value compared to its pair and 28-day cured T2 monoliths; this demonstrates the deleterious impact of crack formation on ^{99}Tc D_{eff} . Furthermore, the addition of ^{99}Tc getter (Sn-apatite) to T6 monoliths did not significantly reduce ^{99}Tc D_{eff} values, again likely due to the severe cracks that formed. The release of ^{99}Tc from most of the HL-based monoliths is not considered to follow a pure diffusion trend since ^{99}Tc release after 28 days of leaching is significantly suppressed by physical and/or chemical reactions, such as ongoing ^{99}Tc co-precipitation with continued ettringite formation under the sustained reducing conditions produced with slow dissolution of BFS. This mechanism of ^{99}Tc immobilization is supported by XRD patterns of 28-day and 60-day cured monoliths after 100-day leach testing that show increased ettringite [$\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26\text{H}_2\text{O}$] formation and a decrease in portlandite and gypsum. Late and continuous formation of ettringite can also be considered as a major contributor to crack growth. Similar results of increasing ettringite content with decreasing portlandite content were also found in the 406-day leached FY 2015 monoliths made with WTP simulant; however, no severe cracks were found in the FY2015 monoliths because 20% HL addition was sufficient to form ettringite during early curing stages and sequester the lower sulfate concentrations found in the WTP simulant.

All ^{99}Tc sorption tests were conducted inside an anoxic chamber to maintain reducing conditions and used size-reduced (0.3–2 mm), non- ^{99}Tc -spiked, T7 monolith material to initially sorb ~ 1.2 ppb of soluble ^{99}Tc for 30 days. ^{99}Tc -sorbed material was then used to perform ^{99}Tc desorption testing under oxidizing conditions for four reaction times (30, 54, 90, and 120 days). Interestingly, the average ^{99}Tc desorption K_d value increased slightly after 120 days, suggesting that less ^{99}Tc partitions into the aqueous phase and that ^{99}Tc that presumably desorbed during early reaction periods resorbs to the solid monolith material at later contact times, likely because very slow dissolution of residual un-reacted BFS continues to supply reduction capacity. The average ^{99}Tc desorption K_d value (25.7 ± 5.9 mL/g), calculated from all 12 samples under oxidizing conditions, is similar to that found in previous tests, using monoliths prepared with the WTP waste simulant published by Um et al. (2016), 24 ± 5.4 mL/g. These values are likely higher than ^{99}Tc desorption K_d values (0–10 mL/g) reported by Kaplan (2010) for oxidizing cementitious solids because the added BFS in these 12 samples is still acting as a strong reductant.

Solubility tests of ^{99}Tc in the two crushed (size fraction of 0.3–2 mm) LSWG monoliths (T1 and T7) were conducted for 30, 60, 120, and 150 days under reducing conditions inside the anoxic chamber. Generally, the aqueous ^{99}Tc concentration in all filtrates isolated from T1 and T7 crushed LSWG slurries rapidly decreased with increasing reaction time during early reaction periods (up to 60-day reaction). The rapid decrease was followed by a gradual decrease (up to 120-day reaction) and finally a concentration plateau for the remainder of the tests (150 days). The difference in filtrate ^{99}Tc aqueous concentration for tests using three initial concentrations (2.0, 20, and 200 $\mu\text{g/L}$) also decreased with reaction time for both T1 and T7 tests. For T1 solubility experiments, the ^{99}Tc concentrations in all the filtrates leveled off to a similar single ^{99}Tc aqueous concentration of $\sim 1.1 \pm 0.12 \times 10^{-8}$ M, despite the different initial ^{99}Tc concentrations (2.0, 20, and 200 $\mu\text{g/L}$), indicating a solubility control likely by a $^{99}\text{Tc}(\text{IV})$ -bearing solid phase. For T7 batch solubility experiments, the average value ^{99}Tc aqueous concentration of $7.1 \pm 0.65 \times 10^{-9}$ M was found. This value could also be considered to be a solubility control by a $^{99}\text{Tc}(\text{IV})$ -bearing solid phase; however, equilibrium aqueous ^{99}Tc concentrations for the different initial

^{99}Tc concentrations (2.0, 20, and 200 $\mu\text{g/L}$) did not converge to a single concentration value, which is a requirement to invoke a solubility control. Considering the identical grout recipe for T1 and T7 (20 wt% HL, 35 wt% OPC, and 45 wt% BFS dry ingredients), with the exception of ^{99}Tc spiking the sulfate-rich EMF/CS simulant used to make T1. The mass of ^{99}Tc in the initial solutions in contact with the crushed T7 material likely did not exceed the sorption capacity of non- ^{99}Tc -spiked T7 crushed material. In such a scenario, the observed ^{99}Tc aqueous concentration in the filtrates from the T7 solubility test may be undersaturated with respect to a discrete ^{99}Tc solid such that a true solubility control would result in a higher ^{99}Tc concentration in filtrates.

Regardless we offer an overall average value range for solubility control by $^{99}\text{Tc(IV)}$ solids as 7.1×10^{-9} M to 1.1×10^{-8} M based on the results of this study. This range agrees well with values reported by Estes et al. (2012) and Um et al. (2016), who respectively reported solubility values of 10^{-9} to 10^{-8} M and 4.8×10^{-9} M for empirical solubility experiments conducted under reducing conditions with several different cementitious grout formulations.

A summary of the suggested values for ^{99}Tc effective diffusion coefficients, solubility controlled aqueous concentrations, and desorption K_d s for use in future IDF PA modeling activities is provided in Table 9.1 below. However, these values are dependent on the specific conditions and reaction times tested here and additional testing will be required to provide values that encompass a more comprehensive range of LSWG conditions and reaction times that address the variability of DFLAW.

Table 9.1. Summary of Measured ^{99}Tc D_{eff} , Desorption ^{99}Tc K_d s, and ^{99}Tc Solubility Values

Experiments and Conditions	^{99}Tc D_{eff} DIW or VZPW (100% water saturation)	^{99}Tc Solubility in reducing conditions ($E_h = -400$ mV and pH ~ 12)	Desorption ^{99}Tc K_d in oxidizing conditions ($E_h > +100$ mV and pH ~ 12)
Suggested Values	10^{-9} to 10^{-14} cm^2/s	7.1×10^{-9} M – 1.1×10^{-8} M	25.7 ± 5.9 mL/g

Finally, additional testing was performed on LSWG samples carried over from FY 2015 EPA Method 1315 and solubility tests, some of which were characterized by XRD and autoradiography imaging to determine long-term leaching effects on LSWGs. From the FY 2015 report published by Um et al. (2016), two monoliths from each batch had their leach testing extended, one each in DIW and VZPW, to a total of 406 days. In DIW, the D_{eff} for ^{99}Tc remained within the range of diffusivities measured previously for the 28-day and 140-day intervals and followed the trend of continually decreasing or stabilizing beyond the 140 d cumulative leaching for these samples. However, in VZPW, several exceptions were observed for the long-term ^{99}Tc D_{eff} values, specifically for T5, T7, T8, and T16, where an increase in ^{99}Tc D_{eff} was found at longer leach times. Some clues to these exceptions can be gathered from visual examination of the monoliths and XRD characterization. T5, for instance, showed development of a visible crack in the VZPW-leached monolith after 140 days of leaching. Further, the long-term leached T5 monolith showed an increase in ettringite formation relative to the T5 monolith leached in DIW. Other observations included the presence of a spotted exterior on the T15 monolith leached in DIW, which contained Sn(II)-apatite getter and circular deposits on the wall of the T15 monolith leached in VZPW.

In general, solid-phase characterization of extended-leached monoliths characterized by XRD indicated that they are primarily amorphous and all leached monoliths contained ettringite ($\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12} \cdot 26\text{H}_2\text{O}$), calcite (CaCO_3), and larnite (Ca_2SiO_4). The HL-based samples all contained portlandite ($\text{Ca}(\text{OH})_2$) except T2-4 and T5-4. Leached monoliths that contained brucite ($\text{Mg}(\text{OH})_2$) were all leached in VZPW. Vaterite (a CaCO_3 polymorph) was only present in samples fabricated with the ERDF leachate simulant. In all cases, except T11 and T13, which were fabricated with

FA instead of HL, the monoliths leached in VZPW contained significantly more ettringite than their DIW-leached counter parts. In addition, long-term leached monoliths from FY2016 tests, the DIW-leached samples contain a higher amount of portlandite than the VZPW-leached monoliths. The additional ettringite formation in the VZPW-leached monoliths likely results from transformation from the portlandite as SO_4^{2-} from the VZPW migrates into the monolith.

Monolith material from the outer walls and the interiors of long-term leached monoliths was analyzed by XRD and showed, in some cases (T3), a decrease in ettringite formation from the outer wall into the monolith interior. However, this trend was not observed in all samples, such as T11, which includes FA instead of HL in its formulation. Based on autoradiography imaging of ^{99}Tc in monolith “pucks”, ^{99}Tc was found to migrate to the outer edges of the monoliths during extended leaching. The exception to this trend was the monolith that contained ^{99}Tc getter (Sn(II)-apatite) and which was leached in VZPW, which shows ^{99}Tc to be present in discrete spots throughout the sample. From previous analysis. This particular monolith, T2, when imaged by autoradiography show discrete “hot spots” resulting from ^{99}Tc being associated with the Sn(II)-apatite getter (Asmussen et al. 2016).

Finally, in addition to the ^{99}Tc solubility experiments with LSWG T1 and T7 described above, this report also includes additional extended data analysis on ^{99}Tc (mol/L) solubility measurements using powdered samples of monoliths T19, T20, and T21 from FY 2015, which were fabricated using WTP simulant. The solubility tests used three different initial ^{99}Tc concentrations (2.5, 10, and 25 $\mu\text{g/L}$) for three extended reaction times (121, 210, and 370 days) to be compared to early-stage measurements (14, 30, and 51 days) reported in Um et al. (2016). Based on the data analysis up to 370 days on LSWG T19, T20, and T21, an overall average value for solubility of $^{99}\text{Tc(IV)}$ can be reported as $\sim 1.7 \pm 0.6 \times 10^{-9} \text{ M}$, which is lower than the $\sim 10^{-8} \text{ M}$ value from shorter-term reaction (<150 days) times and also lower than ^{99}Tc aqueous concentration values reported here for T1 and T7 through 150 days of reaction (see Table 9.1).

9.2 Recommendations

The results obtained in this task help fill existing data gaps and should support final selection of a LSWG waste form. Recommendations for additional studies to provide more technical defensibility for long-term waste form performance are listed below:

1. The new formulation with HL addition should replace the Cast Stone formulation when sulfate-rich LSW waste streams are being solidified. However, a formulation with 20% HL, 35% OPC, and 45% BFS may not provide sufficient sources of Ca^{2+} and Al^{3+} to ensure complete sequestration of sulfate concentrations if the liquid waste stream sulfate concentration exceeds 122 g/L. Formulation optimization is required to ensure monoliths will not crack and facilitate ^{99}Tc release by late formation of ettringite.
2. Ettringite formation during later periods of leaching for formulations containing HL instead of FA likely contributes to non-diffusion-controlled ^{99}Tc leachability after 28 days of leaching. ^{99}Tc immobilization within ettringite is one mechanism by which ^{99}Tc leachability is reduced in the later stages. This mechanism is supported by batch studies performed under reducing conditions that demonstrated successful ^{99}Tc immobilization by co-precipitation with ettringite (Um et al. 2017). Further solid-phase characterization by XRD, autoradiography imaging, and x-ray absorption spectroscopy (XAS) is recommended to understand this process mechanistically and to identify additional mechanisms.
3. Sustained slow BFS dissolution maintains reducing conditions favorable for ^{99}Tc immobilization in ettringite, but remains poorly characterized. A systematic study to determine the long-term reducing

capacity and slow dissolution kinetics of BFS and the effect on $^{99}\text{Tc } D_{eff}$ from LSWG waste forms once the reducing capacity of BFS is diminished is required. Extended leach testing (beyond 100 days) for new LSWG formulations with variable BFS compositions are recommended.

4. Due to the young (or fresh) monolithic material used in ^{99}Tc desorption testing, the reduction capacity is expected to be higher than that of aged LSWG material. It is recommended that tests be performed to assess the impact of aged HL-containing LSWG waste forms on $^{99}\text{Tc } D_{eff}$, ^{99}Tc solubility, and ^{99}Tc desorption K_d values, using fully weathered samples after artificially reacting with oxygen to mimic the low (or zero) reduction capacity of aged monoliths.

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Appendix A

Additional Data

Appendix A

Additional Data

A.1 Photographs of the 100-Day-Leached Monoliths with Cracks

After 28-day curing

After 60-day curing

A.2 Additional Results for Cations and Anions from Environmental Protection Agency (EPA) Method 1315 Tests

Table A.1. Concentrations of Major Cations Measured in Leachates from EPA Method 1315 Tests (28-Day Cured Monoliths). EQL is estimated quantification limit; ND indicates “not detected”; cumulative release of Na (%) is shown in parentheses.

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-DI BLK1 0.08d	115	101	ND	8.11	ND	483	ND	134	ND	164
16-SWCS-DI BLK1 1d	474	101	13	8.11	ND	483	ND	134	ND	164
16-SWCS-DI BLK1 2d	194	101	ND	8.11	ND	483	ND	134	ND	164
16-SWCS-DI BLK1 7d	204	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK1 14d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK1 28d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK1 42d	194	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK1 49d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK1 63d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK1 100d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 0.08d	158	101	17.4	8.11	ND	483	248	134	ND	164
16-SWCS-DI BLK2 1d	662	101	11.2	8.11	ND	483	ND	134	ND	164
16-SWCS-DI BLK2 2d	266	101	8.48	8.11	ND	483	ND	134	ND	164
16-SWCS-DI BLK2 7d	174	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 14d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 28d	207	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 42d	175	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 49d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 63d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-DI BLK2 100d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-PW BLK1 0.08d	324000	336	113000	27	24300	1610	126000	447	ND	548
16-SWCS-PW BLK1 1d	330000	336	114000	27	25800	1610	131000	447	ND	548
16-SWCS-PW BLK1 2d	328000	336	116000	27	25400	1610	131000	447	ND	548
16-SWCS-PW BLK1 7d	328000	168	109000	13.5	27100	806	130000	223	ND	274
16-SWCS-PW BLK1 14d	343000	168	106000	13.5	24600	806	117000	223	ND	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-PW BLK1 28d	372000	168	105000	13.5	25700	806	116000	223	ND	274
16-SWCS-PW BLK1 42d	435000	168	116000	13.5	24000	806	126000	223	ND	274
16-SWCS-PW BLK1 49d	326000	168	109000	13.5	25700	806	114000	223	ND	274
16-SWCS-PW BLK1 63d	404000	168	109000	13.5	25800	806	132000	223	ND	274
16-SWCS-PW BLK1 100d	494000	168	115000	13.5	30000	806	139000	223	ND	274
16-SWCS-PW BLK2 0.08d	321000	336	113000	27	24900	1610	128000	447	ND	548
16-SWCS-PW BLK2 1d	332000	336	115000	27	25200	1610	131000	447	ND	548
16-SWCS-PW BLK2 2d	333000	336	112000	27	25900	1610	132000	447	ND	548
16-SWCS-PW BLK2 7d	325000	168	108000	13.5	25000	806	121000	223	ND	274
16-SWCS-PW BLK2 14d	356000	168	106000	13.5	25400	806	116000	223	ND	274
16-SWCS-PW BLK2 28d	374000	168	107000	13.5	25400	806	113000	223	ND	274
16-SWCS-PW BLK2 42d	461000	168	117000	13.5	24500	806	129000	223	ND	274
16-SWCS-PW BLK2 49d	342000	168	112000	13.5	26600	806	118000	223	ND	274
16-SWCS-PW BLK2 63d	411000	168	112000	13.5	26300	806	134000	223	ND	274
16-SWCS-PW BLK2 100d	488000	168	112000	13.5	29600	806	137000	223	ND	274
16-SWCS-T1- 1 0.08d	12800	101	23.7	8.11	1690	483	38100 (1.15)	134	340	164
16-SWCS-T1- 1 1d	90100	101	47.9	8.11	8760	483	161000 (5.99)	134	798	164
16-SWCS-T1- 1 2d	68200	101	23.5	8.11	5580	483	103000 (9.09)	134	860	164
16-SWCS-T1- 1 7d	151000	168	28.3	13.5	20800	806	350000 (19.6)	223	1530	274
16-SWCS-T1- 1 14d	131000	168	19.3	13.5	19500	806	329000 (29.5)	223	2000	274
16-SWCS-T1- 1 28d	98200	168	ND	13.5	22900	806	352000 (40.1)	223	2580	274
16-SWCS-T1- 1 42d	78300	168	19.7	13.5	15700	806	286000 (48.7)	223	3040	274
16-SWCS-T1- 1 49d	49900	168	30	13.5	6280	806	97900 (51.7)	223	2740	274
16-SWCS-T1- 1 63d	59000	168	ND	13.5	9980	806	187000 (57.3)	223	4040	274
16-SWCS-T1- 1 100d	96900	168	76.9	13.5	20900	806	339000 (67.5)	223	2950	274
16-SWCS-T1- 2 0.08d	8540	101	16.5	8.11	1390	483	25300 (0.766)	134	314	164
16-SWCS-T1- 2 1d	81300	101	43	8.11	8410	483	160000 (5.61)	134	748	164
16-SWCS-T1- 2 2d	68100	101	19.8	8.11	6210	483	116000 (9.13)	134	731	164
16-SWCS-T1- 2 7d	138000	168	16.4	13.5	20300	806	347000 (19.6)	223	1310	274
16-SWCS-T1- 2 14d	108000	168	23.1	13.5	13000	806	203000 (25.8)	223	1450	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T1-2 28d	121000	168	ND	13.5	18700	806	273000 (34.1)	223	2700	274
16-SWCS-T1-2 42d	93900	168	20.4	13.5	9610	806	170000 (39.2)	223	3080	274
16-SWCS-T1-2 49d	61400	168	34.1	13.5	3780	806	55100 (40.9)	223	2570	274
16-SWCS-T1-2 63d	80500	168	19.4	13.5	6200	806	109000 (44.2)	223	3850	274
16-SWCS-T1-2 100d	124000	168	ND	13.5	13700	806	212000 (50.6)	223	3300	274
16-SWCS-T1-3 0.08d	339000	101	98600	8.11	27700	483	179000 (1.60)	134	ND	164
16-SWCS-T1-3 1d	400000	101	34700	8.11	34300	483	293000 (6.49)	134	306	164
16-SWCS-T1-3 2d	395000	101	43800	8.11	33300	483	257000 (10.3)	134	335	164
16-SWCS-T1-3 7d	439000	168	78.9	13.5	45000	806	464000 (20.4)	223	693	274
16-SWCS-T1-3 14d	473000	168	337	13.5	40800	806	366000 (27.9)	223	520	274
16-SWCS-T1-3 28d	512000	168	77.2	13.5	48500	806	448000 (37.9)	223	485	274
16-SWCS-T1-3 42d	558000	168	121	13.5	39600	806	393000 (46.0)	223	301	274
16-SWCS-T1-3 49d	403000	168	6880	13.5	32600	806	223000 (49.3)	223	ND	274
16-SWCS-T1-3 63d	463000	168	440	13.5	35800	806	315000 (54.8)	223	ND	274
16-SWCS-T1-3 100d	572000	168	103	13.5	49000	806	469000 (64.7)	223	ND	274
16-SWCS-T1-4 0.08d	341000	101	98000	8.11	28000	483	176000 (1.50)	134	ND	164
16-SWCS-T1-4 1d	403000	101	30800	8.11	34800	483	296000 (6.45)	134	373	164
16-SWCS-T1-4 2d	390000	101	49400	8.11	33200	483	275000 (10.8)	134	292	164
16-SWCS-T1-4 7d	449000	168	107	13.5	48100	806	521000 (22.5)	223	659	274
16-SWCS-T1-4 14d	474000	168	163	13.5	41200	806	401000 (31.0)	223	348	274
16-SWCS-T1-4 28d	530000	168	63.2	13.5	47300	806	440000 (40.7)	223	432	274
16-SWCS-T1-4 42d	567000	168	85	13.5	38600	806	391000 (48.7)	223	410	274
16-SWCS-T1-4 49d	412000	168	5140	13.5	32900	806	225000 (52.0)	223	ND	274
16-SWCS-T1-4 63d	480000	168	318	13.5	35100	806	307000 (57.2)	223	ND	274
16-SWCS-T1-4 100d	657000	168	84.6	13.5	50800	806	487000 (67.7)	223	ND	274
16-SWCS-T2-1 0.08d	8630	101	33.2	8.11	1720	483	46200 (1.29)	134	503	164
16-SWCS-T2-1 1d	61100	101	38.6	8.11	9900	483	223000 (7.50)	134	585	164
16-SWCS-T2-1 2d	59300	101	17.7	8.11	6560	483	150000 (11.7)	134	563	164
16-SWCS-T2-1 7d	155000	168	14.5	13.5	21100	806	465000 (24.6)	223	1210	274
16-SWCS-T2-1 14d	130000	168	18.7	13.5	14900	806	352000 (34.4)	223	1410	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T2-1 28d	101000	168	ND	13.5	16200	806	413000 (45.9)	223	2410	274
16-SWCS-T2-1 42d	64100	168	ND	13.5	8460	806	278000 (53.7)	223	3270	274
16-SWCS-T2-1 49d	56300	168	14.8	13.5	3980	806	113000 (56.8)	223	2930	274
16-SWCS-T2-1 63d	60400	168	ND	13.5	3950	806	128000 (60.4)	223	4040	274
16-SWCS-T2-1 100d	83700	168	40.2	13.5	6450	806	131000 (64.1)	223	4520	274
16-SWCS-T2-2 0.08d	12100	101	29.8	8.11	2180	483	66400 (1.84)	134	511	164
16-SWCS-T2-2 1d	75900	101	37.1	8.11	11200	483	250000 (8.77)	134	794	164
16-SWCS-T2-2 2d	67400	101	18.2	8.11	7100	483	167000 (13.4)	134	800	164
16-SWCS-T2-2 7d	157000	168	38.4	13.5	24100	806	533000 (28.2)	223	1500	274
16-SWCS-T2-2 14d	125000	168	21.2	13.5	18200	806	414000 (39.7)	223	1780	274
16-SWCS-T2-2 28d	103000	168	237	13.5	21200	806	525000 (54.2)	223	2870	274
16-SWCS-T2-2 42d	68700	168	ND	13.5	9810	806	312000 (62.9)	223	3140	274
16-SWCS-T2-2 49d	54800	168	ND	13.5	3920	806	109000 (65.9)	223	2940	274
16-SWCS-T2-2 63d	69600	168	ND	13.5	4840	806	150000 (70.1)	223	3850	274
16-SWCS-T2-2 100d	85700	168	48.5	13.5	7070	806	147000 (74.1)	223	4160	274
16-SWCS-T2-3 0.08d	335000	101	97400	8.11	28900	483	214000 (2.49)	134	270	164
16-SWCS-T2-3 1d	384000	101	23600	8.11	36600	483	384000 (9.65)	134	300	164
16-SWCS-T2-3 2d	396000	101	30900	8.11	34700	483	333000 (15.4)	134	447	164
16-SWCS-T2-3 7d	441000	168	36.7	13.5	50300	806	678000 (30.9)	223	809	274
16-SWCS-T2-3 14d	484000	168	77	13.5	45900	806	594000 (44.4)	223	620	274
16-SWCS-T2-3 28d	482000	168	36.1	13.5	45600	806	614000 (58.4)	223	548	274
16-SWCS-T2-3 42d	555000	168	65.1	13.5	34000	806	452000 (67.7)	223	522	274
16-SWCS-T2-3 49d	426000	168	5370	13.5	30100	806	215000 (70.5)	223	ND	274
16-SWCS-T2-3 63d	517000	168	624	13.5	28900	806	236000 (73.5)	223	ND	274
16-SWCS-T2-3 100d	662000	168	109	13.5	37700	806	240000 (76.3)	223	380	274
16-SWCS-T2-4 0.08d	336000	101	96100	8.11	28000	483	192000 (1.88)	134	ND	164
16-SWCS-T2-4 1d	400000	101	19100	8.11	37400	483	376000 (8.85)	134	273	164
16-SWCS-T2-4 2d	390000	101	38200	8.11	33400	483	295000 (13.5)	134	444	164
16-SWCS-T2-4 7d	450000	168	146	13.5	50300	806	645000 (28.2)	223	821	274
16-SWCS-T2-4 14d	464000	168	139	13.5	44900	806	568000 (41.0)	223	680	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T2-4 28d	464000	168	78.7	13.5	46200	806	582000 (54.3)	223	576	274
16-SWCS-T2-4 42d	536000	168	125	13.5	35400	806	461000 (63.8)	223	450	274
16-SWCS-T2-4 49d	410000	168	4010	13.5	30500	806	233000 (67.2)	223	ND	274
16-SWCS-T2-4 63d	468000	168	1460	13.5	28500	806	255000 (70.7)	223	ND	274
16-SWCS-T2-4 100d	591000	168	127	13.5	37500	806	266000 (74.3)	223	ND	274
16-SWCS-T3-1 0.08d	6220	101	16.2	8.11	1010	483	27600 (0.771)	134	289	164
16-SWCS-T3-1 1d	53700	101	26.9	8.11	7880	483	185000 (5.94)	134	812	164
16-SWCS-T3-1 2d	40800	101	13.5	8.11	5780	483	142000 (9.90)	134	845	164
16-SWCS-T3-1 7d	88400	168	ND	13.5	18600	806	428000 (21.9)	223	1830	274
16-SWCS-T3-1 14d	96700	168	13.9	13.5	18700	806	437000 (34.1)	223	2390	274
16-SWCS-T3-1 28d	87200	168	ND	13.5	19100	806	403000 (45.3)	223	1950	274
16-SWCS-T3-1 42d	94500	168	13.7	13.5	10900	806	256000 (52.5)	223	2440	274
16-SWCS-T3-1 49d	78100	168	15.6	13.5	5110	806	102000 (55.3)	223	2470	274
16-SWCS-T3-1 63d	100000	168	14	13.5	6840	806	154000 (59.6)	223	2350	274
16-SWCS-T3-1 100d	181000	168	16.1	13.5	13400	806	234000 (66.1)	223	2390	274
16-SWCS-T3-2 0.08d	5790	101	18.4	8.11	1190	483	39900 (1.12)	134	402	164
16-SWCS-T3-2 1d	50300	101	30	8.11	9580	483	236000 (7.76)	134	919	164
16-SWCS-T3-2 2d	38500	101	10.9	8.11	5720	483	150000 (12.0)	134	888	164
16-SWCS-T3-2 7d	95600	168	24.4	13.5	21600	806	540000 (27.2)	223	2330	274
16-SWCS-T3-2 14d	79200	168	15.1	13.5	16400	806	355000 (37.2)	223	2370	274
16-SWCS-T3-2 28d	74800	168	ND	13.5	18100	806	373000 (47.7)	223	2820	274
16-SWCS-T3-2 42d	85500	168	ND	13.5	11900	806	286000 (55.7)	223	3220	274
16-SWCS-T3-2 49d	59800	168	13.7	13.5	4580	806	89300 (58.2)	223	2350	274
16-SWCS-T3-2 63d	85900	168	ND	13.5	7610	806	173000 (63.1)	223	3410	274
16-SWCS-T3-2 100d	139000	168	23	13.5	13800	806	242000 (69.9)	223	3350	274
16-SWCS-T3-3 0.08d	329000	101	97000	8.11	26800	483	177000 (1.43)	134	180	164
16-SWCS-T3-3 1d	370000	101	31800	8.11	35100	483	362000 (7.93)	134	384	164
16-SWCS-T3-3 2d	361000	101	47500	8.11	32100	483	304000 (12.8)	134	372	164
16-SWCS-T3-3 7d	380000	168	97.1	13.5	44500	806	598000 (25.9)	223	791	274
16-SWCS-T3-3 14d	401000	168	217	13.5	43100	806	547000 (38.0)	223	702	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T3-3 28d	417000	168	107	13.5	44500	806	556000 (50.4)	223	630	274
16-SWCS-T3-3 42d	515000	168	232	13.5	36400	806	451000 (59.5)	223	ND	274
16-SWCS-T3-3 49d	389000	168	17500	13.5	33400	806	263000 (63.7)	223	ND	274
16-SWCS-T3-3 63d	443000	168	2010	13.5	32300	806	345000 (69.7)	223	ND	274
16-SWCS-T3-3 100d	625000	168	89.9	13.5	44500	806	474000 (79.1)	223	380	274
16-SWCS-T3-4 0.08d	333000	101	96300	8.11	26900	483	175000 (1.39)	134	ND	164
16-SWCS-T3-4 1d	381000	101	25600	8.11	34500	483	351000 (7.64)	134	357	164
16-SWCS-T3-4 2d	372000	101	45800	8.11	32100	483	291000 (12.2)	134	324	164
16-SWCS-T3-4 7d	411000	168	122	13.5	44900	806	562000 (24.5)	223	764	274
16-SWCS-T3-4 14d	425000	168	112	13.5	42700	806	529000 (36.2)	223	635	274
16-SWCS-T3-4 28d	454000	168	160	13.5	45800	806	541000 (48.2)	223	409	274
16-SWCS-T3-4 42d	547000	168	409	13.5	34400	806	391000 (55.8)	223	ND	274
16-SWCS-T3-4 49d	427000	168	8620	13.5	32000	806	218000 (58.7)	223	ND	274
16-SWCS-T3-4 63d	513000	168	384	13.5	30400	806	267000 (62.6)	223	ND	274
16-SWCS-T3-4 100d	670000	168	70.6	13.5	41400	806	311000 (67.5)	223	486	274
16-SWCS-T4-1 0.08d	6290	101	17.5	8.11	1280	483	32500 (0.932)	134	200	164
16-SWCS-T4-1 1d	52700	101	25.6	8.11	10200	483	222000 (7.34)	134	793	164
16-SWCS-T4-1 2d	37000	101	12.6	8.11	6140	483	141000 (11.4)	134	822	164
16-SWCS-T4-1 7d	91400	168	18.9	13.5	20600	806	445000 (24.3)	223	2080	274
16-SWCS-T4-1 14d	105000	168	21.8	13.5	15000	806	335000 (33.9)	223	2570	274
16-SWCS-T4-1 28d	109000	168	18.7	13.5	13600	806	263000 (41.5)	223	2700	274
16-SWCS-T4-1 42d	107000	168	41.9	13.5	6620	806	132000 (45.4)	223	2730	274
16-SWCS-T4-1 49d	88500	168	23.5	13.5	3870	806	59600 (47.1)	223	2900	274
16-SWCS-T4-1 63d	118000	168	20.9	13.5	5090	806	69500 (49.1)	223	3690	274
16-SWCS-T4-1 100d	147000	168	17.7	13.5	11200	806	77800 (51.3)	223	4700	274
16-SWCS-T4-2 0.08d	6820	101	16.4	8.11	1520	483	35800 (1.03)	134	191	164
16-SWCS-T4-2 1d	55000	101	31	8.11	10500	483	227000 (7.63)	134	819	164
16-SWCS-T4-2 2d	44200	101	12.8	8.11	7640	483	175000 (12.7)	134	972	164
16-SWCS-T4-2 7d	99600	168	16.8	13.5	21400	806	473000 (26.5)	223	2330	274
16-SWCS-T4-2 14d	105000	168	16.2	13.5	13700	806	306000 (35.4)	223	2400	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T4-2 28d	120000	168	ND	13.5	11700	806	225000 (41.9)	223	2490	274
16-SWCS-T4-2 42d	128000	168	16.1	13.5	6340	806	107000 (45.0)	223	2860	274
16-SWCS-T4-2 49d	74900	168	19.4	13.5	2580	806	26900 (45.8)	223	2170	274
16-SWCS-T4-2 63d	106000	168	60.6	13.5	3650	806	42400 (47.0)	223	3020	274
16-SWCS-T4-2 100d	172000	168	24.4	13.5	11500	806	74400 (49.2)	223	4070	274
16-SWCS-T4-3 0.08d	333000	101	96400	8.11	27000	483	163000 (1.01)	134	ND	164
16-SWCS-T4-3 1d	376000	101	40500	8.11	37600	483	387000 (8.36)	134	322	164
16-SWCS-T4-3 2d	369000	101	61800	8.11	34800	483	311000 (13.5)	134	262	164
16-SWCS-T4-3 7d	395000	168	217	13.5	46700	806	589000 (26.9)	223	492	274
16-SWCS-T4-3 14d	413000	168	1130	13.5	38400	806	382000 (34.6)	223	ND	274
16-SWCS-T4-3 28d	492000	168	206	13.5	39800	806	381000 (42.3)	223	277	274
16-SWCS-T4-3 42d	585000	168	350	13.5	32300	806	287000 (46.8)	223	ND	274
16-SWCS-T4-3 49d	444000	168	13900	13.5	29800	806	175000 (48.4)	223	ND	274
16-SWCS-T4-3 63d	523000	168	716	13.5	28700	806	197000 (50.3)	223	ND	274
16-SWCS-T4-3 100d	673000	168	76.4	13.5	41200	806	222000 (52.7)	223	725	274
16-SWCS-T4-4 0.08d	329000	101	98200	8.11	28200	483	188000 (1.71)	134	ND	164
16-SWCS-T4-4 1d	377000	101	37100	8.11	38200	483	408000 (9.63)	134	322	164
16-SWCS-T4-4 2d	375000	101	50600	8.11	34900	483	337000 (15.5)	134	299	164
16-SWCS-T4-4 7d	425000	168	64.6	13.5	59300	806	940000 (38.9)	223	757	274
16-SWCS-T4-4 14d	446000	168	282	13.5	41300	806	514000 (50.3)	223	285	274
16-SWCS-T4-4 28d	506000	168	251	13.5	39800	806	391000 (58.2)	223	ND	274
16-SWCS-T4-4 42d	602000	168	492	13.5	31500	806	271000 (62.3)	223	ND	274
16-SWCS-T4-4 49d	491000	168	6810	13.5	30400	806	172000 (63.8)	223	ND	274
16-SWCS-T4-4 63d	564000	168	510	13.5	29800	806	186000 (65.3)	223	ND	274
16-SWCS-T4-4 100d	646000	168	74	13.5	40700	806	203000 (67.2)	223	739	274
16-SWCS-T6-1 0.08d	10600	101	15	8.11	1790	483	46900 (1.31)	134	221	164
16-SWCS-T6-1 1d	66400	101	24.5	8.11	10300	483	240000 (8.07)	134	629	164
16-SWCS-T6-1 2d	52100	101	11.9	8.11	6630	483	161000 (12.6)	134	838	164
16-SWCS-T6-1 7d	120000	168	ND	13.5	23700	806	537000 (27.7)	223	1770	274
16-SWCS-T6-1 14d	93900	168	ND	13.5	17500	806	383000 (38.5)	223	2150	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T6-1 28d	91600	168	ND	13.5	22300	806	499000 (52.5)	223	2480	274
16-SWCS-T6-1 42d	84700	168	ND	13.5	11600	806	320000 (61.5)	223	2280	274
16-SWCS-T6-1 49d	70900	168	ND	13.5	3620	806	93800 (64.2)	223	2380	274
16-SWCS-T6-1 63d	123000	168	24.6	13.5	5700	806	156000 (68.6)	223	2330	274
16-SWCS-T6-1 100d	456000	168	26	13.5	9340	806	149000 (72.8)	223	539	274
16-SWCS-T6-2 0.08d	8870	101	18.3	8.11	1570	483	40000 (1.12)	134	239	164
16-SWCS-T6-2 1d	63800	101	18.2	8.11	9530	483	217000 (7.24)	134	578	164
16-SWCS-T6-2 2d	58000	101	11.7	8.11	7180	483	178000 (12.3)	134	893	164
16-SWCS-T6-2 7d	130000	168	21.9	13.5	24500	806	565000 (28.2)	223	1890	274
16-SWCS-T6-2 14d	105000	168	16.3	13.5	18900	806	413000 (39.8)	223	1850	274
16-SWCS-T6-2 28d	93400	168	ND	13.5	21300	806	472000 (53.2)	223	2340	274
16-SWCS-T6-2 42d	86400	168	ND	13.5	11300	806	316000 (62.1)	223	2190	274
16-SWCS-T6-2 49d	67500	168	ND	13.5	3410	806	86400 (64.5)	223	1790	274
16-SWCS-T6-2 63d	128000	168	ND	13.5	5150	806	146000 (68.6)	223	1210	274
16-SWCS-T6-2 100d	506000	168	19.3	13.5	9180	806	128000 (72.2)	223	418	274
16-SWCS-T6-3 0.08d	335000	101	98700	8.11	28700	483	191000 (1.75)	134	ND	164
16-SWCS-T6-3 1d	379000	101	34500	8.11	37400	483	409000 (9.50)	134	339	164
16-SWCS-T6-3 2d	385000	101	43700	8.11	33700	483	330000 (15.0)	134	333	164
16-SWCS-T6-3 7d	428000	168	69	13.5	47400	806	654000 (29.9)	223	753	274
16-SWCS-T6-3 14d	470000	168	254	13.5	44200	806	543000 (41.7)	223	628	274
16-SWCS-T6-3 28d	470000	168	100	13.5	45600	806	588000 (55.0)	223	487	274
16-SWCS-T6-3 42d	549000	168	154	13.5	35100	806	475000 (64.6)	223	359	274
16-SWCS-T6-3 49d	440000	168	1840	13.5	29200	806	230000 (67.7)	223	311	274
16-SWCS-T6-3 63d	543000	168	276	13.5	28900	806	253000 (71.0)	223	ND	274
16-SWCS-T6-3 100d	909000	168	80.3	13.5	38500	806	220000 (73.4)	223	ND	274
16-SWCS-T6-4 0.08d	331000	101	97900	8.11	27800	483	182000 (1.52)	134	ND	164
16-SWCS-T6-4 1d	386000	101	20600	8.11	36900	483	394000 (8.92)	134	297	164
16-SWCS-T6-4 2d	393000	101	39400	8.11	34200	483	320000 (14.2)	134	341	164
16-SWCS-T6-4 7d	419000	168	41.4	13.5	48100	806	648000 (29.0)	223	803	274
16-SWCS-T6-4 14d	439000	168	52.3	13.5	45700	806	595000 (42.5)	223	698	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T6-4 28d	457000	168	64.9	13.5	47100	806	604000 (56.3)	223	517	274
16-SWCS-T6-4 42d	563000	168	52.2	13.5	37300	806	530000 (67.6)	223	433	274
16-SWCS-T6-4 49d	443000	168	948	13.5	31300	806	258000 (71.5)	223	374	274
16-SWCS-T6-4 63d	600000	168	163	13.5	37400	806	318000 (76.7)	223	1110	274
16-SWCS-T6-4 100d	871000	168	63.6	13.5	38900	806	248000 (79.8)	223	ND	274

Table A.2. Concentrations of Major Anions and ^{99}Tc Measured in Leachates from EPA Method 1315 Tests (28-Day Cured Monoliths). Cumulative release of NO_3^- , ^{99}Tc , and ^{127}I (%) are shown in parentheses.

A.11

Sample ID	Cl^- (mg/L)	EQL (mg/L)	F^- (mg/L)	EQL (mg/L)	NO_3^- (mg/L)	EQL (mg/L)	NO_2^- (mg/L)	EQL (mg/L)	SO_4^{2-} (mg/L)	EQL (mg/L)	^{99}Tc ($\mu\text{g/L}$)	EQL ($\mu\text{g/L}$)	^{127}I ($\mu\text{g/L}$)	EQL ($\mu\text{g/L}$)
16-SWCS-DI BLK1 0.08d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 1d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 2d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 7d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 14d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 28d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 42d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 49d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 63d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK1 100d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 0.08d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	0.0263 ^(a)	0.0165	ND	0.063
16-SWCS-DI BLK2 1d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 2d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 7d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 14d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 28d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 42d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 49d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 63d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-DI BLK2 100d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 0.08d	248	5	ND	2	200	10	ND	10	997	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 1d	249	5	ND	2	202	10	ND	10	1010	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 2d	253	5	ND	2	204	10	ND	10	1030	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 7d	252	5	ND	2	203	10	ND	10	1030	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 14d	253	6.25	ND	2.5	204	12.5	ND	12.5	1080	18.8	ND	0.0165	ND	0.063

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-PW BLK1 28d	255	6.25	ND	2.5	211	12.5	ND	12.5	1170	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 42d	256	6.25	ND	2.5	212	12.5	ND	12.5	1310	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 49d	253	6.25	ND	2.5	204	12.5	ND	12.5	1100	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 63d	253	6.25	ND	2.5	208	12.5	ND	12.5	1170	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK1 100d	255	6.25	ND	2.5	208	12.5	ND	12.5	1250	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 0.08d	250	5	ND	2	201	10	ND	10	1010	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 1d	251	5	ND	2	202	10	ND	10	1020	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 2d	253	5	ND	2	204	10	ND	10	1030	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 7d	254	5	ND	2	204	10	ND	10	1050	15	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 14d	252	6.25	ND	2.5	203	12.5	ND	12.5	1090	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 28d	254	6.25	ND	2.5	211	12.5	ND	12.5	1180	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 42d	255	6.25	ND	2.5	211	12.5	ND	12.5	1330	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 49d	255	6.25	ND	2.5	205	12.5	ND	12.5	1110	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 63d	251	6.25	ND	2.5	207	12.5	ND	12.5	1170	18.8	ND	0.0165	ND	0.063
16-SWCS-PW BLK2 100d	257	6.25	ND	2.5	210	12.5	ND	12.5	1250	18.8	ND	0.0165	ND	0.063
16-SWCS-T1-1 0.08d	ND	0.25	ND	0.1	2.79 (0.21)	0.5	3.17	0.5	41.8	0.75	3.24 (0.33)	0.0165	24.3 (0.53)	0.063
16-SWCS-T1-1 1d	0.795	0.75	ND	0.3	16.7 (1.44)	1.5	16.3	1.5	163	2.25	23.4 (2.75)	0.0165	147 (3.71)	0.63
16-SWCS-T1-1 2d	ND	0.5	ND	0.2	10.6 (2.22)	1	9.74	1	90.7	1.5	16 (4.40)	0.0165	97.4 (5.83)	0.63
16-SWCS-T1-1 7d	1.8	0.75	ND	0.3	35.9 (4.86)	1.5	24.8	1.5	270	2.25	57.6 (10.3)	0.0165	349 (13.4)	1.26
16-SWCS-T1-1 14d	1.7	1.25	ND	0.5	31.6 (7.19)	2.5	27	2.5	220	3.75	52.1 (15.7)	0.165	316 (20.3)	1.26
16-SWCS-T1-1 28d	1.73	1.25	ND	0.5	27.4 (9.21)	2.5	22.9	2.5	165	3.75	3.41 (16.1)	0.165	278 (26.3)	0.63
16-SWCS-T1-1 42d	ND	1.25	ND	0.5	16.1 (10.4)	2.5	15.5	2.5	97.7	3.75	0.402 (16.1)	0.165	177 (30.1)	1.26
16-SWCS-T1-1 49d	ND	1.25	ND	0.5	5.11 (10.8)	2.5	5.23	2.5	35.6	3.75	0.0818 (16.1)	0.0165	55 (31.3)	1.26
16-SWCS-T1-1 63d	ND	1.25	ND	0.5	8.84 (11.4)	2.5	9.15	2.5	50.6	3.75	0.128 (16.1)	0.0165	100 (33.5)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T1-1 100d	ND	1.25	ND	0.5	16.3 (12.6)	2.5	16.2	2.5	87.1	3.75	0.258 (16.2)	0.0165	174 (37.3)	1.26
16-SWCS-T1-2 0.08d	ND	0.25	ND	0.1	2.06 (0.15)	0.5	2.4	0.5	29.5	0.75	2.39 (0.25)	0.0165	17.3 (0.38)	0.063
16-SWCS-T1-2 1d	0.756	0.75	ND	0.3	15.7 (1.32)	1.5	15.2	1.5	173	2.25	21.7 (2.50)	0.0165	143 (3.50)	0.63
16-SWCS-T1-2 2d	0.57	0.5	ND	0.2	11.8 (2.19)	1	10	1	108	1.5	17.4 (4.31)	0.0165	109 (5.88)	0.63
16-SWCS-T1-2 7d	1.73	0.75	ND	0.3	35 (4.79)	1.5	21.8	1.5	318	2.25	51 (9.61)	0.0165	334 (13.2)	1.26
16-SWCS-T1-2 14d	ND	1.25	ND	0.5	21.5 (6.39)	2.5	16.4	2.5	156	3.75	22.5 (11.9)	0.165	205 (17.7)	1.26
16-SWCS-T1-2 28d	1.28	1.25	ND	0.5	24.7 (8.22)	2.5	17.3	2.5	173	3.75	2.14 (12.2)	0.165	230 (22.7)	0.63
16-SWCS-T1-2 42d	ND	1.25	ND	0.5	11.7 (9.09)	2.5	9.24	2.5	74.8	3.75	0.318 (12.2)	0.165	103 (24.9)	1.26
16-SWCS-T1-2 49d	ND	1.25	ND	0.5	4.28 (9.40)	2.5	3.16	2.5	34.2	3.75	0.0824 (12.2)	0.0165	34.1 (25.7)	1.26
16-SWCS-T1-2 63d	ND	1.25	ND	0.5	7.69 (10.0)	2.5	6.02	2.5	45.5	3.75	0.131 (12.2)	0.0165	65.6 (27.1)	1.26
16-SWCS-T1-2 100d	ND	1.25	ND	0.5	14.5 (11.0)	2.5	11.8	2.5	73.9	3.75	0.25 (12.2)	0.0165	120 (29.7)	1.26
16-SWCS-T1-3 0.08d	247	5	ND	2	2 (0.15)	10	ND	10	1040	15	5.71 (0.59)	0.0165	37.2 (0.81)	0.063
16-SWCS-T1-3 1d	247	5	ND	2	11 (0.96)	10	19.3	10	1100	15	25.1 (3.19)	0.0165	160 (4.29)	0.63
16-SWCS-T1-3 2d	248	5	ND	2	5 (1.33)	10	13.5	10	1050	15	19.4 (5.20)	0.0165	119 (6.88)	0.63
16-SWCS-T1-3 7d	240	5	ND	2	20 (2.81)	10	37.3	10	1190	15	61.8 (11.6)	0.0165	369 (14.9)	1.26
16-SWCS-T1-3 14d	239	6.25	ND	2.5	4 (3.11)	12.5	27	12.5	1110	18.8	33.6 (15.1)	0.165	277 (20.9)	1.26
16-SWCS-T1-3 28d	244	6.25	ND	2.5	2 (3.25)	12.5	30.6	12.5	1140	18.8	3.34 (15.4)	0.165	354 (28.6)	0.63
16-SWCS-T1-3 42d	247	6.25	ND	2.5	ND (3.79)	12.5	18.4	12.5	1200	18.8	0.538 (15.5)	0.165	219 (33.4)	1.26
16-SWCS-T1-3 49d	245	6.25	ND	2.5	ND (4.71)	12.5	ND	12.5	1030	18.8	0.111 (15.5)	0.0165	92.2 (35.4)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T1-3 63d	246	6.25	ND	2.5	ND (5.64)	12.5	ND	12.5	1080	18.8	0.171 (15.5)	0.0165	140 (38.5)	1.26
16-SWCS-T1-3 100d	254	6.25	ND	2.5	ND (6.56)	12.5	20.3	12.5	1130	18.8	0.371 (15.5)	0.0165	244 (43.8)	1.26
16-SWCS-T1-4 0.08d	247	5	ND	2	3 (0.22)	10	ND	10	1030	15	4.79 (0.49)	0.0165	32.3 (0.70)	0.063
16-SWCS-T1-4 1d	247	5	ND	2	13 (1.17)	10	20.3	10	1090	15	24.4 (3.00)	0.0165	136 (3.64)	0.63
16-SWCS-T1-4 2d	250	5	ND	2	11 (1.98)	10	15.8	10	1100	15	24.4 (5.51)	0.0165	141 (6.69)	0.63
16-SWCS-T1-4 7d	238	5	ND	2	24 (3.75)	10	39.8	10	1220	15	72.3 (12.9)	0.0165	423 (15.8)	1.26
16-SWCS-T1-4 14d	239	6.25	ND	2.5	10 (4.48)	12.5	30.7	12.5	1160	18.8	38.1 (16.9)	0.165	326 (22.9)	1.26
16-SWCS-T1-4 28d	241	6.25	ND	2.5	2 (4.63)	12.5	30.5	12.5	1130	18.8	3.55 (17.2)	0.165	335 (30.1)	0.63
16-SWCS-T1-4 42d	248	6.25	ND	2.5	ND (5.16)	12.5	19.6	12.5	1210	18.8	0.582 (17.3)	0.165	224 (35.0)	1.26
16-SWCS-T1-4 49d	245	6.25	ND	2.5	ND (6.08)	12.5	ND	12.5	1030	18.8	0.134 (17.3)	0.0165	91.8 (36.9)	1.26
16-SWCS-T1-4 63d	247	6.25	ND	2.5	ND (6.99)	12.5	ND	12.5	1080	18.8	0.176 (17.3)	0.0165	137 (39.9)	1.26
16-SWCS-T1-4 100d	262	6.25	ND	2.5	ND (7.91)	12.5	21.6	12.5	1120	18.8	0.584 (17.4)	0.0165	274 (45.8)	1.26
16-SWCS-T2-1 0.08d	ND	0.25	ND	0.1	5.51 (0.38)	0.5	4.25	0.5	51.3	0.75	1.99 (0.19)	0.0165	34.6 (0.70)	0.063
16-SWCS-T2-1 1d	1.17	0.75	ND	0.3	36.6 (2.87)	1.5	24.1	1.5	199	2.25	14 (1.53)	0.0165	234 (5.40)	0.63
16-SWCS-T2-1 2d	0.726	0.5	ND	0.2	22.6 (4.42)	1	15.1	1	117	1.5	7.33 (2.23)	0.0165	142 (8.25)	0.63
16-SWCS-T2-1 7d	2.39	0.75	ND	0.3	71.7 (9.31)	1.5	37.4	1.5	360	2.25	14.7 (3.63)	0.0165	474 (17.8)	1.26
16-SWCS-T2-1 14d	1.54	1.25	ND	0.5	46 (12.4)	2.5	34.5	2.5	239	3.75	3.14 (3.93)	0.165	310 (24.0)	1.26
16-SWCS-T2-1 28d	1.39	1.25	ND	0.5	36 (14.9)	2.5	28.9	2.5	189	3.75	1.21 (4.05)	0.165	248 (29.0)	0.63
16-SWCS-T2-1 42d	ND	1.25	ND	0.5	12.4 (15.8)	2.5	13.7	2.5	69.7	3.75	0.167 (4.06)	0.165	84.3 (30.7)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T2-1 49d	ND	1.25	ND	0.5	5.52 (16.1)	2.5	6.04	2.5	37.7	3.75	0.0676 (4.07)	0.0165	38.2 (31.4)	1.26
16-SWCS-T2-1 63d	ND	1.25	ND	0.5	5.16 (16.5)	2.5	6.25	2.5	33.9	3.75	0.0695 (4.08)	0.0165	31.5 (32.1)	1.26
16-SWCS-T2-1 100d	ND	1.25	ND	0.5	5.83 (16.9)	2.5	7.84	2.5	36.8	3.75	0.114 (4.09)	0.0165	41.5 (32.9)	1.26
16-SWCS-T2-2 0.08d	ND	0.25	ND	0.1	6.77 (0.46)	0.5	4.77	0.5	71.5	0.75	3.5 (0.33)	0.0165	43.5 (0.87)	0.063
16-SWCS-T2-2 1d	1.34	0.75	ND	0.3	39.7 (3.16)	1.5	24.1	1.5	219	2.25	23.9 (2.61)	0.0165	258 (6.03)	0.63
16-SWCS-T2-2 2d	0.836	0.5	ND	0.2	25.1 (4.86)	1	15.5	1	128	1.5	13.4 (3.88)	0.0165	163 (9.29)	0.63
16-SWCS-T2-2 7d	2.76	0.75	ND	0.3	80.1 (10.3)	1.5	38.5	1.5	401	2.25	39.4 (7.63)	0.0165	535 (20.0)	1.26
16-SWCS-T2-2 14d	1.85	1.25	ND	0.5	52.6 (13.9)	2.5	36.1	2.5	257	3.75	13 (8.86)	0.165	359 (27.2)	1.26
16-SWCS-T2-2 28d	1.84	1.25	ND	0.5	46.9 (17.1)	2.5	33.5	2.5	238	3.75	1.84 (9.04)	0.165	318 (33.5)	0.63
16-SWCS-T2-2 42d	ND	1.25	ND	0.5	18.3 (18.3)	2.5	17.7	2.5	101	3.75	0.253 (9.06)	0.165	120 (35.9)	1.26
16-SWCS-T2-2 49d	ND	1.25	ND	0.5	5.56 (18.7)	2.5	6.09	2.5	38	3.75	0.0756 (9.07)	0.0165	38.8 (36.7)	1.26
16-SWCS-T2-2 63d	ND	1.25	ND	0.5	7.18 (19.2)	2.5	7.88	2.5	44.4	3.75	0.0881 (9.08)	0.0165	49.8 (37.7)	1.26
16-SWCS-T2-2 100d	ND	1.25	ND	0.5	7.43 (19.7)	2.5	9.14	2.5	48.5	3.75	0.128 (9.09)	0.0165	57.1 (38.8)	1.26
16-SWCS-T2-3 0.08d	248	5	ND	2	5 (0.35)	10	ND	10	1100	15	4.03 (0.39)	0.0165	35.5 (0.72)	0.063
16-SWCS-T2-3 1d	248	5	ND	2	32 (2.56)	10	32.8	10	1150	15	31 (3.40)	0.0165	236 (5.54)	0.63
16-SWCS-T2-3 2d	251	5	ND	2	24 (4.23)	10	26.1	10	1110	15	23.3 (5.66)	0.0165	186 (9.33)	0.63
16-SWCS-T2-3 7d	243	5	ND	2	63 (8.59)	10	63.6	10	1280	15	62.5 (11.7)	0.0165	602 (21.6)	1.26
16-SWCS-T2-3 14d	242	6.25	ND	2.5	39 (11.3)	12.5	53.4	12.5	1240	18.8	29.4 (14.6)	0.165	470 (31.2)	1.26
16-SWCS-T2-3 28d	246	6.25	ND	2.5	21 (12.8)	12.5	45.1	12.5	1260	18.8	2.16 (14.8)	0.165	413 (39.6)	0.63

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T2-3 42d	247	6.25	ND	2.5	ND (13.9)	12.5	23.8	12.5	1240	18.8	0.624 (14.8)	0.165	225 (44.2)	1.26
16-SWCS-T2-3 49d	243	6.25	ND	2.5	ND (14.8)	12.5	ND	12.5	1020	18.8	0.126 (14.9)	0.0165	79.6 (45.8)	1.26
16-SWCS-T2-3 63d	246	6.25	ND	2.5	ND (15.6)	12.5	ND	12.5	1060	18.8	0.2045 ^(a) (14.9)	0.165	110 (48.1)	1.26
16-SWCS-T2-3 100d	248	6.25	ND	2.5	ND (16.5)	12.5	ND	12.5	1070	18.8	0.59 (14.9)	0.0165	154 (51.2)	1.26
16-SWCS-T2-4 0.08d	248	5	ND	2	4 (0.28)	10	ND	10	1050	15	3.51 (0.34)	0.0165	39.6 (0.81)	0.063
16-SWCS-T2-4 1d	247	5	ND	2	29 (2.30)	10	30.8	10	1140	15	22 (2.49)	0.0165	222 (5.37)	0.63
16-SWCS-T2-4 2d	249	5	ND	2	17 (3.49)	10	20.8	10	1080	15	15.2 (3.97)	0.0165	158 (8.61)	0.63
16-SWCS-T2-4 7d	244	5	ND	2	55 (7.32)	10	58.5	10	1250	15	47.7 (8.63)	0.0165	493 (18.7)	1.26
16-SWCS-T2-4 14d	274	6.25	ND	2.5	67 (12.0)	12.5	55.7	12.5	1480	18.8	20.3 (10.6)	0.165	432 (27.6)	1.26
16-SWCS-T2-4 28d	244	6.25	ND	2.5	20 (13.4)	12.5	42.7	12.5	1220	18.8	1.8 (10.8)	0.165	381 (35.4)	0.63
16-SWCS-T2-4 42d	246	6.25	ND	2.5	ND (14.5)	12.5	23	12.5	1240	18.8	0.525 (10.8)	0.165	212 (39.8)	1.26
16-SWCS-T2-4 49d	242	6.25	ND	2.5	ND (15.4)	12.5	ND	12.5	1010	18.8	0.187 ^(a) (10.9)	0.165	81.5 (41.4)	1.26
16-SWCS-T2-4 63d	242	6.25	ND	2.5	ND (16.3)	12.5	ND	12.5	1060	18.8	0.131 (10.9)	0.0165	100 (43.5)	1.26
16-SWCS-T2-4 100d	246	6.25	ND	2.5	ND (17.1)	12.5	ND	12.5	1060	18.8	0.222 (10.9)	0.0165	137 (46.3)	1.26
16-SWCS-T3-1 0.08d	ND	0.25	ND	0.1	2.12 (0.15)	0.5	1.58	0.5	28.3	0.75	3.93 (0.38)	0.0165	ND (0.00)	0.063
16-SWCS-T3-1 1d	ND	1	ND	0.4	22.6 (1.69)	2	14.7	2	166	3	53.1 (5.46)	0.0165	ND (0.00)	0.063
16-SWCS-T3-1 2d	0.666	0.5	ND	0.2	16.4 (2.81)	1	9.67	1	113	1.5	39.4 (9.23)	0.0165	ND (0.00)	0.063
16-SWCS-T3-1 7d	2	0.75	ND	0.3	48.7 (6.14)	1.5	22.5	1.5	344	2.25	122 (20.9)	0.0165	ND (0.00)	0.126
16-SWCS-T3-1 14d	2	1.25	ND	0.5	46.2 (9.30)	2.5	24	2.5	379	3.75	125 (32.9)	0.165	ND (0.03)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T3-1 28d	1.81	1.25	ND	0.5	36.1 (11.8)	2.5	17.3	2.5	302	3.75	103 (42.8)	0.165	ND (0.04)	0.63
16-SWCS-T3-1 42d	ND	1.25	ND	0.5	16.5 (12.9)	2.5	8.44	2.5	148	3.75	52 (47.7)	0.165	ND (0.07)	1.26
16-SWCS-T3-1 49d	ND	1.25	ND	0.5	7.4 (13.4)	2.5	3.88	2.5	82.1	3.75	18.4 (49.5)	0.165	ND (0.10)	1.26
16-SWCS-T3-1 63d	ND	1.25	ND	0.5	10.4 (14.1)	2.5	5.76	2.5	111	3.75	18.6 (51.3)	0.165	ND (0.12)	1.26
16-SWCS-T3-1 100d	ND	1.25	ND	0.5	16.8 (15.3)	2.5	10.4	2.5	209	3.75	1.29 (51.4)	0.0165	ND (0.15)	1.26
16-SWCS-T3-2 0.08d	ND	0.25	ND	0.1	2.95 (0.20)	0.5	2.04	0.5	49.9	0.75	5.37 (0.52)	0.0165	ND (0.00)	0.063
16-SWCS-T3-2 1d	1.2	1	ND	0.4	30.1 (2.28)	2	19.3	2	226	3	69.5 (7.22)	0.0165	ND (0.00)	0.063
16-SWCS-T3-2 2d	0.692	0.5	ND	0.2	17.6 (3.49)	1	10.9	1	122	1.5	40.9 (11.2)	0.0165	ND (0.00)	0.063
16-SWCS-T3-2 7d	2.61	0.75	ND	0.3	65.3 (7.99)	1.5	30.1	1.5	478	2.25	165 (27.1)	0.0165	ND (0.01)	0.126
16-SWCS-T3-2 14d	1.66	1.25	ND	0.5	37.5 (10.6)	2.5	23.3	2.5	232	3.75	102 (36.9)	0.165	ND (0.03)	1.26
16-SWCS-T3-2 28d	1.72	1.25	ND	0.5	33 (12.9)	2.5	19.7	2.5	224	3.75	100 (46.6)	0.165	ND (0.04)	0.63
16-SWCS-T3-2 42d	1.26	1.25	ND	0.5	18.5 (14.1)	2.5	12.2	2.5	156	3.75	65.1 (52.9)	0.165	ND (0.07)	1.26
16-SWCS-T3-2 49d	ND	1.25	ND	0.5	5.85 (14.5)	2.5	4.04	2.5	62.5	3.75	15.5 (54.4)	0.165	ND (0.10)	1.26
16-SWCS-T3-2 63d	ND	1.25	ND	0.5	10.4 (15.2)	2.5	7.64	2.5	114	3.75	16 (55.9)	0.165	ND (0.12)	1.26
16-SWCS-T3-2 100d	ND	1.25	ND	0.5	14.8 (16.3)	2.5	11.5	2.5	166	3.75	0.328 (55.9)	0.0165	ND (0.15)	1.26
16-SWCS-T3-3 0.08d	247	5	ND	2	5 (0.34)	10	ND	10	1050	15	10.2 (0.98)	0.0165	ND (0.00)	0.063
16-SWCS-T3-3 1d	243	5	ND	2	26 (2.13)	10	23.4	10	1150	15	68 (7.54)	0.0165	ND (0.00)	0.063
16-SWCS-T3-3 2d	247	5	ND	2	18 (3.37)	10	17	10	1120	15	49.4 (12.3)	0.0165	ND (0.00)	0.063
16-SWCS-T3-3 7d	241	5	ND	2	46 (6.54)	10	45	10	1280	15	149 (26.7)	0.0165	ND (0.00)	0.126

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T3-3 14d	245	6.25	ND	2.5	32 (8.74)	12.5	38.7	12.5	1260	18.8	141 (40.3)	0.165	ND (0.01)	1.26
16-SWCS-T3-3 28d	249	6.25	ND	2.5	19 (10.1)	12.5	33.5	12.5	1300	18.8	129 (52.7)	0.165	ND (0.03)	0.63
16-SWCS-T3-3 42d	249	6.25	ND	2.5	ND (11.1)	12.5	18.2	12.5	1330	18.8	73.3 (59.8)	0.165	ND (0.04)	1.26
16-SWCS-T3-3 49d	247	6.25	ND	2.5	ND (12.0)	12.5	ND	12.5	1100	18.8	27 (62.4)	0.165	ND (0.10)	1.26
16-SWCS-T3-3 63d	247	6.25	ND	2.5	ND (12.9)	12.5	ND	12.5	1180	18.8	17.4 (64.0)	0.165	ND (0.12)	1.26
16-SWCS-T3-3 100d	256	6.25	ND	2.5	ND (13.7)	12.5	22.3	12.5	1270	18.8	1.4 (64.2)	0.0165	ND (0.15)	1.26
16-SWCS-T3-4 0.08d	248	5	ND	2	5 (0.35)	10	ND	10	1050	15	8.1 (0.79)	0.0165	ND (0.00)	0.063
16-SWCS-T3-4 1d	243	5	ND	2	21 (1.81)	10	20	10	1140	15	61.6 (6.79)	0.0165	ND (0.00)	0.063
16-SWCS-T3-4 2d	246	5	ND	2	15 (2.85)	10	14.1	10	1110	15	46.3 (11.3)	0.0165	ND (0.00)	0.063
16-SWCS-T3-4 7d	239	5	ND	2	35 (5.29)	10	35.5	10	1290	15	130 (24.0)	0.0165	ND (0.06)	2.52
16-SWCS-T3-4 14d	241	6.25	ND	2.5	25 (7.03)	12.5	31.9	12.5	1310	18.8	119 (35.6)	0.165	ND (0.08)	1.26
16-SWCS-T3-4 28d	243	6.25	ND	2.5	7 (7.52)	12.5	24.8	12.5	1320	18.8	108 (46.1)	0.165	ND (0.09)	0.63
16-SWCS-T3-4 42d	246	6.25	ND	2.5	ND (8.20)	12.5	13	12.5	1310	18.8	52.6 (51.2)	0.165	ND (0.12)	1.26
16-SWCS-T3-4 49d	245	6.25	ND	2.5	ND (9.07)	12.5	ND	12.5	1060	18.8	13.6 (52.5)	0.165	ND (0.15)	1.26
16-SWCS-T3-4 63d	244	6.25	ND	2.5	ND (9.94)	12.5	ND	12.5	1100	18.8	10.1 (53.5)	0.165	ND (0.17)	1.26
16-SWCS-T3-4 100d	257	6.25	ND	2.5	ND (10.8)	12.5	13.5	12.5	1130	18.8	0.559 (53.6)	0.0165	ND (0.20)	1.26
16-SWCS-T4-1 0.08d	ND	0.25	ND	0.1	2.77 (0.20)	0.5	3.3	0.5	35.8	0.75	3.75 (0.37)	0.0165	35.2 (0.73)	0.063
16-SWCS-T4-1 1d	1.46	1	ND	0.4	24.4 (1.92)	2	24.7	2	222	3	39.3 (4.26)	0.0165	329 (7.59)	1.26
16-SWCS-T4-1 2d	0.858	0.5	ND	0.2	14.6 (2.96)	1	13.8	1	122	1.5	24.3 (6.67)	0.0165	195 (11.6)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T4-1 7d	2.6	0.75	ND	0.3	44.7 (6.12)	1.5	32.7	1.5	400	2.25	71.8 (13.8)	0.0165	598 (24.1)	1.26
16-SWCS-T4-1 14d	1.75	1.25	ND	0.5	31.8 (8.37)	2.5	30.3	2.5	312	3.75	17.8 (15.5)	0.165	402 (32.5)	1.26
16-SWCS-T4-1 28d	ND	1.25	ND	0.5	22.6 (10.0)	2.5	22.3	2.5	216	3.75	0.893 (15.6)	0.165	259 (37.9)	0.63
16-SWCS-T4-1 42d	ND	1.25	ND	0.5	10.3 (10.7)	2.5	11.3	2.5	100	3.75	0.37 (15.7)	0.165	100 (40.0)	1.26
16-SWCS-T4-1 49d	ND	1.25	ND	0.5	5.94 (11.1)	2.5	6.47	2.5	68.5	3.75	0.263 (15.7)	0.165	46.8 (40.9)	1.26
16-SWCS-T4-1 63d	ND	1.25	ND	0.5	7.76 (11.7)	2.5	8.23	2.5	83.5	3.75	0.347 (15.7)	0.165	56.1 (42.1)	1.26
16-SWCS-T4-1 100d	ND	1.25	ND	0.5	10.3 (12.4)	2.5	11.7	2.5	85.4	3.75	0.556 (15.8)	0.0165	74.3 (43.7)	1.26
16-SWCS-T4-2 0.08d	ND	0.25	ND	0.1	3.11 (0.22)	0.5	3.58	0.5	37.2	0.75	4.51 (0.45)	0.0165	40.4 (0.85)	0.063
16-SWCS-T4-2 1d	1.48	1	ND	0.4	24.6 (1.97)	2	24.9	2	229	3	40.7 (4.51)	0.0165	333 (7.83)	1.26
16-SWCS-T4-2 2d	1.02	0.75	ND	0.3	17.6 (3.23)	1.5	17.4	1.5	155	2.25	28.8 (7.38)	0.0165	231 (12.7)	1.26
16-SWCS-T4-2 7d	2.64	0.75	ND	0.3	46.2 (6.52)	1.5	32.8	1.5	418	2.25	81.1 (15.5)	0.0165	603 (25.3)	1.26
16-SWCS-T4-2 14d	1.47	1.25	ND	0.5	29.2 (8.60)	2.5	28.3	2.5	274	3.75	16.4 (17.1)	0.165	338 (32.4)	1.26
16-SWCS-T4-2 28d	ND	1.25	ND	0.5	20.1 (10.0)	2.5	20.1	2.5	176	3.75	0.75 (17.2)	0.165	205 (36.7)	0.63
16-SWCS-T4-2 42d	ND	1.25	ND	0.5	10.5 (10.8)	2.5	11.2	2.5	98.9	3.75	0.434 (17.2)	0.165	88.9 (38.6)	1.26
16-SWCS-T4-2 49d	ND	1.25	ND	0.5	3.92 (11.1)	2.5	3.8	2.5	44	3.75	0.203 (17.2)	0.165	23.8 (39.1)	1.26
16-SWCS-T4-2 63d	ND	1.25	ND	0.5	6.22 (11.5)	2.5	6.38	2.5	65.1	3.75	0.333 (17.3)	0.165	40.8 (39.9)	1.26
16-SWCS-T4-2 100d	ND	1.25	ND	0.5	11 (12.3)	2.5	12	2.5	85.4	3.75	0.906 (17.4)	0.0165	73.4 (41.5)	1.26
16-SWCS-T4-3 0.08d	250	5	ND	2	4 (0.28)	10	ND	10	1040	15	4.59 (0.45)	0.0165	42.2 (0.88)	0.063
16-SWCS-T4-3 1d	251	5	ND	2	25 (2.04)	10	38.1	10	1190	15	45.4 (4.92)	0.0165	393 (9.01)	1.26

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16-SWCS-T4-3 2d	253	5	ND	2	15 (3.10)	10	24.7	10	1130	15	29.6 (7.84)	0.0165	249 (14.2)	1.26
16-SWCS-T4-3 7d	243	5	ND	2	30 (5.21)	10	57.8	10	1350	15	83.2 (16.0)	0.0165	639 (27.4)	1.26
16-SWCS-T4-3 14d	235	6.25	ND	2.5	ND (6.70)	12.5	34.1	12.5	1170	18.8	14.1 (17.4)	0.165	321 (34.1)	1.26
16-SWCS-T4-3 28d	236	6.25	ND	2.5	ND (7.58)	12.5	33.4	12.5	1180	18.8	1.05 (17.5)	0.165	258 (39.4)	0.63
16-SWCS-T4-3 42d	246	6.25	ND	2.5	ND (8.46)	12.5	20.8	12.5	1250	18.8	0.635 (17.6)	0.165	156 (42.6)	1.26
16-SWCS-T4-3 49d	245	6.25	ND	2.5	ND (9.34)	12.5	ND	12.5	1050	18.8	0.417 (17.6)	0.165	58.4 (43.8)	1.26
16-SWCS-T4-3 63d	247	6.25	ND	2.5	ND (10.2)	12.5	ND	12.5	1080	18.8	0.927 (17.7)	0.165	82.2 (45.5)	1.26
16-SWCS-T4-3 100d	256	6.25	ND	2.5	ND (11.1)	12.5	16.1	12.5	1040	18.8	2.05 (17.9)	0.0165	110 (47.8)	1.26
16-SWCS-T4-4 0.08d	250	5	ND	2	6 (0.42)	10	ND	10	1060	15	7.84 (0.77)	0.0165	67.9 (1.40)	0.063
16-SWCS-T4-4 1d	249	5	ND	2	27 (2.31)	10	38.8	10	1210	15	46.4 (5.32)	0.0165	364 (8.90)	1.26
16-SWCS-T4-4 2d	251	5	ND	2	18 (3.57)	10	28.5	10	1160	15	36.1 (8.85)	0.0165	289 (14.9)	1.26
16-SWCS-T4-4 7d	247	5	ND	2	67 (8.26)	10	87.5	10	1730	15	137 (22.3)	0.0165	1140 (38.3)	1.26
16-SWCS-T4-4 14d	240	6.25	ND	2.5	12 (9.10)	12.5	46.9	12.5	1330	18.8	19.4 (24.2)	0.165	457 (47.8)	1.26
16-SWCS-T4-4 28d	239	6.25	ND	2.5	ND (10.0)	12.5	35	12.5	1220	18.8	0.911 (24.3)	0.165	305 (54.1)	0.63
16-SWCS-T4-4 42d	245	6.25	ND	2.5	ND (10.8)	12.5	21.3	12.5	1260	18.8	0.602 (24.3)	0.165	153 (57.2)	1.26
16-SWCS-T4-4 49d	246	6.25	ND	2.5	ND (11.7)	12.5	ND	12.5	1060	18.8	0.434 (24.4)	0.165	59.9 (58.4)	1.26
16-SWCS-T4-4 63d	248	6.25	ND	2.5	ND (12.6)	12.5	ND	12.5	1080	18.8	0.749 (24.4)	0.165	74 (60.0)	1.26
16-SWCS-T4-4 100d	259	6.25	ND	2.5	ND (13.5)	12.5	16.1	12.5	1000	18.8	1.98 (24.6)	0.0165	107 (62.2)	1.26
16-SWCS-T6-1 0.08d	0.603	0.25	ND	0.1	4.45 (0.31)	0.5	3.52	0.5	49.9	0.75	3.45 (0.33)	0.0165	47.3 (0.96)	0.063

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16-SWCS-T6-1 1d	4.2	0.25	ND	0.1	31.3 (2.46)	0.5	13.7	0.5	202	15	30 (3.23)	0.0165	342 (7.90)	1.26
16-SWCS-T6-1 2d	2.58	0.5	ND	0.2	19.6 (3.82)	1	13	1	117	1.5	19.2 (5.08)	0.0165	218 (12.3)	1.26
16-SWCS-T6-1 7d	9.21	0.75	ND	0.3	66.8 (8.42)	1.5	33.6	1.5	394	2.25	61.3 (11.0)	0.0165	768 (27.9)	1.26
16-SWCS-T6-1 14d	6.42	1.25	ND	0.5	43.4 (11.4)	2.5	30.6	2.5	251	3.75	13.9 (12.3)	0.165	506 (38.2)	1.26
16-SWCS-T6-1 28d	6.68	1.25	ND	0.5	41.2 (14.3)	2.5	30.4	2.5	279	3.75	2.52 (12.6)	0.165	502 (48.4)	0.63
16-SWCS-T6-1 42d	3	1.25	ND	0.5	19 (15.6)	2.5	17.9	2.5	160	3.75	1.16 (12.7)	0.165	227 (53.0)	1.26
16-SWCS-T6-1 49d	ND	1.25	ND	0.5	8.15 (16.1)	2.5	8.83	2.5	85.4	3.75	0.621 (12.8)	0.165	89 (54.8)	1.26
16-SWCS-T6-1 63d	1.28	1.25	ND	0.5	10.1 (16.8)	2.5	10.8	2.5	115	3.75	0.883 (12.8)	0.165	106 (56.9)	1.26
16-SWCS-T6-1 100d	1.76	1.25	ND	0.5	17.9 (18.1)	2.5	19	2.5	401	3.75	2.35 (13.1)	0.0165	166 (60.3)	1.26
16-SWCS-T6-2 0.08d	0.467	0.25	ND	0.1	3.52 (0.24)	0.5	3.02	0.5	41.8	0.75	3.07 (0.30)	0.0165	35.5 (0.72)	0.063
16-SWCS-T6-2 1d	3.72	0.25	ND	0.1	27.7 (2.16)	0.5	13.3	0.5	184	15	28.8 (3.08)	0.0165	306 (6.95)	1.26
16-SWCS-T6-2 2d	2.85	0.5	ND	0.2	21.3 (3.63)	1	14.5	1	130	1.5	23 (5.31)	0.0165	234 (11.7)	1.26
16-SWCS-T6-2 7d	9.68	0.75	ND	0.3	69.5 (8.43)	1.5	35.7	1.5	439	2.25	73 (12.4)	0.0165	786 (27.7)	1.26
16-SWCS-T6-2 14d	7.02	1.25	ND	0.5	47.1 (11.7)	2.5	33.7	2.5	288	3.75	19.3 (14.2)	0.165	558 (39.0)	1.26
16-SWCS-T6-2 28d	6.29	1.25	ND	0.5	39.1 (14.4)	2.5	29.8	2.5	274	3.75	2.58 (14.5)	0.165	478 (48.8)	0.63
16-SWCS-T6-2 42d	3.07	1.25	ND	0.5	19.8 (15.8)	2.5	18.9	2.5	175	3.75	1.09 (14.6)	0.165	222 (53.3)	1.26
16-SWCS-T6-2 49d	ND	1.25	ND	0.5	6.02 (16.2)	2.5	6.7	2.5	63.2	3.75	0.423 (14.6)	0.165	64.6 (54.6)	1.26
16-SWCS-T6-2 63d	ND	1.25	ND	0.5	9.86 (16.8)	2.5	11	2.5	125	3.75	0.92 (14.7)	0.165	102 (56.7)	1.26
16-SWCS-T6-2 100d	1.64	1.25	ND	0.5	17.5 (18.1)	2.5	19	2.5	435	3.75	2.62 (15.0)	0.0165	159 (59.9)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T6-3 0.08d	250	5	ND	2	7 (0.48)	10	ND	10	1060	15	3.33 (0.32)	0.0165	72.5 (1.46)	0.063
16-SWCS-T6-3 1d	252	5	ND	2	37 (3.00)	10	44.6	10	1190	15	20.8 (2.30)	0.0165	422 (9.93)	1.26
16-SWCS-T6-3 2d	254	5	ND	2	22 (4.50)	10	29.6	10	1120	15	12.3 (3.48)	0.0165	264 (15.2)	1.26
16-SWCS-T6-3 7d	252	5	ND	2	61 (8.66)	10	75.6	10	1310	15	21.8 (5.56)	0.0165	774 (30.8)	1.26
16-SWCS-T6-3 14d	251	6.25	ND	2.5	36 (11.1)	12.5	62	12.5	1230	18.8	3.72 (5.92)	0.165	590 (42.6)	1.26
16-SWCS-T6-3 28d	251	6.25	ND	2.5	17 (12.3)	12.5	56.2	12.5	1280	18.8	2.7 (6.18)	0.165	517 (53.0)	0.63
16-SWCS-T6-3 42d	249	6.25	ND	2.5	ND (13.3)	12.5	33.4	12.5	1320	18.8	1.67 (6.33)	0.165	285 (58.7)	1.26
16-SWCS-T6-3 49d	244	6.25	ND	2.5	ND (14.1)	12.5	13	12.5	1040	18.8	0.94 (6.42)	0.165	99.9 (60.7)	1.26
16-SWCS-T6-3 63d	244	6.25	ND	2.5	ND (15.0)	12.5	17.8	12.5	1080	18.8	1.78 (6.59)	0.165	133 (63.4)	1.26
16-SWCS-T6-3 100d	259	6.25	ND	2.5	ND (15.8)	12.5	30.8	12.5	1190	18.8	10.4 (7.59)	0.0165	201 (67.5)	1.26
16-SWCS-T6-4 0.08d	249	5	ND	2	4 (0.28)	10	ND	10	1050	15	4.68 (0.45)	0.0165	53.9 (1.09)	0.063
16-SWCS-T6-4 1d	252	5	ND	2	30 (2.34)	10	34.6	10	1160	15	36.5 (3.97)	0.0165	307 (7.32)	1.26
16-SWCS-T6-4 2d	253	5	ND	2	19 (3.65)	10	23.4	10	1100	15	25.7 (6.45)	0.0165	249 (12.4)	1.26
16-SWCS-T6-4 7d	250	5	ND	2	52 (7.24)	10	61	10	1290	15	72.2 (13.4)	0.0165	760 (27.8)	1.26
16-SWCS-T6-4 14d	254	6.25	ND	2.5	40 (10.0)	12.5	57.3	12.5	1290	18.8	23.9 (15.7)	0.165	677 (41.5)	1.26
16-SWCS-T6-4 28d	251	6.25	ND	2.5	17 (11.2)	12.5	47.4	12.5	1300	18.8	3.48 (16.1)	0.165	519 (52.1)	0.63
16-SWCS-T6-4 42d	251	6.25	ND	2.5	ND (12.2)	12.5	31.5	12.5	1390	18.8	1.87 (16.2)	0.165	330 (58.7)	1.26
16-SWCS-T6-4 49d	244	6.25	ND	2.5	ND (13.0)	12.5	ND	12.5	1060	18.8	0.881 (16.3)	0.165	122 (61.2)	1.26
16-SWCS-T6-4 63d	246	6.25	ND	2.5	ND (13.9)	12.5	16.7	12.5	1100	18.8	1.42 (16.5)	0.165	159 (64.4)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T6-4 100d	256	6.25	ND	2.5	ND (14.8)	12.5	26.9	12.5	1180	18.8	7.7 (17.2)	0.0165	230 (69.1)	1.26
a. Duplicate samples averaged														

Table A.3. Concentrations of Major Cations Measured in Leachates from EPA Method 1315 Tests (60-Day Cured Monoliths). Cumulative release of Na (%) is shown in parentheses.

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-60-DI BLK1 0.08d	4240	168	201	13.5	ND	806	757	223	718	274
16-SWCS-60-DI BLK1 1d	441	168	ND	13.5	ND	806	318	223	ND	274
16-SWCS-60-DI BLK1 2d	3890	168	178	13.5	ND	806	568	223	353	274
16-SWCS-60-DI BLK1 7d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK1 14d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK1 28d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK1 42d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK1 49d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK1 63d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK1 100d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 0.08d	ND	168	ND	13.5	ND	806	385	223	ND	274
16-SWCS-60-DI BLK2 1d	303	168	ND	13.5	ND	806	274	223	ND	274
16-SWCS-60-DI BLK2 2d	234	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 7d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 14d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 28d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 42d	714	168	25.7	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 49d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 63d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-DI BLK2 100d	ND	168	ND	13.5	ND	806	ND	223	ND	274
16-SWCS-60-PW BLK1 0.08d	325000	168	116000	13.5	24900	806	122000	223	ND	274
16-SWCS-60-PW BLK1 1d	327000	168	115000	13.5	24500	806	121000	223	ND	274
16-SWCS-60-PW BLK1 2d	335000	168	115000	13.5	24600	806	120000	223	ND	274
16-SWCS-60-PW BLK1 7d	325000	168	112000	13.5	26800	806	119000	223	ND	274
16-SWCS-60-PW BLK1 14d	346000	168	122000	13.5	25400	806	132000	223	ND	274
16-SWCS-60-PW BLK1 28d	384000	168	112000	13.5	24300	806	125000	223	ND	274
16-SWCS-60-PW BLK1 42d	400000	168	104000	13.5	26100	806	118000	223	ND	274
16-SWCS-60-PW BLK1 49d	474000	168	109000	13.5	25300	806	122000	223	ND	274
16-SWCS-60-PW BLK1 63d	456000	168	108000	13.5	26200	806	122000	223	ND	274
16-SWCS-60-PW BLK1 100d	486000	168	113000	13.5	26400	806	121000	223	ND	274
16-SWCS-60-PW BLK2 0.08d	324000	168	115000	13.5	25000	806	122000	223	ND	274
16-SWCS-60-PW BLK2 1d	332000	168	115000	13.5	24900	806	122000	223	ND	274
16-SWCS-60-PW BLK2 2d	327000	168	117000	13.5	24200	806	119000	223	ND	274
16-SWCS-60-PW BLK2 7d	330000	168	114000	13.5	26700	806	120000	223	ND	274
16-SWCS-60-PW BLK2 14d	347000	168	121000	13.5	23800	806	124000	223	ND	274
16-SWCS-60-PW BLK2 28d	402000	168	110000	13.5	25400	806	130000	223	ND	274
16-SWCS-60-PW BLK2 42d	398000	168	107000	13.5	26100	806	117000	223	ND	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-60-PW BLK2 49d	463000	168	111000	13.5	25000	806	120000	223	ND	274
16-SWCS-60-PW BLK2 63d	459000	168	109000	13.5	26300	806	122000	223	ND	274
16-SWCS-60-PW BLK2 100d	493000	168	116000	13.5	26700	806	122000	223	ND	274
16-SWCS-T1-6 0.08d	12500	168	60.1	13.5	1260	806	28400 (0.833)	223	ND	274
16-SWCS-T1-6 1d	78300	168	24.3	13.5	7080	806	126000 (4.62)	223	499	274
16-SWCS-T1-6 2d	60000	168	13.5	13.5	4560	806	86900 (7.22)	223	682	274
16-SWCS-T1-6 7d	143000	168	16	13.5	21700	806	343000 (17.6)	223	1290	274
16-SWCS-T1-6 14d	126000	168	15.3	13.5	16900	806	302000 (26.7)	223	1610	274
16-SWCS-T1-6 28d	112000	168	ND	13.5	20900	806	357000 (37.4)	223	1910	274
16-SWCS-T1-6 42d	80300	168	ND	13.5	15100	806	228000 (44.3)	223	2300	274
16-SWCS-T1-6 49d	57900	168	ND	13.5	4390	806	72000 (46.5)	223	1020	274
16-SWCS-T1-6 63d	65900	168	14.6	13.5	9690	806	148000 (50.9)	223	3000	274
16-SWCS-T1-6 100d	80000	168	ND	13.5	18500	806	308000 (60.2)	223	3860	274
16-SWCS-T1-7 0.08d	38200	168	1120	13.5	1550	806	32000 (0.942)	223	5440	274
16-SWCS-T1-7 1d	96500	168	20.5	13.5	8420	806	145000 (5.30)	223	610	274
16-SWCS-T1-7 2d	58100	168	14.9	13.5	4330	806	82600 (7.77)	223	715	274
16-SWCS-T1-7 7d	149000	168	13.6	13.5	22700	806	365000 (18.8)	223	1140	274
16-SWCS-T1-7 14d	118000	168	ND	13.5	16400	806	311000 (28.1)	223	1270	274
16-SWCS-T1-7 28d	144000	168	14.4	13.5	22700	806	399000 (40.2)	223	2020	274
16-SWCS-T1-7 42d	86300	168	ND	13.5	16000	806	256000 (47.9)	223	2730	274
16-SWCS-T1-7 49d	54600	168	ND	13.5	4990	806	88700 (50.6)	223	2060	274
16-SWCS-T1-7 63d	59300	168	ND	13.5	9830	806	147000 (55.0)	223	3220	274
16-SWCS-T1-7 100d	90200	168	ND	13.5	19500	806	313000 (64.4)	223	3040	274
16-SWCS-T1-8 0.08d	331000	168	104000	13.5	27000	806	160000 (1.16)	223	ND	274
16-SWCS-T1-8 1d	381000	168	45400	13.5	33200	806	260000 (5.41)	223	ND	274
16-SWCS-T1-8 2d	376000	168	67100	13.5	29600	806	204000 (7.98)	223	ND	274
16-SWCS-T1-8 7d	450000	168	98.3	13.5	46200	806	444000 (17.9)	223	ND	274
16-SWCS-T1-8 14d	461000	168	598	13.5	39700	806	404000 (26.2)	223	ND	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T1-8 28d	529000	168	82.4	13.5	48000	806	529000 (38.6)	223	ND	274
16-SWCS-T1-8 42d	473000	168	134	13.5	42700	806	377000 (46.5)	223	ND	274
16-SWCS-T1-8 49d	521000	168	11000	13.5	31800	806	234000 (50.0)	223	ND	274
16-SWCS-T1-8 63d	506000	168	2420	13.5	36300	806	276000 (54.7)	223	ND	274
16-SWCS-T1-8 100d	539000	168	ND	13.5	46200	806	452000 (64.8)	223	ND	274
16-SWCS-T1-9 0.08d	333000	168	96100	13.5	28200	806	77000 (2.69)	223	ND	274
16-SWCS-T1-9 1d	398000	168	21400	13.5	37900	806	269000 (12.1)	223	ND	274
16-SWCS-T1-9 2d	391000	168	47900	13.5	32700	806	162000 (17.8)	223	ND	274
16-SWCS-T1-9 7d	467000	168	118	13.5	54900	806	482000 (34.6)	223	326	274
16-SWCS-T1-9 14d	475000	168	191	13.5	42300	806	351000 (46.9)	223	ND	274
16-SWCS-T1-9 28d	518000	168	59.4	13.5	41700	806	334000 (58.6)	223	ND	274
16-SWCS-T1-9 42d	480000	168	127	13.5	36200	806	179000 (64.9)	223	ND	274
16-SWCS-T1-9 49d	527000	168	20200	13.5	31000	806	70000 (67.3)	223	ND	274
16-SWCS-T1-9 63d	517000	168	2170	13.5	31400	806	84000 (70.2)	223	ND	274
16-SWCS-T1-9 100d	590000	168	ND	13.5	36200	806	144000 (75.3)	223	ND	274
16-SWCS-T2-5 0.08d	15200	168	65.4	13.5	2780	806	67400 (1.92)	223	303	274
16-SWCS-T2-5 1d	75200	168	16.9	13.5	11400	806	243000 (8.92)	223	469	274
16-SWCS-T2-5 2d	54900	168	ND	13.5	6140	806	135000 (12.8)	223	500	274
16-SWCS-T2-5 7d	152000	168	14.5	13.5	23000	806	481000 (26.7)	223	1050	274
16-SWCS-T2-5 14d	159000	168	14.8	13.5	15000	806	374000 (37.5)	223	1020	274
16-SWCS-T2-5 28d	188000	168	16.6	13.5	15200	806	371000 (48.2)	223	942	274
16-SWCS-T2-5 42d	169000	168	17.1	13.5	8400	806	181000 (53.4)	223	1020	274
16-SWCS-T2-5 49d	180000	168	ND	13.5	3280	806	90700 (56.0)	223	1090	274
16-SWCS-T2-5 63d	147000	168	13.9	13.5	4070	806	72500 (58.1)	223	1560	274
16-SWCS-T2-5 100d	279000	168	ND	13.5	7480	806	84700 (60.5)	223	1090	274
16-SWCS-T2-6 0.08d	16200	168	62.9	13.5	2640	806	81000 (2.21)	223	449	274
16-SWCS-T2-6 1d	82200	168	25	13.5	12700	806	263000 (9.43)	223	705	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T2-6 2d	70800	168	16.5	13.5	7300	806	162000 (13.9)	223	759	274
16-SWCS-T2-6 7d	171000	168	15.2	13.5	25200	806	514000 (28.0)	223	1070	274
16-SWCS-T2-6 14d	172000	168	ND	13.5	18000	806	471000 (40.9)	223	1290	274
16-SWCS-T2-6 28d	147000	168	14	13.5	18400	806	525000 (55.4)	223	1660	274
16-SWCS-T2-6 42d	79000	168	ND	13.5	10700	806	301000 (63.6)	223	2650	274
16-SWCS-T2-6 49d	64400	168	ND	13.5	3000	806	122000 (67.0)	223	2590	274
16-SWCS-T2-6 63d	64400	168	ND	13.5	4650	806	134000 (70.7)	223	3700	274
16-SWCS-T2-6 100d	74200	168	ND	13.5	5880	806	140000 (74.5)	223	4370	274
16-SWCS-T2-7 0.08d	326000	168	107000	13.5	26900	806	45000 (1.28)	223	ND	274
16-SWCS-T2-7 1d	383000	168	28300	13.5	36400	806	250000 (8.36)	223	ND	274
16-SWCS-T2-7 2d	392000	168	44200	13.5	33800	806	188000 (13.7)	223	ND	274
16-SWCS-T2-7 7d	459000	168	54.8	13.5	53300	806	525000 (28.6)	223	313	274
16-SWCS-T2-7 14d	471000	168	221	13.5	42700	806	475000 (42.0)	223	ND	274
16-SWCS-T2-7 28d	521000	168	75.9	13.5	48500	806	676000 (61.2)	223	ND	274
16-SWCS-T2-7 42d	467000	168	93.3	13.5	36200	806	329000 (70.5)	223	ND	274
16-SWCS-T2-7 49d	511000	168	8830	13.5	29200	806	122000 (74.0)	223	ND	274
16-SWCS-T2-7 63d	519000	168	1850	13.5	30600	806	138000 (77.9)	223	ND	274
16-SWCS-T2-7 100d	585000	168	ND	13.5	32700	806	132000 (81.6)	223	314	274
16-SWCS-T2-8 0.08d	330000	168	96500	13.5	27600	806	65000 (1.82)	223	ND	274
16-SWCS-T2-8 1d	384000	168	20300	13.5	36900	806	250000 (8.83)	223	ND	274
16-SWCS-T2-8 2d	386000	168	41800	13.5	33400	806	179000 (13.9)	223	ND	274
16-SWCS-T2-8 7d	464000	168	133	13.5	54300	806	557000 (29.5)	223	375	274
16-SWCS-T2-8 14d	466000	168	169	13.5	45100	806	511000 (43.8)	223	ND	274
16-SWCS-T2-8 28d	512000	168	57.5	13.5	47700	806	633000 (61.6)	223	ND	274
16-SWCS-T2-8 42d	487000	168	98.9	13.5	38100	806	347000 (71.3)	223	ND	274
16-SWCS-T2-8 49d	510000	168	7150	13.5	28800	806	124000 (74.8)	223	1030	274
16-SWCS-T2-8 63d	520000	168	1050	13.5	32300	806	155000 (79.1)	223	ND	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T2-8 100d	620000	168	ND	13.5	33600	806	150000 (83.3)	223	481	274
16-SWCS-T3-5 0.08d	13000	168	266	13.5	1040	806	33700 (0.93)	223	1070	274
16-SWCS-T3-5 1d	47200	168	ND	13.5	7220	806	173000 (5.81)	223	700	274
16-SWCS-T3-5 2d	35900	168	ND	13.5	4660	806	117000 (9.09)	223	844	274
16-SWCS-T3-5 7d	85300	168	ND	13.5	20400	806	439000 (21.5)	223	2100	274
16-SWCS-T3-5 14d	85400	168	22.6	13.5	16400	806	408000 (33.0)	223	2450	274
16-SWCS-T3-5 28d	85000	168	ND	13.5	19400	806	457000 (45.9)	223	2630	274
16-SWCS-T3-5 42d	71400	168	ND	13.5	13400	806	272000 (53.6)	223	2520	274
16-SWCS-T3-5 49d	65900	168	ND	13.5	4870	806	120000 (57.0)	223	1680	274
16-SWCS-T3-5 63d	69000	168	14.3	13.5	7320	806	148000 (61.2)	223	2800	274
16-SWCS-T3-5 100d	124000	168	ND	13.5	12400	806	248000 (68.2)	223	3030	274
16-SWCS-T3-6 0.08d	9220	168	45.6	13.5	1210	806	40600 (1.14)	223	ND	274
16-SWCS-T3-6 1d	49400	168	ND	13.5	7010	806	174000 (6.10)	223	641	274
16-SWCS-T3-6 2d	43500	168	ND	13.5	5470	806	129000 (9.77)	223	881	274
16-SWCS-T3-6 7d	85700	168	ND	13.5	19500	806	410000 (21.5)	223	1700	274
16-SWCS-T3-6 14d	85100	168	ND	13.5	15200	806	375000 (32.2)	223	1860	274
16-SWCS-T3-6 28d	88600	168	ND	13.5	19100	806	454000 (45.2)	223	2580	274
16-SWCS-T3-6 42d	82400	168	ND	13.5	11800	806	236000 (51.9)	223	2910	274
16-SWCS-T3-6 49d	65700	168	ND	13.5	3730	806	83000 (54.3)	223	1330	274
16-SWCS-T3-6 63d	106000	168	ND	13.5	7310	806	136000 (58.2)	223	3890	274
16-SWCS-T3-6 100d	156000	168	ND	13.5	11500	806	205000 (64.0)	223	2550	274
16-SWCS-T3-7 0.08d	325000	168	101000	13.5	27000	806	192000 (2.01)	223	ND	274
16-SWCS-T3-7 1d	359000	168	37900	13.5	35400	806	387000 (9.64)	223	ND	274
16-SWCS-T3-7 2d	341000	168	53400	13.5	29800	806	270000 (13.9)	223	ND	274
16-SWCS-T3-7 7d	398000	168	155	13.5	45100	806	528000 (25.7)	223	ND	274
16-SWCS-T3-7 14d	417000	168	463	13.5	33300	806	383000 (32.9)	223	ND	274
16-SWCS-T3-7 28d	555000	168	116	13.5	36600	806	359000 (39.6)	223	ND	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T3-7 42d	583000	168	68	13.5	33500	806	219000 (42.5)	223	ND	274
16-SWCS-T3-7 49d	589000	168	2220	13.5	27900	806	151000 (43.3)	223	ND	274
16-SWCS-T3-7 63d	709000	168	128	13.5	34200	806	169000 (44.7)	223	ND	274
16-SWCS-T3-7 100d	662000	168	ND	13.5	33300	806	153000 (45.6)	223	604	274
16-SWCS-T3-8 0.08d	324000	168	103000	13.5	26600	806	166000 (1.24)	223	ND	274
16-SWCS-T3-8 1d	345000	168	41800	13.5	32100	806	319000 (6.84)	223	ND	274
16-SWCS-T3-8 2d	370000	168	54800	13.5	32500	806	296000 (11.8)	223	ND	274
16-SWCS-T3-8 7d	381000	168	162	13.5	46100	806	570000 (24.6)	223	ND	274
16-SWCS-T3-8 14d	400000	168	667	13.5	38100	806	491000 (34.7)	223	ND	274
16-SWCS-T3-8 28d	485000	168	214	13.5	43700	806	561000 (47.0)	223	ND	274
16-SWCS-T3-8 42d	476000	168	249	13.5	37000	806	351000 (53.6)	223	ND	274
16-SWCS-T3-8 49d	531000	168	8190	13.5	30200	806	239000 (56.9)	223	ND	274
16-SWCS-T3-8 63d	626000	168	1600	13.5	39100	806	319000 (62.5)	223	ND	274
16-SWCS-T3-8 100d	583000	168	ND	13.5	37600	806	357000 (69.2)	223	601	274
16-SWCS-T4-5 0.08d	7700	168	15.1	13.5	1240	806	38500 (1.11)	223	ND	274
16-SWCS-T4-5 1d	54500	168	ND	13.5	11700	806	243000 (8.16)	223	705	274
16-SWCS-T4-5 2d	38800	168	ND	13.5	6440	806	144000 (12.3)	223	809	274
16-SWCS-T4-5 7d	96600	168	13.9	13.5	21200	806	449000 (25.4)	223	1960	274
16-SWCS-T4-5 14d	108000	168	15.2	13.5	12000	806	313000 (34.5)	223	1780	274
16-SWCS-T4-5 28d	133000	168	16.7	13.5	11400	806	273000 (42.4)	223	1910	274
16-SWCS-T4-5 42d	126000	168	23.2	13.5	6980	806	127000 (46.1)	223	2490	274
16-SWCS-T4-5 49d	94300	168	14.7	13.5	1630	806	36700 (47.2)	223	1990	274
16-SWCS-T4-5 63d	136000	168	21.8	13.5	4370	806	51100 (48.7)	223	3980	274
16-SWCS-T4-5 100d	167000	168	ND	13.5	8970	806	57400 (50.3)	223	3600	274
16-SWCS-T4-6 0.08d	6650	168	24	13.5	1280	806	31400 (0.915)	223	ND	274
16-SWCS-T4-6 1d	42000	168	ND	13.5	8750	806	180000 (6.21)	223	561	274
16-SWCS-T4-6 2d	34700	168	ND	13.5	6050	806	132000 (10.1)	223	732	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T4-6 7d	81400	168	ND	13.5	19900	806	406000 (22.1)	223	1720	274
16-SWCS-T4-6 14d	101000	168	14.1	13.5	13300	806	355000 (32.5)	223	1720	274
16-SWCS-T4-6 28d	114000	168	16	13.5	11600	806	290000 (41.1)	223	1910	274
16-SWCS-T4-6 42d	111000	168	18.3	13.5	5970	806	105000 (44.2)	223	2360	274
16-SWCS-T4-6 49d	84600	168	ND	13.5	1410	806	27000 (45.0)	223	1580	274
16-SWCS-T4-6 63d	126000	168	31.3	13.5	3690	806	37100 (46.1)	223	2890	274
16-SWCS-T4-6 100d	132000	168	ND	13.5	8380	806	37100 (47.2)	223	3160	274
16-SWCS-T4-7 0.08d	323000	168	109000	13.5	26500	806	161000 (1.15)	223	ND	274
16-SWCS-T4-7 1d	355000	168	57900	13.5	34800	806	341000 (7.64)	223	ND	274
16-SWCS-T4-7 2d	341000	168	65600	13.5	30900	806	283000 (12.5)	223	ND	274
16-SWCS-T4-7 7d	366000	168	1180	13.5	45500	806	552000 (25.3)	223	ND	274
16-SWCS-T4-7 14d	428000	168	533	13.5	36900	806	460000 (35.2)	223	ND	274
16-SWCS-T4-7 28d	500000	168	675	13.5	35900	806	389000 (42.9)	223	ND	274
16-SWCS-T4-7 42d	520000	168	660	13.5	33700	806	239000 (46.5)	223	ND	274
16-SWCS-T4-7 49d	562000	168	10600	13.5	28000	806	172000 (48.1)	223	ND	274
16-SWCS-T4-7 63d	677000	168	1070	13.5	35000	806	200000 (50.4)	223	ND	274
16-SWCS-T4-7 100d	605000	168	ND	13.5	33300	806	160000 (51.5)	223	906	274
16-SWCS-T4-8 0.08d	324000	168	107000	13.5	26900	806	49000 (1.45)	223	ND	274
16-SWCS-T4-8 1d	346000	168	49100	13.5	35100	806	241000 (8.58)	223	ND	274
16-SWCS-T4-8 2d	365000	168	61800	13.5	33100	806	190000 (14.2)	223	ND	274
16-SWCS-T4-8 7d	410000	168	340	13.5	50200	806	530000 (29.9)	223	ND	274
16-SWCS-T4-8 14d	432000	168	2190	13.5	34100	806	257000 (37.5)	223	ND	274
16-SWCS-T4-8 28d	517000	168	386	13.5	34900	806	209000 (43.7)	223	ND	274
16-SWCS-T4-8 42d	534000	168	511	13.5	32800	806	102000 (46.7)	223	ND	274
16-SWCS-T4-8 49d	572000	168	7430	13.5	28100	806	51000 (48.2)	223	ND	274
16-SWCS-T4-8 63d	693000	168	974	13.5	35800	806	88000 (50.8)	223	ND	274
16-SWCS-T4-8 100d	595000	168	ND	13.5	33500	806	52000 (52.3)	223	857	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T6-5 0.08d	21800	168	224	13.5	2630	806	76800 (2.15)	223	497	274
16-SWCS-T6-5 1d	72000	168	ND	13.5	12500	806	269000 (9.69)	223	547	274
16-SWCS-T6-5 2d	56400	168	ND	13.5	7440	806	172000 (14.5)	223	761	274
16-SWCS-T6-5 7d	120000	168	ND	13.5	22500	806	481000 (28.0)	223	1390	274
16-SWCS-T6-5 14d	129000	168	ND	13.5	14800	806	395000 (39.1)	223	1300	274
16-SWCS-T6-5 28d	175000	168	17.1	13.5	13600	806	367000 (49.4)	223	1250	274
16-SWCS-T6-5 42d	199000	168	18.2	13.5	7070	806	145000 (53.5)	223	1070	274
16-SWCS-T6-5 49d	170000	168	ND	13.5	1880	806	43200 (54.7)	223	898	274
16-SWCS-T6-5 63d	178000	168	18.4	13.5	2780	806	36900 (55.8)	223	ND	274
16-SWCS-T6-5 100d	389000	168	ND	13.5	9180	806	50900 (57.2)	223	475	274
16-SWCS-T6-6 0.08d	14900	168	71.3	13.5	2840	806	90300 (2.60)	223	ND	274
16-SWCS-T6-6 1d	79400	168	ND	13.5	14800	806	347000 (12.6)	223	398	274
16-SWCS-T6-6 2d	63300	168	ND	13.5	6400	806	160000 (17.3)	223	464	274
16-SWCS-T6-6 7d	159000	168	ND	13.5	16500	806	359000 (27.6)	223	806	274
16-SWCS-T6-6 14d	223000	168	16.5	13.5	9290	806	229000 (34.3)	223	657	274
16-SWCS-T6-6 28d	281000	168	19	13.5	10100	806	211000 (40.4)	223	523	274
16-SWCS-T6-6 42d	252000	168	20.8	13.5	6950	806	115000 (43.7)	223	731	274
16-SWCS-T6-6 49d	161000	168	ND	13.5	1800	806	31300 (44.6)	223	716	274
16-SWCS-T6-6 63d	128000	168	29	13.5	2850	806	26800 (45.4)	223	ND	274
16-SWCS-T6-6 100d	368000	168	ND	13.5	8350	806	49400 (46.8)	223	890	274
16-SWCS-T6-7 0.08d	325000	168	100000	13.5	26700	806	52000 (1.45)	223	ND	274
16-SWCS-T6-7 1d	378000	168	40000	13.5	35400	806	233000 (7.97)	223	ND	274
16-SWCS-T6-7 2d	372000	168	53100	13.5	32200	806	170000 (12.7)	223	ND	274
16-SWCS-T6-7 7d	410000	168	130	13.5	48500	806	486000 (26.3)	223	313	274
16-SWCS-T6-7 14d	458000	168	389	13.5	42200	806	459000 (39.1)	223	ND	274
16-SWCS-T6-7 28d	528000	168	179	13.5	46100	806	536000 (54.1)	223	ND	274
16-SWCS-T6-7 42d	505000	168	216	13.5	36500	806	262000 (61.4)	223	304	274

Sample ID	Ca (µg/L)	EQL (µg/L)	Mg (µg/L)	EQL (µg/L)	K (µg/L)	EQL (µg/L)	Na (µg/L)	EQL (µg/L)	Si (µg/L)	EQL (µg/L)
16-SWCS-T6-7 49d	566000	168	2000	13.5	29600	806	113000 (64.6)	223	ND	274
16-SWCS-T6-7 63d	400000	168	26.6	13.5	19800	806	42000 (65.8)	223	ND	274
16-SWCS-T6-7 100d	826000	168	ND	13.5	37700	806	114000 (69.0)	223	ND	274
16-SWCS-T6-8 0.08d	331000	168	110000	13.5	27100	806	47000 (1.30)	223	ND	274
16-SWCS-T6-8 1d	367000	168	44300	13.5	35000	806	227000 (7.59)	223	ND	274
16-SWCS-T6-8 2d	384000	168	49400	13.5	33100	806	186000 (12.7)	223	ND	274
16-SWCS-T6-8 7d	427000	168	103	13.5	51100	806	517000 (27.1)	223	281	274
16-SWCS-T6-8 14d	443000	168	471	13.5	43600	806	443000 (39.3)	223	ND	274
16-SWCS-T6-8 28d	483000	168	53.2	13.5	46900	806	586000 (55.5)	223	ND	274
16-SWCS-T6-8 42d	486000	168	181	13.5	40100	806	388000 (66.3)	223	ND	274
16-SWCS-T6-8 49d	518000	168	3880	13.5	29800	806	150000 (70.4)	223	ND	274
16-SWCS-T6-8 63d	495000	168	397	13.5	29000	806	142000 (74.4)	223	ND	274
16-SWCS-T6-8 100d	721000	168	ND	13.5	34100	806	130000 (78.0)	223	459	274

Table A.4. Concentrations of Major Anions and ^{99}Tc Measured in Leachates from EPA Method 1315 Tests (60-Day Cured Monoliths). Cumulative release of NO_3^- , ^{99}Tc , and ^{127}I (%) are shown in parenthesis.

A.33

Sample ID	Cl^- (mg/L)	EQL (mg/L)	F^- (mg/L)	EQL (mg/L)	NO_3^- (mg/L)	EQL (mg/L)	NO_2^- (mg/L)	EQL (mg/L)	SO_4^{2-} (mg/L)	EQL (mg/L)	^{99}Tc ($\mu\text{g/L}$)	EQL ($\mu\text{g/L}$)	^{127}I ($\mu\text{g/L}$)	EQL ($\mu\text{g/L}$)
16-SWCS-60-DI BLK1 0.08d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 1d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 2d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 7d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 14d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 28d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 42d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 49d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 63d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK1 100d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 0.08d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 1d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 2d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 7d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 14d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 28d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 42d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 49d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 63d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-DI BLK2 100d	ND	0.25	ND	0.1	ND	0.5	ND	0.5	ND	0.75	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 0.08d	256	6.25	ND	2.5	207	12.5	ND	12.5	1040	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 1d	256	6.25	ND	2.5	207	12.5	ND	12.5	1050	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 2d	254	6.25	ND	2.5	205	12.5	ND	12.5	1070	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 7d	253	6.25	ND	2.5	204	12.5	ND	12.5	1070	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 14d	252	6.25	ND	2.5	204	12.5	ND	12.5	1080	18.8	ND	0.0165	ND	0.063

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-60-PW BLK1 28d	252	6.25	ND	2.5	208	12.5	ND	12.5	1170	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 42d	254	6.25	ND	2.5	209	12.5	ND	12.5	1250	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 49d	257	6.25	ND	2.5	211	12.5	ND	12.5	1340	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 63d	254	6.25	ND	2.5	208	12.5	ND	12.5	1320	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK1 100d	256	6.25	ND	2.5	209	12.5	ND	12.5	1450	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 0.08d	253	6.25	ND	2.5	204	12.5	ND	12.5	1030	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 1d	257	6.25	ND	2.5	207	12.5	ND	12.5	1070	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 2d	254	6.25	ND	2.5	205	12.5	ND	12.5	1070	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 7d	254	6.25	ND	2.5	204	12.5	ND	12.5	1070	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 14d	253	6.25	ND	2.5	205	12.5	ND	12.5	1090	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 28d	252	6.25	ND	2.5	208	12.5	ND	12.5	1170	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 42d	255	6.25	ND	2.5	209	12.5	ND	12.5	1240	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 49d	256	6.25	ND	2.5	211	12.5	ND	12.5	1340	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 63d	255	6.25	ND	2.5	208	12.5	ND	12.5	1320	18.8	ND	0.0165	ND	0.063
16-SWCS-60-PW BLK2 100d	256	6.25	ND	2.5	209	12.5	ND	12.5	1450	18.8	ND	0.0165	ND	0.063
16-SWCS-T1-6 0.08d	ND	0.25	ND	0.1	2.16 (0.16)	0.5	2.14	0.5	30.1	0.75	3.08 (0.32)	0.0165	18 (0.39)	0.063
16-SWCS-T1-6 1d	0.675	0.25	ND	0.1	12.4 (1.07)	0.5	8.7	0.5	137	0.75	22.35 ^(a) (2.63)	0.0165	115 (2.89)	0.63
16-SWCS-T1-6 2d	ND	1.25	ND	0.5	8.8 (1.72)	2.5	9.04	2.5	83.4	3.75	15.7 (4.25)	0.0165	81.6 (4.66)	0.63
16-SWCS-T1-6 7d	1.8	1.25	ND	0.5	31.7 (4.06)	2.5	25.9	2.5	300	3.75	71.5 ^(a) (11.6)	0.165	303 (11.2)	1.26
16-SWCS-T1-6 14d	1.47	1.25	ND	0.5	26.7 (6.04)	2.5	21.9	2.5	219	3.75	52.4 (17.1)	0.165	252 (16.7)	1.26
16-SWCS-T1-6 28d	1.62	1.25	ND	0.5	27.9 (8.09)	2.5	22.1	2.5	195	3.75	27.4 (19.9)	0.165	265 (22.5)	1.26
16-SWCS-T1-6 42d	ND	1.25	ND	0.5	16 (9.28)	2.5	14	2.5	102	3.75	0.535 (20.0)	0.165	159 (25.9)	1.26
16-SWCS-T1-6 49d	ND	1.25	ND	0.5	5.82 (9.71)	2.5	5	2.5	35.6	3.75	0.187 (20.0)	0.0165	49.4 (27.0)	1.26
16-SWCS-T1-6 63d	ND	1.25	ND	0.5	8.81 (10.4)	2.5	8.39	2.5	53.3	3.75	0.115 (20.0)	0.0165	91.1 (29.0)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T1-6 100d	ND	1.25	ND	0.5	17.8 (11.7)	2.5	16.1	2.5	101	3.75	0.145 (20.0)	0.0165	185 (33.0)	1.26
16-SWCS-T1-7 0.08d	ND	1.25	ND	0.5	2.64 (0.20)	2.5	3.02	2.5	31.1	3.75	3.46 (0.36)	0.0165	20.2 (0.44)	0.063
16-SWCS-T1-7 1d	ND	1.25	ND	0.5	16 (1.38)	2.5	16.1	2.5	173	3.75	25.3 (2.97)	0.0165	138 (3.44)	0.63
16-SWCS-T1-7 2d	ND	1.25	ND	0.5	8.8 (2.03)	2.5	9.4	2.5	82.2	3.75	14.5 (4.47)	0.0165	77.7 (5.13)	0.63
16-SWCS-T1-7 7d	1.92	1.25	ND	0.5	36.7 (4.74)	2.5	28.8	2.5	322	3.75	72 (11.9)	0.165	333 (12.4)	1.26
16-SWCS-T1-7 14d	1.46	1.25	ND	0.5	28.6 (6.85)	2.5	22.4	2.5	237	3.75	49 (17.0)	0.165	254 (17.9)	1.26
16-SWCS-T1-7 28d	1.74	1.25	ND	0.5	31.2 (9.15)	2.5	23.9	2.5	205	3.75	26.3 (19.7)	0.165	294 (24.3)	1.26
16-SWCS-T1-7 42d	ND	1.25	ND	0.5	18.1 (10.5)	2.5	15.7	2.5	107	3.75	0.506 (19.7)	0.165	176 (28.1)	1.26
16-SWCS-T1-7 49d	ND	1.25	ND	0.5	5.3 (10.9)	2.5	5.14	2.5	35.4	3.75	0.0627 (19.8)	0.0165	49.4 (29.2)	1.26
16-SWCS-T1-7 63d	ND	1.25	ND	0.5	9.06 (11.5)	2.5	8.89	2.5	49.5	3.75	0.0907 (19.8)	0.0165	91.3 (31.2)	1.26
16-SWCS-T1-7 100d	1.34	1.25	ND	0.5	21.5 (13.1)	2.5	18.6	2.5	117	3.75	0.185 (19.8)	0.0165	204 (35.6)	1.26
16-SWCS-T1-8 0.08d	253	6.25	ND	2.5	ND (0.94)	12.5	ND	12.5	1070	18.8	5.44 (0.57)	0.0165	30.3 (0.67)	0.063
16-SWCS-T1-8 1d	251	6.25	ND	2.5	9 (1.61)	12.5	18.2	12.5	1130	18.8	25.25 ^(a) (3.22)	0.0165	135 (3.65)	0.63
16-SWCS-T1-8 2d	253	6.25	ND	2.5	6 (2.06)	12.5	ND	12.5	1100	18.8	16.1 (4.91)	0.0165	86.9 (5.56)	0.63
16-SWCS-T1-8 7d	245	6.25	ND	2.5	22 (3.71)	12.5	39.1	12.5	1210	18.8	67.1 ^(a) (11.9)	0.165	326 (12.8)	1.26
16-SWCS-T1-8 14d	242	6.25	ND	2.5	10 (4.46)	12.5	30	12.5	1110	18.8	50.8 (17.3)	0.165	269 (18.7)	1.26
16-SWCS-T1-8 28d	244	6.25	ND	2.5	13 (5.43)	12.5	37.2	12.5	1180	18.8	32.4 (20.7)	0.165	361 (26.7)	1.26
16-SWCS-T1-8 42d	244	6.25	ND	2.5	ND (6.39)	12.5	23.5	12.5	1160	18.8	0.836 (20.8)	0.165	240 (31.9)	1.26
16-SWCS-T1-8 49d	247	6.25	ND	2.5	ND (7.32)	12.5	ND	12.5	1240	18.8	0.155 (20.8)	0.0165	94.1 (34.0)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T1-8 63d	248	6.25	ND	2.5	ND (8.26)	12.5	13	12.5	1220	18.8	0.197 (20.8)	0.0165	141 (37.1)	1.26
16-SWCS-T1-8 100d	251	6.25	ND	2.5	ND (9.20)	12.5	24.8	12.5	1320	18.8	0.318 (20.8)	0.0165	274 (43.2)	1.26
16-SWCS-T1-9 0.08d	254	6.25	ND	2.5	3 (0.26)	12.5	ND	12.5	1110	18.8	6.34 (0.76)	0.0165	55.6 (1.40)	0.063
16-SWCS-T1-9 1d	251	6.25	ND	2.5	18 (1.80)	12.5	27.6	12.5	1290	18.8	32.5 (4.66)	0.0165	244 (7.56)	0.63
16-SWCS-T1-9 2d	251	6.25	ND	2.5	11 (2.74)	12.5	17.1	12.5	1190	18.8	20.9 (7.17)	0.0165	164 (11.7)	0.63
16-SWCS-T1-9 7d	246	6.25	ND	2.5	33 (5.57)	12.5	45.4	12.5	1400	18.8	56.1 (13.9)	0.165	467 (23.5)	1.26
16-SWCS-T1-9 14d	242	6.25	ND	2.5	14 (6.77)	12.5	32.5	12.5	1220	18.8	28 (17.3)	0.165	342 (32.1)	1.26
16-SWCS-T1-9 28d	245	6.25	ND	2.5	9 (7.54)	12.5	33.7	12.5	1200	18.8	11.1 (18.6)	0.165	356 (41.1)	1.26
16-SWCS-T1-9 42d	246	6.25	ND	2.5	ND (8.46)	12.5	19.8	12.5	1130	18.8	1.05 (18.7)	0.165	204 (46.2)	1.26
16-SWCS-T1-9 49d	246	6.25	ND	2.5	ND (9.53)	12.5	ND	12.5	1230	18.8	0.251 (18.8)	0.0165	77.3 (48.2)	1.26
16-SWCS-T1-9 63d	250	6.25	ND	2.5	ND (10.6)	12.5	ND	12.5	1180	18.8	0.318 (18.8)	0.0165	122 (51.3)	1.26
16-SWCS-T1-9 100d	253	6.25	ND	2.5	ND (11.7)	12.5	16.8	12.5	1200	18.8	0.505 (18.8)	0.0165	185 (55.9)	1.26
16-SWCS-T2-5 0.08d	ND	1.25	ND	0.5	7.82 (0.55)	2.5	6.71	2.5	72.6	3.75	8.67 (0.86)	0.0165	51.1 (1.06)	0.063
16-SWCS-T2-5 1d	1.43	0.5	ND	0.2	34.7 (3.00)	1	18.7	1	265	1.5	44.1 ^(a) (5.22)	0.0165	244 (6.14)	0.63
16-SWCS-T2-5 2d	ND	1.25	ND	0.5	18.9 (4.34)	2.5	14.8	2.5	133	3.75	22.1 (7.41)	0.0165	127 (8.78)	0.63
16-SWCS-T2-5 7d	2.44	1.25	ND	0.5	62.2 (8.73)	2.5	37.1	2.5	469	3.75	79.05 ^(a) (15.2)	0.165	424 (17.6)	1.26
16-SWCS-T2-5 14d	1.55	1.25	ND	0.5	42.2 (11.7)	2.5	27.8	2.5	318	3.75	40 (19.2)	0.165	280 (23.4)	1.26
16-SWCS-T2-5 28d	1.35	1.25	ND	0.5	39 (14.5)	2.5	25.5	2.5	294	3.75	20.2 (21.2)	0.165	258 (28.8)	1.26
16-SWCS-T2-5 42d	ND	1.25	ND	0.5	20.1 (15.9)	2.5	14.6	2.5	156	3.75	1.17 (21.3)	0.165	129 (31.5)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T2-5 49d	ND	1.25	ND	0.5	11.5 (16.7)	2.5	8.78	2.5	118	3.75	0.612 (21.4)	0.0165	73 (33.0)	1.26
16-SWCS-T2-5 63d	ND	1.25	ND	0.5	9.77 (17.4)	2.5	7.26	2.5	91.7	3.75	0.518 (21.4)	0.0165	66.8 (34.4)	1.26
16-SWCS-T2-5 100d	ND	1.25	ND	0.5	15 (18.5)	2.5	11.3	2.5	172	3.75	0.323 (21.4)	0.0165	114 (36.8)	1.26
16-SWCS-T2-6 0.08d	ND	1.25	ND	0.5	10 (0.67)	2.5	9.76	2.5	98.2	3.75	3.76 (0.35)	0.0165	66.2 (1.31)	0.063
16-SWCS-T2-6 1d	1.65	0.5	ND	0.2	45.2 (3.72)	1	24.5	1	281	1.5	20.7 (2.31)	0.0165	297 (7.20)	0.63
16-SWCS-T2-6 2d	ND	1.25	ND	0.5	26.4 (5.49)	2.5	22.1	2.5	153	3.75	11.5 (3.39)	0.0165	173 (10.6)	0.63
16-SWCS-T2-6 7d	2.9	1.25	ND	0.5	79.1 (10.8)	2.5	48.7	2.5	445	3.75	30.6 (6.27)	0.165	511 (20.8)	1.26
16-SWCS-T2-6 14d	2.06	1.25	ND	0.5	57.3 (14.7)	2.5	40.1	2.5	342	3.75	7.64 (6.99)	0.165	366 (28.0)	1.26
16-SWCS-T2-6 28d	1.87	1.25	ND	0.5	50.9 (18.1)	2.5	36.8	2.5	314	3.75	2.91 (7.27)	0.165	334 (34.6)	1.26
16-SWCS-T2-6 42d	ND	1.25	ND	0.5	20.9 (19.5)	2.5	20	2.5	123	3.75	0.46 (7.31)	0.165	146 (37.5)	1.26
16-SWCS-T2-6 49d	ND	1.25	ND	0.5	6.09 (19.9)	2.5	7.16	2.5	43	3.75	0.0645 (7.32)	0.0165	40.5 (38.3)	1.26
16-SWCS-T2-6 63d	ND	1.25	ND	0.5	7.52 (20.4)	2.5	8.96	2.5	49.1	3.75	0.0961 (7.33)	0.0165	51.8 (39.4)	1.26
16-SWCS-T2-6 100d	ND	1.25	ND	0.5	8.3 (21.0)	2.5	10.5	2.5	53.7	3.75	0.113 (7.34)	0.0165	58.7 (40.5)	1.26
16-SWCS-T2-7 0.08d	253	6.25	ND	2.5	3 (0.21)	12.5	ND	12.5	1070	18.8	4.45 (0.43)	0.0165	43.8 (0.90)	0.063
16-SWCS-T2-7 1d	253	6.25	ND	2.5	37 (2.78)	12.5	40.2	12.5	1210	18.8	31.55 ^(a) (3.50)	0.0165	293 (6.88)	0.63
16-SWCS-T2-7 2d	252	6.25	ND	2.5	27 (4.65)	12.5	29.7	12.5	1150	18.8	20.9 (5.53)	0.0165	211 (11.2)	0.63
16-SWCS-T2-7 7d	248	6.25	ND	2.5	72 (9.65)	12.5	73	12.5	1300	18.8	66.85 ^(a) (12.0)	0.165	572 (22.9)	1.26
16-SWCS-T2-7 14d	246	6.25	ND	2.5	46 (12.8)	12.5	57.8	12.5	1210	18.8	40.4 (16.0)	0.165	436 (31.8)	1.26
16-SWCS-T2-7 28d	246	6.25	ND	2.5	45 (16.0)	12.5	65.1	12.5	1320	18.8	21 (18.0)	0.165	504 (42.1)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T2-7 42d	244	6.25	ND	2.5	4 (16.2)	12.5	34.3	12.5	1200	18.8	0.995 (18.1)	0.165	266 (47.5)	1.26
16-SWCS-T2-7 49d	245	6.25	ND	2.5	ND (16.8)	12.5	ND	12.5	1240	18.8	0.157 (18.1)	0.0165	83.1 (49.2)	1.26
16-SWCS-T2-7 63d	245	6.25	ND	2.5	ND (17.7)	12.5	ND	12.5	1190	18.8	0.205 (18.1)	0.0165	115 (51.6)	1.26
16-SWCS-T2-7 100d	245	6.25	ND	2.5	ND (18.6)	12.5	15	12.5	1230	18.8	0.275 (18.2)	0.0165	155 (54.7)	1.26
16-SWCS-T2-8 0.08d	252	6.25	ND	2.5	4 (0.28)	12.5	ND	12.5	1090	18.8	6.65 (0.64)	0.0165	61.6 (1.25)	0.063
16-SWCS-T2-8 1d	251	6.25	ND	2.5	34 (2.61)	12.5	36	12.5	1190	18.8	35.4 (4.04)	0.0165	295 (7.21)	0.63
16-SWCS-T2-8 2d	254	6.25	ND	2.5	25 (4.33)	12.5	25.3	12.5	1150	18.8	24.7 (6.42)	0.0165	201 (11.3)	0.63
16-SWCS-T2-8 7d	248	6.25	ND	2.5	71 (9.21)	12.5	67.9	12.5	1320	18.8	73.3 (13.5)	0.165	588 (23.2)	1.26
16-SWCS-T2-8 14d	246	6.25	ND	2.5	44 (12.2)	12.5	51.3	12.5	1230	18.8	51 (18.5)	0.165	435 (32.0)	1.26
16-SWCS-T2-8 28d	245	6.25	ND	2.5	39 (14.9)	12.5	56.5	12.5	1320	18.8	32.3 (21.5)	0.165	487 (41.8)	1.26
16-SWCS-T2-8 42d	243	6.25	ND	2.5	2 (15.0)	12.5	30.4	12.5	1210	18.8	0.898 (21.6)	0.165	256 (47.0)	1.26
16-SWCS-T2-8 49d	247	6.25	ND	2.5	ND (15.5)	12.5	ND	12.5	1250	18.8	0.176 (21.6)	0.0165	92.1 (48.9)	1.26
16-SWCS-T2-8 63d	247	6.25	ND	2.5	ND (16.4)	12.5	12.8	12.5	1220	18.8	0.267 (21.6)	0.0165	136 (51.6)	1.26
16-SWCS-T2-8 100d	248	6.25	ND	2.5	ND (17.3)	12.5	17.1	12.5	1230	18.8	0.379 (21.6)	0.0165	198 (55.6)	1.26
16-SWCS-T3-5 0.08d	ND	0.25	ND	0.1	2.84 (0.20)	0.5	1.92	0.5	39.3	0.75	6.15 (0.60)	0.0165	ND (0.00)	0.063
16-SWCS-T3-5 1d	ND	1.25	ND	0.5	19.8 (1.57)	2.5	13.5	2.5	178	3.75	50.15 ^(a) (5.45)	0.0165	ND (0.01)	0.63
16-SWCS-T3-5 2d	ND	1.25	ND	0.5	13.6 (2.51)	2.5	9.68	2.5	104	3.75	33 (8.65)	0.0165	ND (0.03)	0.63
16-SWCS-T3-5 7d	2.14	1.25	ND	0.5	48.6 (5.87)	2.5	26.9	2.5	368	3.75	141 ^(a) (22.3)	0.165	ND (0.05)	1.26
16-SWCS-T3-5 14d	1.84	1.25	ND	0.5	39.4 (8.59)	2.5	22.5	2.5	291	3.75	106 (32.6)	0.165	ND (0.08)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T3-5 28d	2	1.25	ND	0.5	36 (11.1)	2.5	20.5	2.5	264	3.75	109 (43.1)	0.165	ND (0.10)	1.26
16-SWCS-T3-5 42d	1.42	1.25	ND	0.5	20.6 (12.5)	2.5	13.7	2.5	170	3.75	72.1 (50.1)	0.165	ND (0.13)	1.26
16-SWCS-T3-5 49d	ND	1.25	ND	0.5	8.52 (13.1)	2.5	6.38	2.5	90	3.75	25 (52.5)	0.0165	ND (0.16)	1.26
16-SWCS-T3-5 63d	ND	1.25	ND	0.5	10.3 (13.8)	2.5	7.58	2.5	101	3.75	19.3 (54.4)	0.0165	ND (0.18)	1.26
16-SWCS-T3-5 100d	ND	1.25	ND	0.5	20.2 (15.2)	2.5	15	2.5	224	3.75	1.66 (54.6)	0.0165	ND (0.21)	1.26
16-SWCS-T3-6 0.08d	ND	0.25	ND	0.1	3.32 (0.23)	0.5	2.2	0.5	46.9	0.75	8.02 (0.79)	0.0165	ND (0.00)	0.063
16-SWCS-T3-6 1d	ND	1.25	ND	0.5	17.5 (1.46)	2.5	12	2.5	182	3.75	46.7 (5.36)	0.0165	ND (0.01)	0.63
16-SWCS-T3-6 2d	ND	1.25	ND	0.5	14 (2.44)	2.5	9.7	2.5	122	3.75	37.7 (9.05)	0.0165	ND (0.03)	0.63
16-SWCS-T3-6 7d	2.05	1.25	ND	0.5	43.4 (5.47)	2.5	23.6	2.5	372	3.75	123 (21.1)	0.165	ND (0.05)	1.26
16-SWCS-T3-6 14d	1.6	1.25	ND	0.5	33.8 (7.84)	2.5	18.5	2.5	295	3.75	92.4 (30.2)	0.165	ND (0.08)	1.26
16-SWCS-T3-6 28d	1.86	1.25	ND	0.5	32.9 (10.1)	2.5	16.9	2.5	292	3.75	95.8 (39.5)	0.165	ND (0.11)	1.26
16-SWCS-T3-6 42d	ND	1.25	ND	0.5	18.3 (11.4)	2.5	10.1	2.5	166	3.75	50.9 (44.5)	0.165	ND (0.13)	1.26
16-SWCS-T3-6 49d	ND	1.25	ND	0.5	6.34 (11.9)	2.5	3.8	2.5	60.3	3.75	12.7 (45.8)	0.0165	ND (0.16)	1.26
16-SWCS-T3-6 63d	ND	1.25	ND	0.5	9.8 (12.6)	2.5	5.78	2.5	91.7	3.75	13.6 (47.1)	0.0165	ND (0.18)	1.26
16-SWCS-T3-6 100d	ND	1.25	ND	0.5	20.7 (14.0)	2.5	13.2	2.5	223	3.75	2.57 (47.4)	0.0165	ND (0.21)	1.26
16-SWCS-T3-7 0.08d	251	6.25	ND	2.5	3 (0.21)	12.5	ND	12.5	1110	18.8	18.2 (1.79)	0.0165	ND (0.00)	0.063
16-SWCS-T3-7 1d	252	6.25	ND	2.5	24 (1.90)	12.5	20.4	12.5	1310	18.8	83 ^(a) (10.0)	0.0165	ND (0.01)	0.63
16-SWCS-T3-7 2d	243	6.25	ND	2.5	7 (2.39)	12.5	12.5	12.5	1160	18.8	49.4 (14.8)	0.0165	ND (0.03)	0.63
16-SWCS-T3-7 7d	241	6.25	ND	2.5	23 (4.01)	12.5	28.2	12.5	1320	18.8	107.5 ^(a) (25.4)	0.165	ND (0.05)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T3-7 14d	215	6.25	ND	2.5	ND (5.25)	12.5	18.3	12.5	1050	18.8	54 (30.7)	0.165	ND (0.08)	1.26
16-SWCS-T3-7 28d	234	6.25	ND	2.5	ND (6.13)	12.5	17.4	12.5	1130	18.8	37.9 (34.4)	0.165	ND (0.11)	1.26
16-SWCS-T3-7 42d	239	6.25	ND	2.5	ND (7.01)	12.5	ND	12.5	1100	18.8	13.2 (35.7)	0.165	ND (0.13)	1.26
16-SWCS-T3-7 49d	241	6.25	ND	2.5	ND (7.89)	12.5	ND	12.5	1190	18.8	1.85 (35.9)	0.0165	ND (0.16)	1.26
16-SWCS-T3-7 63d	246	6.25	ND	2.5	ND (8.77)	12.5	ND	12.5	1130	18.8	0.658 (36.0)	0.0165	ND (0.18)	1.26
16-SWCS-T3-7 100d	257	6.25	ND	2.5	ND (9.65)	12.5	ND	12.5	1070	18.8	0.108 (36.0)	0.0165	ND (0.21)	1.26
16-SWCS-T3-8 0.08d	251	6.25	ND	2.5	1 (0.07)	12.5	ND	12.5	1070	18.8	11.6 (1.12)	0.0165	ND (0.00)	0.063
16-SWCS-T3-8 1d	252	6.25	ND	2.5	20 (1.45)	12.5	17.8	12.5	1220	18.8	65.3 (7.45)	0.0165	ND (0.01)	0.63
16-SWCS-T3-8 2d	253	6.25	ND	2.5	18 (2.70)	12.5	14.2	12.5	1190	18.8	51.5 (12.4)	0.0165	ND (0.03)	0.63
16-SWCS-T3-8 7d	248	6.25	ND	2.5	40 (5.47)	12.5	35.1	12.5	1360	18.8	136 (25.6)	0.165	ND (0.05)	1.26
16-SWCS-T3-8 14d	243	6.25	ND	2.5	20 (6.85)	12.5	25.4	12.5	1240	18.8	88.1 (34.2)	0.165	ND (0.08)	1.26
16-SWCS-T3-8 28d	240	6.25	ND	2.5	10 (7.55)	12.5	27	12.5	1280	18.8	103 (44.2)	0.165	ND (0.10)	1.26
16-SWCS-T3-8 42d	240	6.25	ND	2.5	ND (8.33)	12.5	16.1	12.5	1210	18.8	54.7 (49.5)	0.165	ND (0.13)	1.26
16-SWCS-T3-8 49d	250	6.25	ND	2.5	ND (9.19)	12.5	ND	12.5	1290	18.8	24.7 (51.9)	0.0165	ND (0.16)	1.26
16-SWCS-T3-8 63d	247	6.25	ND	2.5	ND (10.1)	12.5	ND	12.5	1270	18.8	21 (53.9)	0.0165	ND (0.18)	1.26
16-SWCS-T3-8 100d	252	6.25	ND	2.5	ND (10.9)	12.5	18.6	12.5	1330	18.8	2.59 (54.1)	0.0165	ND (0.21)	1.26
16-SWCS-T4-5 0.08d	ND	1.25	ND	0.5	3.98 (0.28)	2.5	5.32	2.5	41.8	3.75	6.55 (0.65)	0.0165	45.6 (0.96)	0.063
16-SWCS-T4-5 1d	1.9	1.25	ND	0.5	28 (2.28)	2.5	28.3	2.5	273	3.75	49.85 ^(a) (5.62)	0.0165	359 (8.48)	0.63
16-SWCS-T4-5 2d	ND	1.25	ND	0.5	16 (3.42)	2.5	18.3	2.5	146	3.75	26.6 (8.27)	0.0165	200 (12.7)	0.63

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T4-5 7d	2.76	1.25	ND	0.5	45.5 (6.66)	2.5	39.4	2.5	442	3.75	78.15 ^(a) (16.1)	0.165	550 (24.2)	1.26
16-SWCS-T4-5 14d	1.49	1.25	ND	0.5	28.4 (8.68)	2.5	27.9	2.5	277	3.75	32.2 (19.3)	0.165	324 (31.0)	1.26
16-SWCS-T4-5 28d	ND	1.25	ND	0.5	23.8 (10.4)	2.5	24.2	2.5	230	3.75	4.02 (19.7)	0.165	257 (36.4)	1.26
16-SWCS-T4-5 42d	ND	1.25	ND	0.5	13.1 (11.3)	2.5	14.6	2.5	132	3.75	0.46 (19.7)	0.165	124 (39.0)	1.26
16-SWCS-T4-5 49d	ND	1.25	ND	0.5	5.3 (11.7)	2.5	5.82	2.5	62.3	3.75	0.22 (19.7)	0.0165	35.5 (39.7)	1.26
16-SWCS-T4-5 63d	ND	1.25	ND	0.5	7.52 (12.2)	2.5	8.14	2.5	78.8	3.75	0.376 (19.8)	0.0165	49.7 (40.8)	1.26
16-SWCS-T4-5 100d	ND	1.25	ND	0.5	12.4 (13.1)	2.5	14.4	2.5	117	3.75	0.629 (19.8)	0.0165	85 (42.5)	1.26
16-SWCS-T4-6 0.08d	ND	1.25	ND	0.5	3.04 (0.22)	2.5	3.84	2.5	36	3.75	4.51 (0.46)	0.0165	33.6 (0.72)	0.063
16-SWCS-T4-6 1d	1.44	1.25	ND	0.5	21.8 (1.79)	2.5	22.4	2.5	195	3.75	36 (4.10)	0.0165	267 (6.39)	0.63
16-SWCS-T4-6 2d	ND	1.25	ND	0.5	14.4 (2.83)	2.5	16.3	2.5	121	3.75	23.6 (6.48)	0.0165	178 (10.2)	0.63
16-SWCS-T4-6 7d	2.48	1.25	ND	0.5	40.9 (5.79)	2.5	35.5	2.5	357	3.75	66 (13.2)	0.165	516 (21.2)	1.26
16-SWCS-T4-6 14d	1.68	1.25	ND	0.5	30.7 (8.01)	2.5	28.9	2.5	296	3.75	39 (17.1)	0.165	354 (28.7)	1.26
16-SWCS-T4-6 28d	ND	1.25	ND	0.5	24.2 (9.76)	2.5	24.1	2.5	245	3.75	6.09 (17.7)	0.165	261 (34.2)	1.26
16-SWCS-T4-6 42d	ND	1.25	ND	0.5	11.3 (10.6)	2.5	12.3	2.5	112	3.75	0.445 (17.8)	0.165	98.8 (36.3)	1.26
16-SWCS-T4-6 49d	ND	1.25	ND	0.5	4.58 (10.9)	2.5	4.82	2.5	53.5	3.75	0.195 (17.8)	0.0165	29 (37.0)	1.26
16-SWCS-T4-6 63d	ND	1.25	ND	0.5	6.54 (11.4)	2.5	7.02	2.5	75.1	3.75	0.312 (17.8)	0.0165	41.1 (37.8)	1.26
16-SWCS-T4-6 100d	ND	1.25	ND	0.5	9.92 (12.1)	2.5	11.3	2.5	96.3	3.75	0.341 (17.9)	0.0165	64.8 (39.2)	1.26
16-SWCS-T4-7 0.08d	254	6.25	ND	2.5	4 (0.29)	12.5	ND	12.5	1070	18.8	6.96 (0.71)	0.0165	50.7 (1.08)	0.063
16-SWCS-T4-7 1d	253	6.25	ND	2.5	22 (1.89)	12.5	35	12.5	1230	18.8	47.45 ^(a) (5.53)	0.0165	354 (8.64)	0.63

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T4-7 2d	256	6.25	ND	2.5	18 (3.19)	12.5	26.6	12.5	1210	18.8	33.9 (8.97)	0.0165	252 (14.0)	0.63
16-SWCS-T4-7 7d	250	6.25	ND	2.5	34 (5.66)	12.5	55.3	12.5	1370	18.8	79.9 ^(a) (17.1)	0.165	546 (25.7)	1.26
16-SWCS-T4-7 14d	242	6.25	ND	2.5	7 (6.17)	12.5	36.7	12.5	1230	18.8	35.1 (20.6)	0.165	345 (33.1)	1.26
16-SWCS-T4-7 28d	232	6.25	ND	2.5	ND (6.87)	12.5	34.6	12.5	1190	18.8	3.86 (21.0)	0.165	295 (39.4)	1.26
16-SWCS-T4-7 42d	235	6.25	ND	2.5	ND (7.78)	12.5	20.6	12.5	1140	18.8	0.882 (21.1)	0.165	145 (42.4)	1.26
16-SWCS-T4-7 49d	249	6.25	ND	2.5	ND (8.69)	12.5	ND	12.5	1250	18.8	0.471 (21.2)	0.0165	63.4 (43.8)	1.26
16-SWCS-T4-7 63d	253	6.25	ND	2.5	ND (9.59)	12.5	13.7	12.5	1210	18.8	1.07 (21.3)	0.0165	90.1 (45.7)	1.26
16-SWCS-T4-7 100d	258	6.25	ND	2.5	ND (10.5)	12.5	16	12.5	1170	18.8	1.82 (21.5)	0.0165	109 (48.1)	1.26
16-SWCS-T4-8 0.08d	253	6.25	ND	2.5	5 (0.36)	12.5	ND	12.5	1080	18.8	9.8 (0.99)	0.0165	64.2 (1.37)	0.063
16-SWCS-T4-8 1d	255	6.25	ND	2.5	23 (2.03)	12.5	36.8	12.5	1280	18.8	56 (6.68)	0.0165	370 (9.26)	0.63
16-SWCS-T4-8 2d	255	6.25	ND	2.5	17 (3.26)	12.5	25.2	12.5	1210	18.8	37.6 (10.5)	0.0165	252 (14.6)	0.63
16-SWCS-T4-8 7d	250	6.25	ND	2.5	37 (5.94)	12.5	61	12.5	1470	18.8	96.2 (20.3)	0.165	647 (28.4)	1.26
16-SWCS-T4-8 14d	238	6.25	ND	2.5	ND (7.74)	12.5	29.6	12.5	1170	18.8	26.4 (22.9)	0.165	270 (34.2)	1.26
16-SWCS-T4-8 28d	235	6.25	ND	2.5	ND (8.64)	12.5	31.9	12.5	1160	18.8	2.03 (23.1)	0.165	268 (39.9)	1.26
16-SWCS-T4-8 42d	240	6.25	ND	2.5	ND (9.55)	12.5	20	12.5	1150	18.8	0.572 (23.2)	0.165	141 (42.9)	1.26
16-SWCS-T4-8 49d	250	6.25	ND	2.5	ND (10.5)	12.5	ND	12.5	1240	18.8	0.322 (23.2)	0.0165	64.3 (44.3)	1.26
16-SWCS-T4-8 63d	253	6.25	ND	2.5	ND (11.4)	12.5	ND	12.5	1200	18.8	0.673 (23.3)	0.0165	83.7 (46.1)	1.26
16-SWCS-T4-8 100d	257	6.25	ND	2.5	ND (12.3)	12.5	14.2	12.5	1190	18.8	1.27 (23.4)	0.0165	102 (48.3)	1.26
16-SWCS-T6-5 0.08d	1.23	0.75	ND	0.3	7.41 (0.51)	1.5	6.76	1.5	95.8	2.25	8.63 (0.83)	0.0165	84.2 (1.71)	0.063

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T6-5 1d	5.25	0.5	ND	0.2	32.2 (2.73)	1	18.3	1	284	1.5	43.35 ^(a) (5.01)	0.0165	384 (9.48)	0.63
16-SWCS-T6-5 2d	3.16	1.25	ND	0.5	20 (4.10)	2.5	16.9	2.5	166	3.75	25.2 (7.43)	0.0165	232 (14.2)	0.63
16-SWCS-T6-5 7d	8.68	1.25	ND	0.5	51.1 (7.62)	2.5	34	2.5	444	3.75	68.1 ^(a) (14.0)	0.165	588 (26.1)	1.26
16-SWCS-T6-5 14d	4.88	1.25	ND	0.5	35.2 (10.0)	2.5	26.5	2.5	337	3.75	26.2 (16.5)	0.165	379 (33.8)	1.26
16-SWCS-T6-5 28d	3.62	1.25	ND	0.5	30 (12.1)	2.5	23.8	2.5	298	3.75	3.4 (16.8)	0.165	297 (39.8)	1.26
16-SWCS-T6-5 42d	1.61	1.25	ND	0.5	17.5 (13.3)	2.5	15	2.5	175	3.75	1.63 (17.0)	0.165	149 (42.8)	1.26
16-SWCS-T6-5 49d	ND	1.25	ND	0.5	8.44 (13.9)	2.5	7.16	2.5	91	3.75	1.01 (17.1)	0.0165	54.7 (43.9)	1.26
16-SWCS-T6-5 63d	ND	1.25	ND	0.5	10.8 (14.6)	2.5	8.76	2.5	123	3.75	1.48 (17.2)	0.0165	66 (45.3)	1.26
16-SWCS-T6-5 100d	ND	1.25	ND	0.5	16.9 (15.8)	2.5	13.5	2.5	250	3.75	1.38 (17.4)	0.0165	111 (47.5)	1.26
16-SWCS-T6-6 0.08d	1.34	1.25	ND	0.5	8 (0.57)	2.5	7.34	2.5	122	3.75	12.3 (1.22)	0.0165	90.9 (1.90)	0.063
16-SWCS-T6-6 1d	6.15	1.25	ND	0.5	38.4 (3.29)	2.5	26.8	2.5	399	3.75	61.1 (7.28)	0.0165	449 (11.3)	0.63
16-SWCS-T6-6 2d	2.66	1.25	ND	0.5	18.4 (4.59)	2.5	15.2	2.5	177	3.75	24.5 (9.71)	0.0165	194 (15.3)	0.63
16-SWCS-T6-6 7d	5.02	1.25	ND	0.5	38.2 (7.30)	2.5	26.4	2.5	369	3.75	45.1 (14.2)	0.165	394 (23.5)	1.26
16-SWCS-T6-6 14d	3.11	1.25	ND	0.5	28.5 (9.32)	2.5	20.9	2.5	271	3.75	12.5 (15.4)	0.165	253 (28.8)	1.26
16-SWCS-T6-6 28d	2.59	1.25	ND	0.5	26.8 (11.2)	2.5	19.7	2.5	271	3.75	3.79 (15.8)	0.165	215 (33.3)	1.26
16-SWCS-T6-6 42d	1.39	1.25	ND	0.5	17.9 (12.5)	2.5	13.3	2.5	180	3.75	1.88 (16.0)	0.165	130 (36.0)	1.26
16-SWCS-T6-6 49d	ND	1.25	ND	0.5	7.56 (13.0)	2.5	5.28	2.5	70.7	3.75	0.604 (16.1)	0.0165	41.6 (36.9)	1.26
16-SWCS-T6-6 63d	ND	1.25	ND	0.5	9.7 (13.7)	2.5	6.85	2.5	94.8	3.75	0.907 (16.1)	0.0165	57.8 (38.1)	1.26
16-SWCS-T6-6 100d	ND	1.25	ND	0.5	16.5 (14.9)	2.5	13.3	2.5	230	3.75	0.773 (16.2)	0.0165	108 (40.3)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T6-7 0.08d	254	6.25	ND	2.5	6 (0.41)	12.5	ND	12.5	1090	18.8	5.76 (0.55)	0.0165	68 (1.37)	0.063
16-SWCS-T6-7 1d	258	6.25	ND	2.5	27 (2.26)	12.5	32.7	12.5	1230	18.8	32.5 ^(a) (3.67)	0.0165	379 (9.01)	0.63
16-SWCS-T6-7 2d	256	6.25	ND	2.5	18 (3.49)	12.5	21.7	12.5	1170	18.8	21.2 (5.70)	0.0165	238 (13.8)	0.63
16-SWCS-T6-7 7d	257	6.25	ND	2.5	50 (6.92)	12.5	58.8	12.5	1360	18.8	61.15 ^(a) (11.6)	0.165	679 (27.5)	1.26
16-SWCS-T6-7 14d	250	6.25	ND	2.5	26 (8.70)	12.5	47.4	12.5	1270	18.8	23.7 (13.8)	0.165	538 (38.3)	1.26
16-SWCS-T6-7 28d	244	6.25	ND	2.5	12 (9.52)	12.5	47.4	12.5	1310	18.8	4.27 (14.2)	0.165	526 (49.0)	1.26
16-SWCS-T6-7 42d	239	6.25	ND	2.5	ND (10.4)	12.5	27.2	12.5	1200	18.8	1.98 (14.4)	0.165	261 (54.2)	1.26
16-SWCS-T6-7 49d	247	6.25	ND	2.5	ND (11.2)	12.5	ND	12.5	1240	18.8	0.894 (14.5)	0.0165	107 (56.4)	1.26
16-SWCS-T6-7 63d	250	6.25	ND	2.5	ND (12.1)	12.5	17.9	12.5	1210	18.8	1.92 (14.7)	0.0165	161 (59.6)	1.26
16-SWCS-T6-7 100d	254	6.25	ND	2.5	ND (12.9)	12.5	24.3	12.5	1210	18.8	6.84 (15.4)	0.0165	217 (64.0)	1.26
16-SWCS-T6-8 0.08d	254	6.25	ND	2.5	5 (0.34)	12.5	ND	12.5	1080	18.8	3.64 (0.35)	0.0165	54.7 (1.09)	0.063
16-SWCS-T6-8 1d	258	6.25	ND	2.5	27 (2.17)	12.5	36.2	12.5	1220	18.8	24.5 (2.67)	0.0165	352 (8.12)	0.63
16-SWCS-T6-8 2d	255	6.25	ND	2.5	20 (3.53)	12.5	26.4	12.5	1160	18.8	17.8 (4.36)	0.0165	254 (13.2)	0.63
16-SWCS-T6-8 7d	257	6.25	ND	2.5	55 (7.26)	12.5	67.8	12.5	1310	18.8	45.5 (8.68)	0.165	721 (27.6)	1.26
16-SWCS-T6-8 14d	248	6.25	ND	2.5	26 (9.02)	12.5	49.7	12.5	1190	18.8	12.6 (9.88)	0.165	508 (37.7)	1.26
16-SWCS-T6-8 28d	250	6.25	ND	2.5	24 (10.6)	12.5	61	12.5	1290	18.8	2.93 (10.2)	0.165	620 (50.1)	1.26
16-SWCS-T6-8 42d	247	6.25	ND	2.5	ND (11.9)	12.5	39.6	12.5	1250	18.8	1.64 (10.3)	0.165	352 (57.1)	1.26
16-SWCS-T6-8 49d	249	6.25	ND	2.5	ND (12.7)	12.5	14.5	12.5	1270	18.8	0.572 (10.4)	0.0165	119 (59.5)	1.26
16-SWCS-T6-8 63d	248	6.25	ND	2.5	ND (13.6)	12.5	20	12.5	1240	18.8	1.14 (10.5)	0.0165	161 (62.7)	1.26

Sample ID	Cl ⁻ (mg/L)	EQL (mg/L)	F ⁻ (mg/L)	EQL (mg/L)	NO ₃ ⁻ (mg/L)	EQL (mg/L)	NO ₂ ⁻ (mg/L)	EQL (mg/L)	SO ₄ ²⁻ (mg/L)	EQL (mg/L)	⁹⁹ Tc (μg/L)	EQL (μg/L)	¹²⁷ I (μg/L)	EQL (μg/L)
16-SWCS-T6-8 100d	252	6.25	ND	2.5	ND (14.4)	12.5	30.4	12.5	1260	18.8	3.24 (10.8)	0.0165	237 (67.5)	1.26
a. Duplicate samples averaged														

A.3 Additional Results of Alkalinity, Electrical Conductivity, and pH from EPA Method 1315 Tests

Table A.5. Results of Alkalinity, Electrical Conductivity, and pH in Leachates from EPA Method 1315 Tests (28-Day Cured Monoliths)

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-DI BLK1 0.08d	6.11	ND	0.01	ND	23.5
16-SWCS-DI BLK1 1d	6.58	ND	0.01	ND	23.5
16-SWCS-DI BLK1 2d	6.48	ND	0.01	ND	23.5
16-SWCS-DI BLK1 7d	6.04	ND	0.01	ND	23.5
16-SWCS-DI BLK1 14d	6.01	ND	0.01	ND	23.5
16-SWCS-DI BLK1 28d	6.79	ND	0.01	ND	23.5
16-SWCS-DI BLK1 42d	6.51	ND	0.01	ND	23.5
16-SWCS-DI BLK1 49d	6.07	ND	0.01	ND	23.5
16-SWCS-DI BLK1 63d	7.30	ND	0.01	ND	23.5
16-SWCS-DI BLK1 100d	5.98	ND	0.01	ND	23.5
16-SWCS-DI BLK2 0.08d	8.47	ND	0.01	ND	23.5
16-SWCS-DI BLK2 1d	7.74	ND	0.01	ND	23.5
16-SWCS-DI BLK2 2d	7.76	ND	0.01	55	23.5
16-SWCS-DI BLK2 7d	8.43	ND	0.01	ND	23.5
16-SWCS-DI BLK2 14d	7.37	ND	0.01	ND	23.5
16-SWCS-DI BLK2 28d	6.89	ND	0.01	ND	23.5
16-SWCS-DI BLK2 42d	8.33	ND	0.01	ND	23.5
16-SWCS-DI BLK2 49d	8.09	ND	0.01	ND	23.5
16-SWCS-DI BLK2 63d	8.66	ND	0.01	ND	23.5
16-SWCS-DI BLK2 100d	6.54	ND	0.01	ND	23.5
16-SWCS-PW BLK1 0.08d	6.78	2.84	0.01	25.3	23.5
16-SWCS-PW BLK1 1d	7.06	2.84	0.01	ND	23.5
16-SWCS-PW BLK1 2d	7.17	2.85	0.01	24.6	23.5
16-SWCS-PW BLK1 7d	7.34	2.86	0.01	ND	23.5
16-SWCS-PW BLK1 14d	7.50	2.93	0.01	24.2	23.5
16-SWCS-PW BLK1 28d	7.42	3.06	0.01	25.5	23.5
16-SWCS-PW BLK1 42d	7.58	3.25	0.01	25.1	23.5
16-SWCS-PW BLK1 49d	7.28	2.97	0.01	ND	23.5
16-SWCS-PW BLK1 63d	7.39	3.08	0.01	ND	23.5
16-SWCS-PW BLK1 100d	6.97	3.17	0.01	ND	23.5
16-SWCS-PW BLK2 0.08d	7.53	2.85	0.01	24.6	23.5
16-SWCS-PW BLK2 1d	7.33	2.85	0.01	24.6	23.5
16-SWCS-PW BLK2 2d	7.38	2.85	0.01	74.8	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-PW BLK2 7d	7.62	2.88	0.01	24.6	23.5
16-SWCS-PW BLK2 14d	7.65	2.96	0.01	24.0	23.5
16-SWCS-PW BLK2 28d	7.81	3.06	0.01	24.0	23.5
16-SWCS-PW BLK2 42d	7.67	3.28	0.01	24.6	23.5
16-SWCS-PW BLK2 49d	7.58	2.98	0.01	ND	23.5
16-SWCS-PW BLK2 63d	7.67	3.08	0.01	ND	23.5
16-SWCS-PW BLK2 100d	7.53	3.16	0.01	ND	23.5
16-SWCS-T1-1 0.08d	11.40	0.93	0.01	129.0	23.5
16-SWCS-T1-1 1d	12.00	3.69	0.01	673.0	23.5
16-SWCS-T1-1 2d	11.90	2.49	0.01	486.0	23.5
16-SWCS-T1-1 7d	12.20	5.35	0.01	1440.0	23.5
16-SWCS-T1-1 14d	12.20	4.87	0.01	1410.0	23.5
16-SWCS-T1-1 28d	12.30	4.98	0.01	1410.0	23.5
16-SWCS-T1-1 42d	12.20	3.68	0.01	1020.0	23.5
16-SWCS-T1-1 49d	12.00	1.85	0.01	455.0	23.5
16-SWCS-T1-1 63d	12.00	2.49	0.01	638.0	23.5
16-SWCS-T1-1 100d	12.20	4.13	0.01	955.0	23.5
16-SWCS-T1-2 0.08d	11.30	0.90	0.01	85.1	23.5
16-SWCS-T1-2 1d	12.00	3.41	0.01	612.0	23.5
16-SWCS-T1-2 2d	11.90	2.56	0.01	502.0	23.5
16-SWCS-T1-2 7d	12.30	5.59	0.01	1290.0	23.5
16-SWCS-T1-2 14d	12.20	6.43	0.01	953.0	23.5
16-SWCS-T1-2 28d	12.30	5.16	0.01	1070.0	23.5
16-SWCS-T1-2 42d	12.20	3.53	0.01	664.0	23.5
16-SWCS-T1-2 49d	11.90	1.83	0.01	279.0	23.5
16-SWCS-T1-2 63d	12.00	2.67	0.01	430.0	23.5
16-SWCS-T1-2 100d	12.20	3.10	0.01	671.0	23.5
16-SWCS-T1-3 0.08d	10.50	3.26	0.01	90.0	23.5
16-SWCS-T1-3 1d	11.50	4.38	0.01	346.0	23.5
16-SWCS-T1-3 2d	11.20	3.62	0.01	288.0	23.5
16-SWCS-T1-3 7d	12.00	5.63	0.01	1020.0	23.5
16-SWCS-T1-3 14d	12.00	5.69	0.01	871.0	23.5
16-SWCS-T1-3 28d	12.10	6.15	0.01	1140.0	23.5
16-SWCS-T1-3 42d	12.00	5.18	0.01	759.0	23.5
16-SWCS-T1-3 49d	11.20	3.21	0.01	167.0	23.5
16-SWCS-T1-3 63d	11.60	3.93	0.01	333.0	23.5
16-SWCS-T1-3 100d	12.00	5.44	0.01	711.0	23.5
16-SWCS-T1-4 0.08d	10.40	3.14	0.01	93.1	23.5
16-SWCS-T1-4 1d	11.50	4.33	0.01	392.0	23.5
16-SWCS-T1-4 2d	11.10	3.74	0.01	288.0	23.5
16-SWCS-T1-4 7d	12.10	6.33	0.01	1150.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T1-4 14d	12.10	6.32	0.01	948.0	23.5
16-SWCS-T1-4 28d	12.20	6.40	0.01	1230.0	23.5
16-SWCS-T1-4 42d	12.00	5.28	0.01	814.0	23.5
16-SWCS-T1-4 49d	11.30	3.28	0.01	195.0	23.5
16-SWCS-T1-4 63d	11.60	3.91	0.01	347.0	23.5
16-SWCS-T1-4 100d	12.20	6.13	0.01	877.0	23.5
16-SWCS-T2-1 0.08d	11.40	1.23	0.01	154.0	23.5
16-SWCS-T2-1 1d	12.00	4.44	0.01	904.0	23.5
16-SWCS-T2-1 2d	12.00	2.92	0.01	636.0	23.5
16-SWCS-T2-1 7d	12.30	6.67	0.01	1810.0	23.5
16-SWCS-T2-1 14d	12.30	6.17	0.01	1320.0	23.5
16-SWCS-T2-1 28d	12.30	5.53	0.01	1250.0	23.5
16-SWCS-T2-1 42d	12.20	3.47	0.01	766.0	23.5
16-SWCS-T2-1 49d	11.90	1.63	0.01	375.0	23.5
16-SWCS-T2-1 63d	11.90	1.83	0.01	409.0	23.5
16-SWCS-T2-1 100d	12.00	1.96	0.01	459.0	23.5
16-SWCS-T2-2 0.08d	11.50	1.45	0.01	209.0	23.5
16-SWCS-T2-2 1d	12.00	4.22	0.01	1040.0	23.5
16-SWCS-T2-2 2d	12.00	2.92	0.01	724.0	23.5
16-SWCS-T2-2 7d	12.40	6.23	0.01	2040.0	23.5
16-SWCS-T2-2 14d	12.40	5.85	0.01	1470.0	23.5
16-SWCS-T2-2 28d	12.40	6.00	0.01	1440.0	23.5
16-SWCS-T2-2 42d	12.30	3.82	0.01	871.0	23.5
16-SWCS-T2-2 49d	12.00	1.84	0.01	377.0	23.5
16-SWCS-T2-2 63d	12.00	2.09	0.01	437.0	23.5
16-SWCS-T2-2 100d	12.00	2.12	0.01	477.0	23.5
16-SWCS-T2-3 0.08d	10.60	3.42	0.01	100.0	23.5
16-SWCS-T2-3 1d	11.50	4.78	0.01	645.0	23.5
16-SWCS-T2-3 2d	11.30	3.90	0.01	480.0	23.5
16-SWCS-T2-3 7d	12.10	7.11	0.01	1750.0	23.5
16-SWCS-T2-3 14d	12.10	6.64	0.01	1300.0	23.5
16-SWCS-T2-3 28d	12.20	7.16	0.01	1120.0	23.5
16-SWCS-T2-3 42d	12.00	5.50	0.01	626.0	23.5
16-SWCS-T2-3 49d	11.30	3.30	0.01	121.0	23.5
16-SWCS-T2-3 63d	11.60	3.73	0.01	226.0	23.5
16-SWCS-T2-3 100d	11.90	4.37	0.01	398.0	23.5
16-SWCS-T2-4 0.08d	10.60	3.38	0.01	117.0	23.5
16-SWCS-T2-4 1d	11.50	4.57	0.01	634.0	23.5
16-SWCS-T2-4 2d	11.20	3.76	0.01	400.0	23.5
16-SWCS-T2-4 7d	12.10	6.62	0.01	1630.0	23.5
16-SWCS-T2-4 14d	12.10	6.64	0.01	1270.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T2-4 28d	12.20	7.14	0.01	1070.0	23.5
16-SWCS-T2-4 42d	12.10	5.49	0.01	578.0	23.5
16-SWCS-T2-4 49d	11.40	3.33	0.01	127.0	23.5
16-SWCS-T2-4 63d	11.50	3.60	0.01	179.0	23.5
16-SWCS-T2-4 100d	11.80	4.09	0.01	330.0	23.5
16-SWCS-T3-1 0.08d	11.30	0.87	0.01	110.0	23.5
16-SWCS-T3-1 1d	12.00	3.50	0.01	807.0	23.5
16-SWCS-T3-1 2d	11.90	2.70	0.01	581.0	23.5
16-SWCS-T3-1 7d	12.30	6.17	0.01	1670.0	23.5
16-SWCS-T3-1 14d	12.30	4.95	0.01	1650.0	23.5
16-SWCS-T3-1 28d	12.20	5.75	0.01	1280.0	23.5
16-SWCS-T3-1 42d	12.30	4.54	0.01	768.0	23.5
16-SWCS-T3-1 49d	12.00	2.16	0.01	394.0	23.5
16-SWCS-T3-1 63d	11.90	2.78	0.01	498.0	23.5
16-SWCS-T3-1 100d	12.10	3.55	0.01	694.0	23.5
16-SWCS-T3-2 0.08d	11.40	1.02	0.01	110.0	23.5
16-SWCS-T3-2 1d	11.90	3.13	0.01	904.0	23.5
16-SWCS-T3-2 2d	11.90	2.61	0.01	587.0	23.5
16-SWCS-T3-2 7d	12.30	5.70	0.01	1980.0	23.5
16-SWCS-T3-2 14d	12.30	5.22	0.01	1410.0	23.5
16-SWCS-T3-2 28d	12.30	5.27	0.01	1390.0	23.5
16-SWCS-T3-2 42d	12.20	3.90	0.01	867.0	23.5
16-SWCS-T3-2 49d	12.00	2.03	0.01	323.0	23.5
16-SWCS-T3-2 63d	12.00	2.71	0.01	492.0	23.5
16-SWCS-T3-2 100d	12.10	3.50	0.01	638.0	23.5
16-SWCS-T3-3 0.08d	10.40	3.26	0.01	105.0	23.5
16-SWCS-T3-3 1d	11.20	4.02	0.01	596.0	23.5
16-SWCS-T3-3 2d	11.10	3.70	0.01	440.0	23.5
16-SWCS-T3-3 7d	12.00	6.32	0.01	1580.0	23.5
16-SWCS-T3-3 14d	12.00	5.57	0.01	1310.0	23.5
16-SWCS-T3-3 28d	12.00	6.18	0.01	1170.0	23.5
16-SWCS-T3-3 42d	12.00	5.25	0.01	581.0	23.5
16-SWCS-T3-3 49d	11.00	3.30	0.01	126.0	23.5
16-SWCS-T3-3 63d	11.40	3.87	0.01	234.0	23.5
16-SWCS-T3-3 100d	12.00	5.31	0.01	582.0	23.5
16-SWCS-T3-4 0.08d	10.50	3.24	0.01	101.0	23.5
16-SWCS-T3-4 1d	11.20	3.85	0.01	586.0	23.5
16-SWCS-T3-4 2d	11.10	3.72	0.01	385.0	23.5
16-SWCS-T3-4 7d	12.10	7.25	0.01	1350.0	23.5
16-SWCS-T3-4 14d	12.00	6.01	0.01	1190.0	23.5
16-SWCS-T3-4 28d	12.10	6.11	0.01	968.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T3-4 42d	12.00	5.31	0.01	505.0	23.5
16-SWCS-T3-4 49d	11.40	3.47	0.01	92.8	23.5
16-SWCS-T3-4 63d	11.60	3.92	0.01	239.0	23.5
16-SWCS-T3-4 100d	11.90	4.75	0.01	481.0	23.5
16-SWCS-T4-1 0.08d	11.40	0.92	0.01	98.8	23.5
16-SWCS-T4-1 1d	11.90	3.31	0.01	730.0	23.5
16-SWCS-T4-1 2d	11.70	2.34	0.01	451.0	23.5
16-SWCS-T4-1 7d	12.10	6.32	0.01	1260.0	23.5
16-SWCS-T4-1 14d	12.20	4.62	0.01	979.0	23.5
16-SWCS-T4-1 28d	12.20	4.35	0.01	832.0	23.5
16-SWCS-T4-1 42d	12.10	3.16	0.01	508.0	23.5
16-SWCS-T4-1 49d	11.90	1.81	0.01	279.0	23.5
16-SWCS-T4-1 63d	11.90	2.03	0.01	370.0	23.5
16-SWCS-T4-1 100d	11.90	2.16	0.01	419.0	23.5
16-SWCS-T4-2 0.08d	11.30	0.81	0.01	113.0	23.5
16-SWCS-T4-2 1d	11.80	3.59	0.01	735.0	23.5
16-SWCS-T4-2 2d	11.70	3.04	0.01	532.0	23.5
16-SWCS-T4-2 7d	12.20	5.85	0.01	1250.0	23.5
16-SWCS-T4-2 14d	12.20	5.02	0.01	867.0	23.5
16-SWCS-T4-2 28d	12.10	4.29	0.01	715.0	23.5
16-SWCS-T4-2 42d	12.10	2.91	0.01	458.0	23.5
16-SWCS-T4-2 49d	11.80	1.62	0.01	201.0	23.5
16-SWCS-T4-2 63d	11.80	1.74	0.01	302.0	23.5
16-SWCS-T4-2 100d	11.90	2.06	0.01	453.0	23.5
16-SWCS-T4-3 0.08d	10.40	3.24	0.01	74.6	23.5
16-SWCS-T4-3 1d	11.20	4.29	0.01	518.0	23.5
16-SWCS-T4-3 2d	10.70	3.56	0.01	293.0	23.5
16-SWCS-T4-3 7d	11.90	6.90	0.01	882.0	23.5
16-SWCS-T4-3 14d	11.80	5.22	0.01	462.0	23.5
16-SWCS-T4-3 28d	11.90	5.47	0.01	601.0	23.5
16-SWCS-T4-3 42d	11.90	4.97	0.01	388.0	23.5
16-SWCS-T4-3 49d	11.30	3.29	0.01	69.5	23.5
16-SWCS-T4-3 63d	11.50	3.71	0.01	212.0	23.5
16-SWCS-T4-3 100d	11.80	4.14	0.01	374.0	23.5
16-SWCS-T4-4 0.08d	10.40	3.16	0.01	108.0	23.5
16-SWCS-T4-4 1d	11.10	4.20	0.01	579.0	23.5
16-SWCS-T4-4 2d	10.70	3.82	0.01	383.0	23.5
16-SWCS-T4-4 7d	12.00	7.37	0.01	1720.0	23.5
16-SWCS-T4-4 14d	11.90	5.72	0.01	681.0	23.5
16-SWCS-T4-4 28d	12.00	5.68	0.01	620.0	23.5
16-SWCS-T4-4 42d	11.90	4.77	0.01	370.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T4-4 49d	11.40	3.39	0.01	97.0	23.5
16-SWCS-T4-4 63d	11.50	3.78	0.01	229.0	23.5
16-SWCS-T4-4 100d	11.80	4.19	0.01	403.0	23.5
16-SWCS-T6-1 0.08d	11.40	1.13	0.01	174.0	23.5
16-SWCS-T6-1 1d	11.90	3.52	0.01	1080.0	23.5
16-SWCS-T6-1 2d	11.80	2.25	0.01	671.0	23.5
16-SWCS-T6-1 7d	12.20	6.16	0.01	2070.0	23.5
16-SWCS-T6-1 14d	12.30	5.52	0.01	1490.0	23.5
16-SWCS-T6-1 28d	12.20	5.84	0.01	1450.0	23.5
16-SWCS-T6-1 42d	12.20	4.32	0.01	818.0	23.5
16-SWCS-T6-1 49d	12.00	2.17	0.01	418.0	23.5
16-SWCS-T6-1 63d	12.00	2.92	0.01	508.0	23.5
16-SWCS-T6-1 100d	12.20	4.71	0.01	933.0	23.5
16-SWCS-T6-2 0.08d	11.50	1.14	0.01	147.0	23.5
16-SWCS-T6-2 1d	11.90	4.08	0.01	948.0	23.5
16-SWCS-T6-2 2d	11.80	2.75	0.01	700.0	23.5
16-SWCS-T6-2 7d	12.20	6.21	0.01	2110.0	23.5
16-SWCS-T6-2 14d	12.30	5.88	0.01	1570.0	23.5
16-SWCS-T6-2 28d	12.30	6.03	0.01	1380.0	23.5
16-SWCS-T6-2 42d	12.30	4.35	0.01	807.0	23.5
16-SWCS-T6-2 49d	12.00	2.14	0.01	342.0	23.5
16-SWCS-T6-2 63d	12.00	2.78	0.01	494.0	23.5
16-SWCS-T6-2 100d	12.20	4.57	0.01	911.0	23.5
16-SWCS-T6-3 0.08d	10.40	3.39	0.01	138.0	23.5
16-SWCS-T6-3 1d	11.20	4.40	0.01	746.0	23.5
16-SWCS-T6-3 2d	10.80	3.57	0.01	454.0	23.5
16-SWCS-T6-3 7d	12.00	6.67	0.01	1740.0	23.5
16-SWCS-T6-3 14d	12.00	6.07	0.01	1280.0	23.5
16-SWCS-T6-3 28d	12.10	6.89	0.01	1140.0	23.5
16-SWCS-T6-3 42d	12.00	5.75	0.01	653.0	23.5
16-SWCS-T6-3 49d	11.50	3.58	0.01	191.0	23.5
16-SWCS-T6-3 63d	11.70	4.19	0.01	345.0	23.5
16-SWCS-T6-3 100d	12.10	5.78	0.01	820.0	23.5
16-SWCS-T6-4 0.08d	10.40	3.14	0.01	117.0	23.5
16-SWCS-T6-4 1d	11.00	4.23	0.01	717.0	23.5
16-SWCS-T6-4 2d	10.90	3.63	0.01	409.0	23.5
16-SWCS-T6-4 7d	12.00	6.62	0.01	1630.0	23.5
16-SWCS-T6-4 14d	12.10	6.28	0.01	1430.0	23.5
16-SWCS-T6-4 28d	12.10	7.29	0.01	1130.0	23.5
16-SWCS-T6-4 42d	12.10	5.94	0.01	697.0	23.5
16-SWCS-T6-4 49d	11.60	3.73	0.01	213.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T6-4 63d	11.80	4.34	0.01	364.0	23.5
16-SWCS-T6-4 100d	12.10	5.68	0.01	754.0	23.5

Table A.6. Results of Alkalinity, Electrical Conductivity, and pH in Leachates from EPA Method 1315 Tests (60-Day Cured Monoliths)

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-60-DI BLK1 0.08d	6.63	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 1d	7.03	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 2d	6.88	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 7d	6.49	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 14d	6.07	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 28d	6.11	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 42d	5.93	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 49d	6.01	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 63d	5.97	ND	0.01	ND	23.5
16-SWCS-60-DI BLK1 100d	6.00	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 0.08d	7.03	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 1d	8.29	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 2d	8.19	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 7d	7.18	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 14d	7.43	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 28d	8.00	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 42d	8.44	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 49d	7.33	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 63d	7.89	ND	0.01	ND	23.5
16-SWCS-60-DI BLK2 100d	7.85	ND	0.01	ND	23.5
16-SWCS-60-PW BLK1 0.08d	7.54	2.90	0.01	ND	23.5
16-SWCS-60-PW BLK1 1d	7.43	2.92	0.01	ND	23.5
16-SWCS-60-PW BLK1 2d	7.49	2.93	0.01	ND	23.5
16-SWCS-60-PW BLK1 7d	7.50	2.93	0.01	25.1	23.5
16-SWCS-60-PW BLK1 14d	7.52	2.95	0.01	ND	23.5
16-SWCS-60-PW BLK1 28d	7.50	3.07	0.01	23.8	23.5
16-SWCS-60-PW BLK1 42d	7.50	3.18	0.01	ND	23.5
16-SWCS-60-PW BLK1 49d	7.39	3.27	0.01	ND	23.5
16-SWCS-60-PW BLK1 63d	7.44	3.28	0.01	23.5	23.5
16-SWCS-60-PW BLK1 100d	7.20	3.43	0.01	ND	23.5
16-SWCS-60-PW BLK2 0.08d	7.62	2.88	0.01	23.8	23.5
16-SWCS-60-PW BLK2 1d	7.82	2.90	0.01	ND	23.5
16-SWCS-60-PW BLK2 2d	7.69	2.92	0.01	ND	23.5
16-SWCS-60-PW BLK2 7d	7.99	2.93	0.01	ND	23.5
16-SWCS-60-PW BLK2 14d	7.81	2.96	0.01	ND	23.5
16-SWCS-60-PW BLK2 28d	7.65	3.07	0.01	24.0	23.5
16-SWCS-60-PW BLK2 42d	7.72	3.17	0.01	24.9	23.5
16-SWCS-60-PW BLK2 49d	7.51	3.27	0.01	ND	23.5
16-SWCS-60-PW BLK2 63d	7.61	3.28	0.01	ND	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-60-PW BLK2 100d	7.42	3.43	0.01	ND	23.5
16-SWCS-T1-6 0.08d	11.10	0.58	0.01	95.7	23.5
16-SWCS-T1-6 1d	12.00	3.13	0.01	512.0	23.5
16-SWCS-T1-6 2d	11.80	2.57	0.01	360.0	23.5
16-SWCS-T1-6 7d	12.30	5.59	0.01	1130.0	23.5
16-SWCS-T1-6 14d	12.20	4.71	0.01	1020.0	23.5
16-SWCS-T1-6 28d	12.40	5.21	0.01	1130.0	23.5
16-SWCS-T1-6 42d	12.10	3.96	0.01	784.0	23.5
16-SWCS-T1-6 49d	12.00	2.25	0.01	339.0	23.5
16-SWCS-T1-6 63d	12.10	2.64	0.01	569.0	23.5
16-SWCS-T1-6 100d	12.20	3.99	0.01	943.0	23.5
16-SWCS-T1-7 0.08d	11.10	0.66	0.01	105.0	23.5
16-SWCS-T1-7 1d	12.00	2.74	0.01	586.0	23.5
16-SWCS-T1-7 2d	11.70	2.69	0.01	350.0	23.5
16-SWCS-T1-7 7d	12.30	5.32	0.01	1240.0	23.5
16-SWCS-T1-7 14d	12.20	4.90	0.01	972.0	23.5
16-SWCS-T1-7 28d	12.40	4.85	0.01	1260.0	23.5
16-SWCS-T1-7 42d	12.20	3.59	0.01	955.0	23.5
16-SWCS-T1-7 49d	11.90	1.83	0.01	367.0	23.5
16-SWCS-T1-7 63d	12.10	2.57	0.01	565.0	23.5
16-SWCS-T1-7 100d	12.20	4.26	0.01	997.0	23.5
16-SWCS-T1-8 0.08d	10.30	3.04	0.01	54.6	23.5
16-SWCS-T1-8 1d	10.80	3.91	0.01	226.0	23.5
16-SWCS-T1-8 2d	10.80	3.46	0.01	121.0	23.5
16-SWCS-T1-8 7d	12.00	5.82	0.01	770.0	23.5
16-SWCS-T1-8 14d	12.00	5.48	0.01	617.0	23.5
16-SWCS-T1-8 28d	12.10	6.24	0.01	1000.0	23.5
16-SWCS-T1-8 42d	11.90	5.20	0.01	598.0	23.5
16-SWCS-T1-8 49d	11.10	3.49	0.01	144.0	23.5
16-SWCS-T1-8 63d	11.60	4.05	0.01	274.0	23.5
16-SWCS-T1-8 100d	12.00	5.69	0.01	738.0	23.5
16-SWCS-T1-9 0.08d	10.40	3.10	0.01	74.8	23.5
16-SWCS-T1-9 1d	10.80	4.10	0.01	305.0	23.5
16-SWCS-T1-9 2d	10.80	3.69	0.01	182.0	23.5
16-SWCS-T1-9 7d	12.00	6.55	0.01	920.0	23.5
16-SWCS-T1-9 14d	12.00	5.51	0.01	663.0	23.5
16-SWCS-T1-9 28d	12.10	5.69	0.01	776.0	23.5
16-SWCS-T1-9 42d	11.80	4.47	0.01	447.0	23.5
16-SWCS-T1-9 49d	11.00	3.34	0.01	87.3	23.5
16-SWCS-T1-9 63d	11.40	3.63	0.01	182.0	23.5
16-SWCS-T1-9 100d	11.90	4.73	0.01	444.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T2-5 0.08d	11.50	0.79	0.01	199.0	23.5
16-SWCS-T2-5 1d	12.10	5.80	0.01	812.0	23.5
16-SWCS-T2-5 2d	11.90	3.64	0.01	436.0	23.5
16-SWCS-T2-5 7d	12.30	6.60	0.01	1420.0	23.5
16-SWCS-T2-5 14d	12.30	5.45	0.01	1030.0	23.5
16-SWCS-T2-5 28d	12.40	6.38	0.01	1040.0	23.5
16-SWCS-T2-5 42d	12.20	5.23	0.01	725.0	23.5
16-SWCS-T2-5 49d	12.10	2.72	0.01	518.0	23.5
16-SWCS-T2-5 63d	12.20	3.22	0.01	464.0	23.5
16-SWCS-T2-5 100d	12.20	3.95	0.01	730.0	23.5
16-SWCS-T2-6 0.08d	11.40	0.87	0.01	236.0	23.5
16-SWCS-T2-6 1d	12.10	4.90	0.01	966.0	23.5
16-SWCS-T2-6 2d	11.90	3.19	0.01	578.0	23.5
16-SWCS-T2-6 7d	12.30	6.39	0.01	1690.0	23.5
16-SWCS-T2-6 14d	12.30	5.78	0.01	1370.0	23.5
16-SWCS-T2-6 28d	12.40	6.16	0.01	1360.0	23.5
16-SWCS-T2-6 42d	12.20	4.10	0.01	802.0	23.5
16-SWCS-T2-6 49d	12.00	1.84	0.01	375.0	23.5
16-SWCS-T2-6 63d	12.10	2.13	0.01	448.0	23.5
16-SWCS-T2-6 100d	12.00	2.22	0.01	493.0	23.5
16-SWCS-T2-7 0.08d	10.40	3.10	0.01	99.0	23.5
16-SWCS-T2-7 1d	11.50	5.36	0.01	534.0	23.5
16-SWCS-T2-7 2d	11.10	4.17	0.01	353.0	23.5
16-SWCS-T2-7 7d	12.10	6.73	0.01	1280.0	23.5
16-SWCS-T2-7 14d	12.10	6.36	0.01	992.0	23.5
16-SWCS-T2-7 28d	12.20	7.47	0.01	1230.0	23.5
16-SWCS-T2-7 42d	12.00	5.72	0.01	653.0	23.5
16-SWCS-T2-7 49d	11.20	3.56	0.01	117.0	23.5
16-SWCS-T2-7 63d	11.50	3.81	0.01	197.0	23.5
16-SWCS-T2-7 100d	11.80	4.44	0.01	371.0	23.5
16-SWCS-T2-8 0.08d	10.40	3.14	0.01	116.0	23.5
16-SWCS-T2-8 1d	11.60	5.08	0.01	555.0	23.5
16-SWCS-T2-8 2d	11.00	3.84	0.01	326.0	23.5
16-SWCS-T2-8 7d	12.10	7.06	0.01	1360.0	23.5
16-SWCS-T2-8 14d	12.10	6.39	0.01	1020.0	23.5
16-SWCS-T2-8 28d	12.30	7.65	0.01	1190.0	23.5
16-SWCS-T2-8 42d	12.00	5.74	0.01	627.0	23.5
16-SWCS-T2-8 49d	11.30	3.64	0.01	128.0	23.5
16-SWCS-T2-8 63d	11.60	4.02	0.01	233.0	23.5
16-SWCS-T2-8 100d	11.90	4.76	0.01	459.0	23.5
16-SWCS-T3-5 0.08d	11.10	0.56	0.01	111.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T3-5 1d	12.00	3.87	0.01	662.0	23.5
16-SWCS-T3-5 2d	11.80	2.70	0.01	437.0	23.5
16-SWCS-T3-5 7d	12.20	5.70	0.01	1470.0	23.5
16-SWCS-T3-5 14d	12.20	4.91	0.01	1280.0	23.5
16-SWCS-T3-5 28d	12.40	5.73	0.01	1250.0	23.5
16-SWCS-T3-5 42d	12.20	4.55	0.01	803.0	23.5
16-SWCS-T3-5 49d	12.00	2.27	0.01	374.0	23.5
16-SWCS-T3-5 63d	12.10	2.86	0.01	432.0	23.5
16-SWCS-T3-5 100d	12.20	3.90	0.01	686.0	23.5
16-SWCS-T3-6 0.08d	11.20	0.55	0.01	138.0	23.5
16-SWCS-T3-6 1d	12.10	4.08	0.01	667.0	23.5
16-SWCS-T3-6 2d	11.80	2.52	0.01	496.0	23.5
16-SWCS-T3-6 7d	12.30	5.43	0.01	1360.0	23.5
16-SWCS-T3-6 14d	12.20	4.85	0.01	1120.0	23.5
16-SWCS-T3-6 28d	12.30	5.66	0.01	1120.0	23.5
16-SWCS-T3-6 42d	12.10	3.97	0.01	698.0	23.5
16-SWCS-T3-6 49d	12.00	2.17	0.01	298.0	23.5
16-SWCS-T3-6 63d	12.10	2.55	0.01	427.0	23.5
16-SWCS-T3-6 100d	12.20	3.55	0.01	661.0	23.5
16-SWCS-T3-7 0.08d	10.40	3.21	0.01	127.0	23.5
16-SWCS-T3-7 1d	11.60	6.17	0.01	513.0	23.5
16-SWCS-T3-7 2d	10.60	4.28	0.01	264.0	23.5
16-SWCS-T3-7 7d	12.00	6.35	0.01	663.0	23.5
16-SWCS-T3-7 14d	12.00	5.39	0.01	517.0	23.5
16-SWCS-T3-7 28d	12.10	5.60	0.01	625.0	23.5
16-SWCS-T3-7 42d	12.00	5.05	0.01	482.0	23.5
16-SWCS-T3-7 49d	11.70	4.04	0.01	155.0	23.5
16-SWCS-T3-7 63d	11.90	4.54	0.01	341.0	23.5
16-SWCS-T3-7 100d	12.00	4.88	0.01	514.0	23.5
16-SWCS-T3-8 0.08d	10.50	3.08	0.01	99.8	23.5
16-SWCS-T3-8 1d	11.20	4.38	0.01	453.0	23.5
16-SWCS-T3-8 2d	10.60	3.63	0.01	319.0	23.5
16-SWCS-T3-8 7d	11.90	5.98	0.01	989.0	23.5
16-SWCS-T3-8 14d	11.90	5.60	0.01	692.0	23.5
16-SWCS-T3-8 28d	12.10	6.22	0.01	895.0	23.5
16-SWCS-T3-8 42d	11.90	5.42	0.01	521.0	23.5
16-SWCS-T3-8 49d	11.40	3.85	0.01	136.0	23.5
16-SWCS-T3-8 63d	11.80	4.44	0.01	260.0	23.5
16-SWCS-T3-8 100d	12.00	5.48	0.01	524.0	23.5
16-SWCS-T4-5 0.08d	11.40	0.68	0.01	123.0	23.5
16-SWCS-T4-5 1d	12.00	3.76	0.01	755.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T4-5 2d	11.80	3.24	0.01	422.0	23.5
16-SWCS-T4-5 7d	12.20	5.71	0.01	1080.0	23.5
16-SWCS-T4-5 14d	12.20	4.74	0.01	777.0	23.5
16-SWCS-T4-5 28d	12.20	4.61	0.01	763.0	23.5
16-SWCS-T4-5 42d	12.00	3.38	0.01	522.0	23.5
16-SWCS-T4-5 49d	11.90	1.91	0.01	280.0	23.5
16-SWCS-T4-5 63d	12.00	2.24	0.01	350.0	23.5
16-SWCS-T4-5 100d	12.00	2.32	0.01	462.0	23.5
16-SWCS-T4-6 0.08d	11.40	0.71	0.01	92.8	23.5
16-SWCS-T4-6 1d	12.00	3.34	0.01	603.0	23.5
16-SWCS-T4-6 2d	11.80	3.05	0.01	383.0	23.5
16-SWCS-T4-6 7d	12.20	7.29	0.01	1000.0	23.5
16-SWCS-T4-6 14d	12.20	4.51	0.01	825.0	23.5
16-SWCS-T4-6 28d	12.20	4.77	0.01	714.0	23.5
16-SWCS-T4-6 42d	12.00	3.71	0.01	469.0	23.5
16-SWCS-T4-6 49d	11.90	1.88	0.01	231.0	23.5
16-SWCS-T4-6 63d	12.00	1.88	0.01	304.0	23.5
16-SWCS-T4-6 100d	12.00	2.18	0.01	349.0	23.5
16-SWCS-T4-7 0.08d	10.40	3.25	0.01	65.6	23.5
16-SWCS-T4-7 1d	11.30	4.74	0.01	406.0	23.5
16-SWCS-T4-7 2d	10.70	4.00	0.01	254.0	23.5
16-SWCS-T4-7 7d	11.70	6.93	0.01	562.0	23.5
16-SWCS-T4-7 14d	11.90	5.71	0.01	367.0	23.5
16-SWCS-T4-7 28d	12.00	6.04	0.01	469.0	23.5
16-SWCS-T4-7 42d	11.80	4.59	0.01	319.0	23.5
16-SWCS-T4-7 49d	11.20	3.53	0.01	95.0	23.5
16-SWCS-T4-7 63d	11.60	3.83	0.01	211.0	23.5
16-SWCS-T4-7 100d	11.80	4.14	0.01	315.0	23.5
16-SWCS-T4-8 0.08d	10.40	3.11	0.01	85.1	23.5
16-SWCS-T4-8 1d	11.20	4.51	0.01	451.0	23.5
16-SWCS-T4-8 2d	10.60	3.91	0.01	239.0	23.5
16-SWCS-T4-8 7d	11.80	6.74	0.01	689.0	23.5
16-SWCS-T4-8 14d	11.80	4.70	0.01	307.0	23.5
16-SWCS-T4-8 28d	12.00	5.16	0.01	476.0	23.5
16-SWCS-T4-8 42d	11.80	4.31	0.01	327.0	23.5
16-SWCS-T4-8 49d	11.20	3.47	0.01	98.7	23.5
16-SWCS-T4-8 63d	11.60	3.82	0.01	207.0	23.5
16-SWCS-T4-8 100d	11.80	4.13	0.01	299.0	23.5
16-SWCS-T6-5 0.08d	11.60	1.21	0.01	252.0	23.5
16-SWCS-T6-5 1d	12.10	3.93	0.01	1010.0	23.5
16-SWCS-T6-5 2d	11.80	3.00	0.01	602.0	23.5

Sample ID	pH	Electrical Conductivity (mS/cm)	EQL (mS/cm)	Alkalinity (µg/mL)	EQL (µg/mL)
16-SWCS-T6-5 7d	12.30	6.51	0.01	1420.0	23.5
16-SWCS-T6-5 14d	12.20	5.63	0.01	1020.0	23.5
16-SWCS-T6-5 28d	12.30	5.78	0.01	972.0	23.5
16-SWCS-T6-5 42d	12.20	4.65	0.01	694.0	23.5
16-SWCS-T6-5 49d	12.00	2.98	0.01	415.0	23.5
16-SWCS-T6-5 63d	12.30	3.98	0.01	612.0	23.5
16-SWCS-T6-5 100d	12.30	4.86	0.01	876.0	23.5
16-SWCS-T6-6 0.08d	11.60	1.29	0.01	227.0	23.5
16-SWCS-T6-6 1d	12.20	6.06	0.01	1010.0	23.5
16-SWCS-T6-6 2d	12.00	4.28	0.01	478.0	23.5
16-SWCS-T6-6 7d	12.30	6.40	0.01	1070.0	23.5
16-SWCS-T6-6 14d	12.20	5.07	0.01	913.0	23.5
16-SWCS-T6-6 28d	12.40	5.63	0.01	955.0	23.5
16-SWCS-T6-6 42d	12.20	4.65	0.01	757.0	23.5
16-SWCS-T6-6 49d	12.10	2.87	0.01	408.0	23.5
16-SWCS-T6-6 63d	12.20	3.35	0.01	532.0	23.5
16-SWCS-T6-6 100d	12.30	4.10	0.01	849.0	23.5
16-SWCS-T6-7 0.08d	10.50	3.29	0.01	131.0	23.5
16-SWCS-T6-7 1d	11.50	4.68	0.01	581.0	23.5
16-SWCS-T6-7 2d	10.70	3.71	0.01	351.0	23.5
16-SWCS-T6-7 7d	12.00	6.49	0.01	1230.0	23.5
16-SWCS-T6-7 14d	12.00	6.13	0.01	917.0	23.5
16-SWCS-T6-7 28d	12.20	7.38	0.01	968.0	23.5
16-SWCS-T6-7 42d	12.00	5.91	0.01	574.0	23.5
16-SWCS-T6-7 49d	11.60	4.01	0.01	204.0	23.5
16-SWCS-T6-7 63d	11.90	4.65	0.01	416.0	23.5
16-SWCS-T6-7 100d	12.10	5.70	0.01	738.0	23.5
16-SWCS-T6-8 0.08d	10.40	3.18	0.01	110.0	23.5
16-SWCS-T6-8 1d	11.20	4.21	0.01	582.0	23.5
16-SWCS-T6-8 2d	10.70	3.75	0.01	385.0	23.5
16-SWCS-T6-8 7d	12.00	6.36	0.01	1380.0	23.5
16-SWCS-T6-8 14d	12.00	5.97	0.01	914.0	23.5
16-SWCS-T6-8 28d	12.20	6.90	0.01	1160.0	23.5
16-SWCS-T6-8 42d	12.00	5.84	0.01	705.0	23.5
16-SWCS-T6-8 49d	11.40	3.76	0.01	171.0	23.5
16-SWCS-T6-8 63d	11.70	4.29	0.01	331.0	23.5
16-SWCS-T6-8 100d	12.10	5.48	0.01	691.0	23.5

A.4 Additional Results of pH and Oxidation/Reduction Potential Measurements from ^{99}Tc Solubility Tests

Label format for ^{99}Tc solubility test: SOL-T1/7(for test batch number)-S1/2/3(for triplicate samples and C1/2/3 for triplicate controls without cementitious solids)-Tc-2/20/200(for initial Tc concentration of 2, 20, or 200 ppb)-D30/60/120/150(for different reaction times)

Table A.7. Results of pH and E_h from ^{99}Tc Solubility Tests for ^{99}Tc -Spiked Monolith T1

Sample ID	pH	E_h (mV)	Sample ID	pH	E_h (mV)
SOL-T1-S1-Tc-2-D-30	12.5	-525	SOL-T1-S1-Tc-2-D-120	12.5	-506
SOL-T1-S2-Tc-2-D-30	12.6	-514	SOL-T1-S2-Tc-2-D-120	12.5	-507
SOL-T1-S3-Tc-2-D-30	12.6	-556	SOL-T1-S3-Tc-2-D-120	12.5	-505
SOL-T1-C1-Tc-2-D-30	12.5	-493	SOL-T1-C1-Tc-2-D-120	12.5	-396
SOL-T1-C2-Tc-2-D-30	12.6	-475	SOL-T1-C2-Tc-2-D-120	12.4	-428
SOL-T1-C3-Tc-2-D-30	12.6	-486	SOL-T1-C3-Tc-2-D-120	12.4	-433
SOL-T1-S1-Tc-20-D-30	12.6	-572	SOL-T1-S1-Tc-20-D-120	12.4	-497
SOL-T1-S2-Tc-20-D-30	12.6	-552	SOL-T1-S2-Tc-20-D-120	12.5	-498
SOL-T1-S3-Tc-20-D-30	12.6	-538	SOL-T1-S3-Tc-20-D-120	12.5	-508
SOL-T1-C1-Tc-20-D-30	12.6	-459	SOL-T1-C1-Tc-20-D-120	12.5	-415
SOL-T1-C2-Tc-20-D-30	12.5	-539	SOL-T1-C2-Tc-20-D-120	12.4	-397
SOL-T1-C3-Tc-20-D-30	12.5	-506	SOL-T1-C3-Tc-20-D-120	12.4	-413
SOL-T1-S1-Tc-200-D-30	12.6	-568	SOL-T1-S1-Tc-200-D-120	12.4	-510
SOL-T1-S2-Tc-200-D-30	12.7	-561	SOL-T1-S2-Tc-200-D-120	12.5	-499
SOL-T1-S3-Tc-200-D-30	12.6	-556	SOL-T1-S3-Tc-200-D-120	12.5	-495
SOL-T1-C1-Tc-200-D-30	12.5	-510	SOL-T1-C1-Tc-200-D-120	12.4	-375
SOL-T1-C2-Tc-200-D-30	12.6	-506	SOL-T1-C2-Tc-200-D-120	12.4	-380
SOL-T1-C3-Tc-200-D-30	12.6	-494	SOL-T1-C3-Tc-200-D-120	12.4	-380
SOL-T1-S1-Tc-2-D-60	12.5	-552	SOL-T1-S1-Tc-2-D-150	12.6	-473
SOL-T1-S2-Tc-2-D-60	12.5	-516.5	SOL-T1-S2-Tc-2-D-150	12.6	-474
SOL-T1-S3-Tc-2-D-60	12.5	-513.8	SOL-T1-S3-Tc-2-D-150	12.5	-476
SOL-T1-C1-Tc-2-D-60	12.5	-494.1	SOL-T1-C1-Tc-2-D-150	12.5	-42
SOL-T1-C2-Tc-2-D-60	12.5	-536	SOL-T1-C2-Tc-2-D-150	12.5	-49
SOL-T1-C3-Tc-2-D-60	12.5	-570	SOL-T1-C3-Tc-2-D-150	12.5	-46
SOL-T1-S1-Tc-20-D-60	12.5	-591	SOL-T1-S1-Tc-20-D-150	12.5	-485
SOL-T1-S2-Tc-20-D-60	12.5	-580	SOL-T1-S2-Tc-20-D-150	12.5	-477
SOL-T1-S3-Tc-20-D-60	12.5	-591	SOL-T1-S3-Tc-20-D-150	12.6	-478
SOL-T1-C1-Tc-20-D-60	12.5	-407	SOL-T1-C1-Tc-20-D-150	12.5	-43
SOL-T1-C2-Tc-20-D-60	12.4	-515	SOL-T1-C2-Tc-20-D-150	12.5	-40
SOL-T1-C3-Tc-20-D-60	12.4	-531	SOL-T1-C3-Tc-20-D-150	12.5	-30
SOL-T1-S1-Tc-200-D-60	12.5	-568	SOL-T1-S1-Tc-200-D-150	12.5	-476

Sample ID	pH	E_h (mV)	Sample ID	pH	E_h (mV)
SOL-T1-S2-Tc-200-D-60	12.5	−558	SOL-T1-S2-Tc-200-D-150	12.6	−479
SOL-T1-S3-Tc-200-D-60	12.5	−562	SOL-T1-S3-Tc-200-D-150	12.5	−476
SOL-T1-C1-Tc-200-D-60	12.5	−494	SOL-T1-C1-Tc-200-D-150	12.5	−38
SOL-T1-C2-Tc-200-D-60	12.5	−495	SOL-T1-C2-Tc-200-D-150	12.5	−32
SOL-T1-C3-Tc-200-D-60	12.5	−497	SOL-T1-C3-Tc-200-D-150	12.5	−28

Table A.8. Results of pH and E_h from ^{99}Tc Solubility Tests for Non- ^{99}Tc -Spiked Monolith T7

Sample ID	pH	E_h (mV)	Sample ID	pH	E_h (mV)
SOL-T7-S1-Tc-2-D-30	12.6	-288	SOL-T7-S1-Tc-2-D-120	12.1	-498
SOL-T7-S2-Tc-2-D-30	12.6	-464	SOL-T7-S2-Tc-2-D-120	11.9	-508
SOL-T7-S3-Tc-2-D-30	12.6	-478	SOL-T7-S3-Tc-2-D-120	11.9	-509
SOL-T7-C1-Tc-2-D-30	12.6	-244	SOL-T7-C1-Tc-2-D-120	11.9	-460
SOL-T7-C2-Tc-2-D-30	12.6	-355	SOL-T7-C2-Tc-2-D-120	12	-487
SOL-T7-C3-Tc-2-D-30	12.6	-482	SOL-T7-C3-Tc-2-D-120	11.9	-529
SOL-T7-S1-Tc-20-D-30	12.6	-562	SOL-T7-S1-Tc-20-D-120	11.9	-544
SOL-T7-S2-Tc-20-D-30	12.6	-556	SOL-T7-S2-Tc-20-D-120	11.9	-552
SOL-T7-S3-Tc-20-D-30	12.7	-586	SOL-T7-S3-Tc-20-D-120	11.9	-547
SOL-T7-C1-Tc-20-D-30	12.6	-522	SOL-T7-C1-Tc-20-D-120	11.9	-390
SOL-T7-C2-Tc-20-D-30	12.5	-488	SOL-T7-C2-Tc-20-D-120	12.4	-426
SOL-T7-C3-Tc-20-D-30	12.6	-517	SOL-T7-C3-Tc-20-D-120	12.5	-435
SOL-T7-S1-Tc-200-D-30	12.5	-554	SOL-T7-S1-Tc-200-D-120	12.5	-511
SOL-T7-S2-Tc-200-D-30	12.5	-550	SOL-T7-S2-Tc-200-D-120	12.5	-525
SOL-T7-S3-Tc-200-D-30	12.6	-576	SOL-T7-S3-Tc-200-D-120	12.5	-532
SOL-T7-C1-Tc-200-D-30	12.6	-531	SOL-T7-C1-Tc-200-D-120	12.4	-382
SOL-T7-C2-Tc-200-D-30	12.6	-538	SOL-T7-C2-Tc-200-D-120	12.4	-413
SOL-T7-C3-Tc-200-D-30	12.6	-513	SOL-T7-C3-Tc-200-D-120	12.5	-389
SOL-T7-S1-Tc-2-D-60	12.5	-654	SOL-T7-S1-Tc-2-D-150	12.4	-465
SOL-T7-S2-Tc-2-D-60	12.5	-652	SOL-T7-S2-Tc-2-D-150	12.5	-472
SOL-T7-S3-Tc-2-D-60	12.5	-638	SOL-T7-S3-Tc-2-D-150	12.5	-483
SOL-T7-C1-Tc-2-D-60	12.5	-593	SOL-T7-C1-Tc-2-D-150	12.4	-32
SOL-T7-C2-Tc-2-D-60	12.4	-502	SOL-T7-C2-Tc-2-D-150	12.4	-17
SOL-T7-C3-Tc-2-D-60	12.5	-493	SOL-T7-C3-Tc-2-D-150	12.4	-32
SOL-T7-S1-Tc-20-D-60	12.6	-560	SOL-T7-S1-Tc-20-D-150	12.4	-477
SOL-T7-S2-Tc-20-D-60	12.6	-572	SOL-T7-S2-Tc-20-D-150	12.4	-486
SOL-T7-S3-Tc-20-D-60	12.5	-574	SOL-T7-S3-Tc-20-D-150	12.4	-475
SOL-T7-C1-Tc-20-D-60	12.7	-466	SOL-T7-C1-Tc-20-D-150	12.4	-23
SOL-T7-C2-Tc-20-D-60	12.4	-534	SOL-T7-C2-Tc-20-D-150	12.5	-39
SOL-T7-C3-Tc-20-D-60	12.5	-526	SOL-T7-C3-Tc-20-D-150	12.5	-34
SOL-T7-S1-Tc-200-D-60	12.5	-562	SOL-T7-S1-Tc-200-D-150	12.5	-475
SOL-T7-S2-Tc-200-D-60	12.5	-566	SOL-T7-S2-Tc-200-D-150	12.5	-480
SOL-T7-S3-Tc-200-D-60	12.5	-566	SOL-T7-S3-Tc-200-D-150	12.5	-486
SOL-T7-C1-Tc-200-D-60	12.5	-500	SOL-T7-C1-Tc-200-D-150	12.5	-26
SOL-T7-C2-Tc-200-D-60	12.5	-494	SOL-T7-C2-Tc-200-D-150	12.5	-31
SOL-T7-C3-Tc-200-D-60	12.5	-478	SOL-T7-C3-Tc-200-D-150	12.5	-25

A.5 Update on Extended EPA Method 1315 Leaching Test for Fiscal Year (FY) 2015 Cementitious Monoliths and Additional Solid Characterization after ~406 Days Leaching.

This section provides analysis of monolith samples prepared in FY 2015 (Um et al. 2016) that had their leach testing using EPA Method 1315 extended to 406 days. Two monoliths from each test batch (T1 through T18) reported by Um et al. (2016) (one each in DIW and vadose zone pore water [VZPW] leachant) were extended. Using the leachate collected after 406 days, effective diffusivities for ^{99}Tc , NO_3^- , and Na^+ were calculated and are presented in this section. Diffusivities for the duplicate monolith in each test, stopped after 140 days of leaching, can be found in Um et al. (2016). Post-leaching solid characterization of the extended-leached monoliths was also performed to determine the distribution of ^{99}Tc (digital autoradiography) and mineralogical composition relative to the solid:solution interface (x-ray diffraction, XRD). More details for these methods are provided in Section 2.0.

A.5.1 Extended 406-Day EPA 1315 Leach Testing ^{99}Tc , NO_3^- , Na^+ Diffusivities

In a previous report (Um et al. 2016), screening tests were performed on 18 batches of hydrated lime (HL)-based and Cast Stone cementitious waste forms in EPA Method 1315 leach testing. Diffusivity values for ^{99}Tc , NO_3^- and Na^+ were reported for leach intervals up to 140 days. Two monoliths from each of these batches had their leach testing extended, one each in DIW and VZPW, to a total of 406 days. Table A.9 shows the calculated diffusivities, D_{eff} , from the full leach period for ^{99}Tc , NO_3^- and Na^+ , highlighting the new data from the 406 day sampling. (Because of their length, Table A.9 through Table A.13 are located after the text in this subsection).

In DIW, the diffusivities for all three species remain mainly within the range of diffusivities measured previously between the 28-day and 140-day intervals. The general trend saw minimal decreases in diffusivity at the 406-day sampling compared to the 140-day interval (by a factor no larger than ~0.8). The lone species to increase in diffusivity over the extended leach interval was the Tc D_{eff} or D_{obs} for the T11-2 sample (leachability index [LI] from 13.2 after 140 days to 13.0 after 406 days). These measurements follow the trend of continual decreasing or steadying of the diffusivity beyond 1 day cumulative leaching for these samples.

The diffusivity values for ^{99}Tc , NO_3^- , and Na^+ from extended leach testing in VZPW are shown in Table A.10. In general, the majority of the sample diffusivities for all three species ranged within the diffusivities previously measured between 28 days and 140 days. However, several exceptions were observed for ^{99}Tc diffusivity. The largest deviation in ^{99}Tc diffusivity was for sample T5-4, which increased to $1.16 \times 10^{-11} \text{ cm}^2/\text{s}$. This diffusivity is larger than the 140-day sampling value (9.96×10^{-14}) and within the range of diffusivities measured before 7-days leaching. For the 406-day T5-4 sampling, the lowest NO_3^- diffusivity ($1.46 \times 10^{-11} \text{ cm}^2/\text{s}$) and Na^+ diffusivity ($1.29 \times 10^{-9} \text{ cm}^2/\text{s}$) resulted compared to the other sampling intervals. An increase in ^{99}Tc diffusivity was also observed for the T7-4 sample, increasing to $2.53 \times 10^{-13} \text{ cm}^2/\text{s}$ at 406 days compared with $3.74 \times 10^{-14} \text{ cm}^2/\text{s}$ at 140 days. This diffusivity at 406 days was the largest diffusivity measured beyond the 28 day interval. As with the T5-4, the T7-4 also had minimum diffusivities for both NO_3^- ($1.63 \times 10^{-11} \text{ cm}^2/\text{s}$) and Na^+ ($7.41 \times 10^{-10} \text{ cm}^2/\text{s}$) for the 406-day interval. Both T5-4 and T7-4 were fabricated using a 25:35:45 wt% ratio of HL: ordinary Portland cement (OPC): blast furnace slag (BFS) with the Environmental Restoration Disposal Facility (ERDF) simulant. T7-4 has a duplicate sample in the long-term leaching set, T2-4. T2-4 also had lower NO_3^- and Na^+ diffusivities, but the ^{99}Tc diffusivity at 406 days ($6.54 \times 10^{-14} \text{ cm}^2/\text{s}$) stayed within the range of ^{99}Tc diffusivity measured past the 28-day interval. Two additional samples also had higher ^{99}Tc diffusivity at 406 days, T8-4 ($5.13 \times 10^{-14} \text{ cm}^2/\text{s}$, largest diffusivity past 42 days) and T16-4 ($8.67 \times 10^{-14} \text{ cm}^2/\text{s}$, largest diffusivity past 28 d). T8 and T16 were fabricated using the Hanford Tank Waste Treatment

and Immobilization Plant (WTP) off-gas simulant and a 25:35:45 HL:OPC:BFS ratio. Significant changes in NO_3^- and Na^+ were not observed for T8-4 and T16-4.

From analysis of the diffusivity values, it is unclear why the differences in diffusivity for some samples occurred at longer leaching times. The decrease in NO_3^- and Na^+ diffusivities may be an artifact of their depleted inventories in the monoliths at the extended leach periods (Serne et al. 2016). However, it is harder to hypothesize regarding the ^{99}Tc diffusivity. Information gained from physical characterization of the extended-leached samples can be used to further understand the leaching behavior and understand waste form evolution. Such a venture previously showed significant structural and chemical evolution in long-term (>3 year) leached low-activity waste (LAW) Cast Stone samples (Asmussen et al. 2016b).

The release of ^{99}Tc did not follow a pure diffusion trend, as was found in previous study (Um et al. 2016), showing a low slope beyond the acceptable limit for the EPA 1315 method (a slope of 0.5 ± 0.15). Therefore, the calculated diffusivity values for ^{99}Tc of the extended 406-day tests in Table A.9 and Table A.10 should be used with care, and are provided only for comparison with previous results. In addition, the cumulative releases of ^{99}Tc , NO_3^- , and Na^+ as a function leaching time are also provided for qualitative understanding of release in Table A.9 and Table A.10.

A.5.2 Evolution of the Monolith Exterior

Following the final leaching interval at 406 d, the monoliths were removed from the leaching buckets and visually inspected. The leached monoliths displayed differing features based on whether they were leached in DIW and VZPW. Photographs of select monoliths following the 406-day leaching are shown in Figure A.1 below. The T3 monoliths showed little exterior difference between the DIW-leached sample, Figure A.1a, and the VZPW sample, Figure A.1b. The outer film present on the monoliths differs between the two leaching environments: the VZPW film is a calcium carbonate polymorph (Serne et al. 2016) and the film in DIW was collected and characterized with XRD which is described in a subsequent section of this report (see Section A.5.4). No cracking was observed on the exterior of the T3 monoliths.

The T5 batch, which had a large increase in ^{99}Tc diffusivity in VZPW after 406 days leaching, displays drastic changes between the DIW- and VZPW-leached monoliths. Few exterior features exist on the outer surface of the DIW sample, Figure A.1c, whereas a large number of vertical cracks appear on the VZPW-leached sample, Figure A.1d. It is likely that this cracking and exposure of the interior to solution played a role in the increased ^{99}Tc diffusivity observed for this sample. The cracks are likely the result of the late-stage growth of ettringite in the monolith, a higher amount of ettringite being present in the VZPW-leached monolith compared with the DIW leached monolith, Table A.11.

The T13 batch, fabricated using the WTP simulant and the standard Cast Stone recipe, displayed no cracking in DIW, Figure A.1e, or in VZPW, Figure A.1f. Less ettringite formation occurs with the Cast Stone OPC:FA:BFS formulation. The film on the outer surface of the T13-4 VZPW sample is more complete compared with the HL formulations.

The presence of the Sn(II)-apatite getter in the T15 batch produced a spotted exterior on the monolith following 406-day leaching in DIW, Figure A.1g. In VZPW, Figure A.1h, the T15-4 monolith displayed horizontal cracks at the top of the monolith, and round deposits on the wall.

Figure A.1. Photographs of Select Monoliths Following the 406-day Extended Leaching. Both the DIW- and VZPW-Leached Samples are displayed.

A.5.3 iQID Radiography of ^{99}Tc Distribution

Determining the distribution of ^{99}Tc within the monolith samples following leaching can assist in understanding the leaching trends. Previous work has shown ^{99}Tc to be evenly distributed throughout the monolith samples in unleached LAW Cast Stone (Asmussen et al. 2016a). Following leach testing, this distribution of ^{99}Tc can change with both a congregation at the outer monolith wall and an appearance of discrete “hot spots” of ^{99}Tc appearing after long-term leaching (>3 year) of LAW Cast Stone (Asmussen et al. 2016b). In systems containing ^{99}Tc getters, the ^{99}Tc is present in “hot spots” associated with the getter following 63day leaching.

iQID imaging was performed to observe ^{99}Tc distribution within the leached monoliths. The archived monoliths -were all fabricated using the WTP simulant with varying dry-blend compositions. Figure A.2

shows iQID radiography images of monolith cross sections of the T3 samples after 406 d leaching in (a) DIW (T3-2) and (b) VZPW (T3-4). In both monoliths, the strongest signal, corresponding to a higher amount of ^{99}Tc , is from the outer edge of the monolith. It should be noted that the ring of ^{99}Tc is not an even circle, as best shown by T3-4, although the outer curved surfaces of the monolith cross sections were smooth.

Figure A.2. Radiography Images Produced by the iQID System of Cross Sections of the (a) T3-2 (DIW) and (b) T3-4 (VZPW) Samples Following 406 d Leach Testing. The duration of collection was 60 h. The scale bar represents the number of β -decays detected at a particular pixel.

iQID radiography images of T6 monoliths, made with a similar recipe to T3 but with a higher water-to-dry-mix ratio (0.6 for T6 vs. 0.5 for T3) can be seen in Figure A.3. A vertical (longitudinal) section was excised from the T6-2 monolith after being leached for 406 days in DIW; the radiography image is shown in Figure A.3a. Similar to the T3 samples, the strongest signal arises from the outer edge of the T6-2 vertical section. An outer ring of Tc was again observed on T6-4, leached 406 d in VZPW; its horizontal cross section is shown in Figure A.3b.

Figure A.3. Radiography Images Produced by the iQID System of (a) Vertical Section of T6-2 (DIW) and (b) Horizontal Cross Section of T6-4 (VZPW) Samples Following 406 d Leach Testing. The duration of collection was 60 h. The scale bar represents the number of β -decays detected at a particular pixel.

Two additional monoliths also displayed Tc congregation in an outer ring, as shown in Figure A.4. The T10-2 monolith, fabricated with a 20:10:70 HL:OPC:BFS dry mix ratio and leached in DIW for 406 days, shows an outer ring of Tc in Figure A.4a. Thus, having a higher reducing capacity, supplied by the higher amount of BFS in T10, does not limit the growth of an outer annular Tc distribution. Changing the formulation used also led to collection of Tc near the outer edge of the monoliths, as shown for the T11-2 monolith in Figure A.4b. The T11 samples were fabricated using a 20:35:45 OPC:FA:BFS mixture. The ^{99}Tc signal arises from the outer edge, although not in a complete ring as for the other monoliths that were imaged. It should be noted that the T11-2 cross section was circular in shape, although the ^{99}Tc signal does not arise from all regions of the outer edge. It may be possible that the lack of HL in the T11 mix leads to inconsistent distribution of ^{99}Tc .

The addition of ^{99}Tc getters, specifically Sn(II)-treated apatite (Sn-A), to the HL:OPC:BFS mixture alters the distribution of ^{99}Tc . The iQID radiography image of a cross section of T15-4, leached for 406 days in VZPW, shows the ^{99}Tc to be present in discrete spots throughout the sample, as shown in Figure A.5. From previous analysis of LAW Cast Stone monolith cross sections containing Sn-A, the chemical makeup at the “hot spots” results from the ^{99}Tc being present with a modified Sn-A (Asmussen et al. 2016a). A similar chemistry can be expected at the “hot spots” observed in the T15-4 sample.

Figure A.4. Radiography Images Produced by the iQID System of Horizontal Cross Sections of (a) T10-2 (DIW) and (b) T11-2 (DIW) Samples Following 406-day Leach Testing. The duration of collection was 60 h. The scale bar represents the number of β -decays detected at a particular pixel.

Figure A.5. Radiography Image Produced by the iQID System of Horizontal Cross Section of T15-4 (VZPW) Following 406-day Leach Testing. The T15 monolith included Sn(II)-treated apatite as a ^{99}Tc getter. The duration of collection was 60 h. The scale bar represents the number of β -decays detected at a particular pixel.

A.5.4 X-Ray Diffraction

At the conclusion of 406 days of leaching, samples were collected from each monolith, from no specific region of the monoliths, and analyzed with XRD to determine the mineral composition. The resulting mineral compositions from XRD are shown in Table A.11. The XRD spectra for all samples leached in DIW are shown in Figure A.6 and XRD spectra for those leached in VZPW are shown in Figure A.7. All the samples are primarily amorphous and all contained ettringite ($\text{Ca}_6\text{Al}_2(\text{SO}_4)_3(\text{OH})_{12}\cdot 26\text{H}_2\text{O}$), calcite (CaCO_3), and larnite (Ca_2SiO_4). The HL-based monoliths all contained portlandite ($\text{Ca}(\text{OH})_2$) except T2-4 and T5-4. The samples containing brucite ($\text{Mg}(\text{OH})_2$) were all leached in VZPW. Vaterite (CaCO_3) was only present in samples fabricated with the ERDF leachate simulant. In all cases, except T11 and T13, which were fabricated with FA instead of HL, the monoliths leached in VZPW contained significantly

more ettringite than their DIW-leached counter parts. The DIW-leached monoliths contain a higher amount of portlandite than the VZPW-leached monoliths. The additional ettringite formation in the VZPW-leached monoliths results from transformation of the portlandite as SO_4^{2-} from the VZPW leachant migrates into the monolith.

Figure A.6. XRD Patterns of the 18 Extended-Leached Samples in DIW. Numbers to the right of each spectrum are the test number of the monolith.

Figure A.7. XRD Patterns of the 18 Extended-Leached Samples in VZPW. Numbers to the right of each spectrum are the test number of the monolith.

A complete evolution of select monoliths can be derived using the XRD analysis of the initial 28-day cured monoliths and both 140-day and 406-day leached monoliths. A comparison of the T3, T6, T11, T12, and T13 mineral makeup is presented in Table A.12. The amount of ettringite in the leached monoliths is higher than that in the cured, unleached samples for the T3 and T6 sets fabricated with the HL present. The VZPW-leached monoliths of both of these sets (samples 3 and 4) have increased ettringite content compared with those leached in DIW, and the amount of ettringite increased between

the 140-day (20% for T3 and 25% for T6) and 406-day (23% for T3 and 27% for T6) leached monoliths. The other two samples fabricated with the WTP simulant and no HL, i.e., T11 and T13, had equal or lower ettringite levels at the 406-day sampling compared with the 140-day sampling. For the T12 monolith, fabricated with ERDF leachate simulant and the standard Cast Stone blend (8:45:47 OPC:FA:BFS), no ettringite growth was observed during leaching in DIW, but ettringite did occur in VZPW-leached sample.

The XRD samples described above were collected from a mixed powder made from random pieces from the entire monolith. More than likely, the leachant is influencing the mineralogical makeup of the monoliths, thus it is plausible that different mineral compositions are possible as a function of distance from the monolith:leachant interface. Pieces of the 406-day leached monoliths were thus excised from within 5 mm of the outer surface of the monolith (“OUT” samples) and from material between 20 and 30 mm from the outer surface (“IN” samples). The resulting XRD measurements from these two regions are presented in Table A.13. The T3-2 sample has more ettringite at the outer wall (14%) compared with the inner core (11%). Expectedly, the amount of portlandite decreased at the outer surface (5.8%) compared to the inner core (8.6%). This increased ettringite at the outer wall may, in fact, be related to the Tc distribution observed in the iQID imaging in Figure A.2a. A similar observation was made for the T3-4 sample leached in VZPW, where a larger amount of ettringite was observed again in the outer region of the sample (15%) compared with the inner core (13%). There was also less portlandite on the outer wall (2.4%) compared with the inner core (7.3%) for the T3-4 monolith. Brucite is also observed on the outer wall of the T3-4 monolith likely from contact with the VZPW, which contains high concentrations of magnesium while the pore water itself supplies the hydroxyl ions at the surface.

Batch testing has shown ettringite to be capable of incorporating ^{99}Tc under reducing conditions (Um et al. 2017). With ^{99}Tc observed to be congregating near the outer edge of the monolith and increased ettringite measured in the outer region of the monolith, it is plausible that the ^{99}Tc is being incorporated into the near-surface ettringite. The case may not be the same with the T11-2 monolith, where the ^{99}Tc was observed at the outer edge of the monolith, but not in a full ring. The XRD spectrum for T11-2 shows a nearly identical mineralogical makeup in the inner and outer portions of the monolith.

Both the T3 and T11 samples leached in DIW displayed an outer film on the monolith surface. This film is surprising, deposits (CaCO_3 and $\text{Mg}(\text{OH})_2$ polymorphs) and have only previously been observed on Cast Stone monoliths leached in VZPW (Serne et al. 2016). This outer deposit was collected from the T3-2 sample and characterized with XRD (DIW Deposit in Table A.13). The film has a crystalline portion comprising calcite (17%) and ettringite (4%). The calcite growth is likely caused by ingress of CO_2 into the DIW, while the ettringite presence on the outermost surface suggests a formation initiating at the monolith:solution interface.

Table A.9. Diffusivity and LI Values of ^{99}Tc , NO_3^- and Na^+ in DIW. Values highlighted in yellow represent new data from the extended leaching period beyond previously reported leaching (Um et al. 2016).

T1-2 for ^{99}Tc				T1-2 for NO_3^-			T1-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)
0.08	1.02E-12	12.0	0.00975	-	-	-	5.18E-09	8.3	0.695
1.0	6.25E-12	11.2	0.0692	-	-	-	8.84E-09	8.1	2.93
2.0	4.71E-12	11.3	0.0993	-	-	-	3.76E-09	8.4	3.78
7.0	5.03E-12	11.3	0.192	-	-	-	3.29E-09	8.5	6.15
14.0	6.78E-13	12.2	0.222	-	-	-	2.52E-09	8.6	7.99
28.0	1.61E-15	14.8	0.224	-	-	-	1.09E-09	9.0	9.70
42.0	2.10E-15	14.7	0.226	-	-	-	6.95E-10	9.2	10.7
49.0	1.10E-14	14.0	0.228	-	-	-	7.13E-10	9.1	11.2
63.0	3.39E-15	14.5	0.229	-	-	-	6.71E-10	9.2	12.0
90.0	1.56E-15	14.8	0.232	-	-	-	4.66E-10	9.3	13.1
140.0	8.03E-16	15.1	0.234	-	-	-	3.75E-10	9.4	14.7
406.0	1.25E-16	15.9	0.237	-	-	-	1.84E-10	9.7	18.4
Average (from 28 d)	2.95E-15	14.8		-	-		5.99E-10	9.3	
“-” indicates “not measured”				¹ Cumulative release					

T2-2 for ^{99}Tc				T2-2 for NO_3^-			T2-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)
0.08	3.95E-10	9.4	0.191	6.08E-10	9.2	0.237	1.14E-08	7.9	1.03
1.0	8.86E-11	10.1	0.414	1.62E-10	9.8	0.538	2.33E-09	8.6	2.17
2.0	1.06E-10	10.0	0.555	2.54E-10	9.6	0.757	3.14E-09	8.5	2.94
7.0	1.31E-10	9.9	1.02	2.34E-10	9.6	1.38	3.40E-09	8.5	5.33
14.0	2.88E-11	10.5	1.22	2.75E-10	9.6	1.99	2.82E-09	8.5	7.27
28.0	1.72E-13	12.8	1.24	1.64E-10	9.8	2.65	1.68E-09	8.8	9.38
42.0	1.57E-13	12.8	1.26	1.08E-10	10.0	3.06	1.19E-09	8.9	10.7
49.0	1.84E-13	12.7	1.26	1.49E-10	9.8	3.27	1.08E-09	9.0	11.3
63.0	2.28E-13	12.6	1.28	9.08E-11	10.0	3.57	1.27E-09	8.9	12.4
90.0	2.68E-13	12.6	1.31	7.93E-11	10.1	4.03	9.20E-10	9.0	14.0
140.0	9.13E-14	13.0	1.33	5.18E-11	10.3	4.59	6.79E-10	9.2	16.0
406.0	2.02E-14	13.7	1.37	2.52E-11	10.6	5.98	3.77E-10	9.4	21.4
Average (from 28 d)	1.60E-13	12.9		9.55E-11	10.1		1.03E-09	9.0	

	T3-2 for ^{99}Tc			T3-2 for NO_3^-			T3-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	8.93E-11	10.0	0.0915	2.65E-09	8.6	0.499	3.45E-08	7.5	1.80
1.0	5.75E-11	10.2	0.272	1.20E-09	8.9	1.33	1.23E-08	7.9	4.44
2.0	5.52E-11	10.3	0.376	8.46E-10	9.1	1.73	1.19E-08	7.9	5.96
7.0	3.68E-11	10.4	0.626	1.21E-09	8.9	3.17	1.01E-08	8.0	10.1
14.0	2.02E-12	11.7	0.678	1.36E-09	8.9	4.53	9.24E-09	8.0	13.6
28.0	3.43E-14	13.5	0.688	7.76E-10	9.1	5.98	4.90E-09	8.3	17.3
42.0	1.55E-14	13.8	0.693	4.77E-10	9.3	6.85	3.44E-09	8.5	19.6
49.0	9.38E-15	14.0	0.695	4.78E-10	9.3	7.23	2.73E-09	8.6	20.5
63.0	1.31E-14	13.9	0.698	3.68E-10	9.4	7.83	3.08E-09	8.5	22.3
90.0	6.25E-15	14.2	0.702	2.65E-10	9.6	8.68	1.75E-09	8.8	24.4
140.0	1.33E-14	13.9	0.712	1.88E-10	9.7	9.76	1.31E-09	8.9	27.3
406.0	2.56E-15	14.6	0.726	1.08E-10	10.0	12.7	7.02E-10	9.2	34.7
Average (from 28 d)	1.35E-14	14.0		3.80E-10	9.5		2.56E-09	8.7	

	T4-2 for ^{99}Tc			T4-2 for NO_3^-			T4-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.53E-10	9.8	0.119	-	-		9.26E-09	8.0	0.926
1.0	3.01E-10	9.5	0.531	-	-		5.76E-09	8.2	2.73
2.0	3.44E-10	9.5	0.787	-	-		6.28E-09	8.2	3.82
7.0	4.70E-10	9.3	1.68	-	-		5.94E-09	8.2	6.99
14.0	2.97E-10	9.5	2.31	-	-		4.68E-09	8.3	9.49
28.0	2.30E-12	11.6	2.39	-	-		1.98E-09	8.7	11.8
42.0	8.90E-15	14.1	2.39	-	-		9.02E-10	9.0	13.0
49.0	1.17E-14	13.9	2.39	-	-		8.00E-10	9.1	13.5
63.0	2.69E-14	13.6	2.40	-	-		8.04E-10	9.1	14.4
90.0	1.72E-14	13.8	2.40	-	-		4.47E-10	9.3	15.4
140.0	1.53E-14	13.8	2.41	-	-		3.29E-10	9.5	16.9
406.0	4.65E-15	14.3	2.43	-	-		1.99E-10	9.7	20.8
Average (from 28 d)	3.41E-13	13.6		-	-		7.80E-10	9.2	
“-” indicates “not measured”				¹ Cumulative release					

	T5-2 for ^{99}Tc			T5-2 for NO_3^-			T5-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	7.67E-12	11.1	0.0268	1.11E-10	10.0	0.102	4.39E-09	8.4	0.642
1.0	2.37E-11	10.6	0.143	2.54E-10	9.6	0.483	4.73E-09	8.3	2.28
2.0	2.41E-11	10.6	0.211	3.12E-10	9.5	0.728	4.45E-09	8.4	3.21
7.0	3.22E-11	10.5	0.446	2.89E-10	9.5	1.43	5.32E-09	8.3	6.22
14.0	6.70E-12	11.2	0.541	3.27E-10	9.5	2.10	4.50E-09	8.3	8.69
28.0	7.93E-14	13.1	0.556	2.20E-10	9.7	2.87	2.75E-09	8.6	11.4
42.0	3.11E-14	13.5	0.563	1.49E-10	9.8	3.35	1.85E-09	8.7	13.1
49.0	6.76E-14	13.2	0.567	2.37E-10	9.6	3.62	2.01E-09	8.7	13.9
63.0	6.58E-14	13.2	0.575	1.32E-10	9.9	3.98	2.12E-09	8.7	15.4
90.0	2.70E-14	13.6	0.584	9.28E-11	10.0	4.48	1.35E-09	8.9	17.3
140.0	2.25E-14	13.6	0.596	7.42E-11	10.1	5.16	1.12E-09	9.0	19.9
406.0	4.13E-15	14.4	0.614	3.75E-11	10.4	6.87	6.50E-10	9.2	27.0
Average (from 28 d)	4.25E-14	13.5		1.35E-10	9.9		1.69E-09	8.8	

	T6-2 for ^{99}Tc			T6-2 for NO_3^-			T6-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	5.38E-11	10.3	0.0705	3.70E-10	9.4	0.185	4.86E-09	8.3	0.671
1.0	6.07E-10	9.2	0.655	1.45E-09	8.8	1.09	1.33E-08	7.9	3.40
2.0	6.02E-10	9.2	0.993	1.93E-09	8.7	1.69	1.23E-08	7.9	4.94
7.0	9.01E-10	9.0	2.23	2.13E-09	8.7	3.59	1.34E-08	7.9	9.69
14.0	4.53E-10	9.3	3.00	2.35E-09	8.6	5.36	1.17E-08	7.9	13.6
28.0	1.30E-11	10.9	3.19	1.34E-09	8.9	7.25	7.41E-09	8.1	18.1
42.0	1.37E-13	12.9	3.20	7.59E-10	9.1	8.34	4.46E-09	8.4	20.7
49.0	1.09E-13	13.0	3.21	7.73E-10	9.1	8.82	4.07E-09	8.4	21.8
63.0	1.65E-13	12.8	3.22	6.05E-10	9.2	9.59	4.60E-09	8.3	24.0
90.0	1.62E-13	12.8	3.24	4.67E-10	9.3	10.7	2.35E-09	8.6	26.5
140.0	4.80E-14	13.3	3.26	3.06E-10	9.5	12.1	1.51E-09	8.8	29.5
406.0	1.82E-14	13.7	3.30	2.21E-10	9.7	16.2	9.36E-10	9.0	38.0
Average (from 28 d)	1.95E-12	12.8		6.39E-10	9.3		3.62E-09	8.5	

	T7-2 for ^{99}Tc			T7-2 for NO_3^-			T7-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	6.24E-11	10.2	0.0758	1.63E-10	9.8	0.123	3.35E-09	8.5	0.555
1.0	1.33E-10	9.9	0.348	2.16E-10	9.7	0.470	2.76E-09	8.6	1.80
2.0	1.09E-10	10.0	0.491	2.61E-10	9.6	0.692	2.51E-09	8.6	2.49
7.0	1.57E-10	9.8	1.00	2.81E-10	9.6	1.38	3.33E-09	8.5	4.85
14.0	3.44E-11	10.5	1.22	3.47E-10	9.5	2.06	2.86E-09	8.5	6.79
28.0	2.02E-13	12.7	1.24	2.01E-10	9.7	2.79	1.63E-09	8.8	8.87
42.0	1.67E-13	12.8	1.26	1.35E-10	9.9	3.25	1.23E-09	8.9	10.3
49.0	1.07E-13	13.0	1.26	1.87E-10	9.7	3.48	1.31E-09	8.9	10.9
63.0	1.57E-13	12.8	1.27	1.09E-10	10.0	3.81	1.42E-09	8.8	12.1
90.0	2.97E-13	12.5	1.30	9.24E-11	10.0	4.30	9.53E-10	9.0	13.7
140.0	1.73E-13	12.8	1.34	6.45E-11	10.2	4.93	6.68E-10	9.2	15.7
406.0	2.92E-14	13.5	1.38	2.98E-11	10.5	6.44	4.05E-10	9.4	21.2
Average (from 28 d)	1.62E-13	12.9		1.17E-10	10.0		1.09E-09	9.0	

	T8-2 for ^{99}Tc			T8-2 for NO_3^-			T8-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	2.34E-11	10.6	0.0465	3.93E-10	9.4	0.191	4.91E-09	8.3	0.674
1.0	3.20E-10	9.5	0.470	2.08E-09	8.7	1.27	1.65E-08	7.8	3.72
2.0	3.06E-10	9.5	0.711	1.71E-09	8.8	1.84	1.23E-08	7.9	5.25
7.0	3.93E-10	9.4	1.52	2.58E-09	8.6	3.92	1.59E-08	7.8	10.4
14.0	1.28E-10	9.9	1.94	2.28E-09	8.6	5.66	1.12E-08	8.0	14.3
28.0	1.73E-12	11.8	2.00	1.32E-09	8.9	7.54	6.37E-09	8.2	18.4
42.0	3.45E-14	13.5	2.01	8.17E-10	9.1	8.67	4.07E-09	8.4	20.9
49.0	3.66E-14	13.4	2.01	7.59E-10	9.1	9.14	3.91E-09	8.4	22.0
63.0	6.96E-14	13.2	2.02	5.46E-10	9.3	9.87	3.74E-09	8.4	23.9
90.0	2.88E-14	13.5	2.03	3.83E-10	9.4	10.9	2.07E-09	8.7	26.2
140.0	1.07E-14	14.0	2.04	2.72E-10	9.6	12.2	1.43E-09	8.8	29.2
406.0	4.42E-15	14.4	2.06	2.01E-10	9.7	16.1	9.50E-10	9.0	37.7
Average (from 28 d)	2.73E-13	13.4		6.14E-10	9.3		3.22E-09	8.6	

	T9-2 for ^{99}Tc			T9-2 for NO_3^-			T9-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	9.43E-13	12.0	0.00936	-	-		5.63E-09	8.2	0.723
1.0	1.06E-12	12.0	0.0338	-	-		3.18E-09	8.5	2.06
2.0	8.43E-13	12.1	0.0465	-	-		1.82E-09	8.7	2.65
7.0	1.76E-13	12.8	0.0637	-	-		1.67E-09	8.8	4.33
14.0	2.84E-14	13.5	0.0699	-	-		9.70E-10	9.0	5.47
28.0	3.40E-14	13.5	0.0794	-	-		4.80E-10	9.3	6.61
42.0	3.93E-14	13.4	0.0873	-	-		2.61E-10	9.6	7.25
49.0	5.17E-14	13.3	0.0913	-	-		2.87E-10	9.5	7.54
63.0	1.12E-13	13.0	0.102	-	-		3.25E-10	9.5	8.11
90.0	1.33E-13	12.9	0.121	-	-		2.00E-10	9.7	8.84
140.0	5.49E-14	13.3	0.139	-	-		1.49E-10	9.8	9.79
406.0	2.85E-14	13.5	0.186	-	-		8.94E-11	10.0	12.4
Average (from 28 d)	6.48E-14	13.3		-	-		2.56E-10	9.6	
“-” indicates “not measured”				¹ Cumulative release					

	T10-2 for ^{99}Tc			T10-2 for NO_3^-			T10-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	2.74E-10	9.6	0.159	8.30E-10	9.1	0.277	1.32E-08	7.9	1.11
1.0	1.42E-09	8.8	1.05	2.64E-09	8.6	1.49	2.04E-08	7.7	4.49
2.0	5.46E-10	9.3	1.38	2.00E-09	8.7	2.11	1.27E-08	7.9	6.04
7.0	1.08E-10	10.0	1.80	1.34E-09	8.9	3.61	8.42E-09	8.1	9.80
14.0	6.92E-13	12.2	1.83	7.45E-10	9.1	4.61	4.32E-09	8.4	12.2
28.0	4.91E-14	13.3	1.84	2.98E-10	9.5	5.50	2.12E-09	8.7	14.6
42.0	3.40E-14	13.5	1.85	1.29E-10	9.9	5.95	1.01E-09	9.0	15.8
49.0	9.18E-14	13.0	1.86	1.49E-10	9.8	6.16	9.82E-10	9.0	16.4
63.0	8.48E-14	13.1	1.86	1.09E-10	10.0	6.49	9.08E-10	9.0	17.3
90.0	1.03E-13	13.0	1.88	6.11E-11	10.2	6.89	4.63E-10	9.3	18.4
140.0	7.23E-14	13.1	1.90	3.93E-11	10.4	7.38	3.48E-10	9.5	19.9
406.0	3.54E-14	13.5	1.95	2.27E-11	10.6	8.70	2.50E-10	9.6	24.3
Average (from 28 d)	6.71E-14	13.2		1.15E-10	10.1		8.68E-10	9.2	

	T11-2 for ^{99}Tc			T11-2 for NO_3^-			T11-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	8.36E-12	11.1	0.0280	5.05E-10	9.3	0.218	1.88E-09	8.7	0.420
1.0	8.29E-11	10.1	0.245	2.39E-09	8.6	1.39	7.77E-09	8.1	2.52
2.0	1.02E-10	10.0	0.386	2.26E-09	8.6	2.05	5.35E-09	8.3	3.54
7.0	1.14E-10	9.9	0.827	2.98E-09	8.5	4.30	6.46E-09	8.2	6.86
14.0	6.13E-12	11.2	0.918	2.03E-09	8.7	5.96	4.34E-09	8.4	9.28
28.0	7.11E-14	13.1	0.932	1.34E-09	8.9	7.87	3.09E-09	8.5	12.2
42.0	6.08E-14	13.2	0.942	9.53E-10	9.0	9.10	3.09E-09	8.5	14.4
49.0	7.79E-14	13.1	0.947	8.19E-10	9.1	9.60	3.21E-09	8.5	15.4
63.0	9.23E-14	13.0	0.956	6.19E-10	9.2	10.4	1.94E-09	8.7	16.8
90.0	9.16E-14	13.0	0.972	4.36E-10	9.4	11.5	1.28E-09	8.9	18.6
140.0	6.31E-14	13.2	0.992	2.53E-10	9.6	12.7	8.44E-10	9.1	20.9
406.0	9.13E-14	13.0	1.08	9.52E-11	10.0	15.4	3.88E-10	9.4	26.4
Average (from 28 d)	7.83E-14	13.1		6.45E-10	9.3		1.98E-09	8.8	

	T12-2 for ^{99}Tc			T12-2 for NO_3^-			T12-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	4.81E-11	10.3	0.0669	-	-		3.37E-09	8.5	0.559
1.0	1.22E-10	9.9	0.330	-	-		5.70E-09	8.2	2.35
2.0	1.42E-10	9.8	0.494	-	-		5.15E-09	8.3	3.35
7.0	1.53E-10	9.8	1.00	-	-		4.02E-09	8.4	5.95
14.0	1.50E-10	9.8	1.45	-	-		2.96E-09	8.5	7.94
28.0	1.33E-11	10.9	1.64	-	-		1.41E-09	8.9	9.89
42.0	4.21E-13	12.4	1.67	-	-		1.03E-09	9.0	11.2
49.0	2.84E-13	12.5	1.67	-	-		8.74E-10	9.1	11.7
63.0	2.47E-13	12.6	1.69	-	-		4.34E-10	9.4	12.3
90.0	2.64E-13	12.6	1.72	-	-		2.62E-10	9.6	13.2
140.0	1.82E-13	12.7	1.75	-	-		1.57E-10	9.8	14.1
406.0	1.78E-13	12.7	1.87	-	-		6.69E-11	10.2	16.4
Average (from 28 d)	2.13E-12	12.4		-	-		6.04E-10	9.4	
“-” indicates “not measured”				¹ Cumulative release					

	T13-2 for ^{99}Tc			T13-2 for NO_3^-			T13-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	5.96E-11	10.2	0.0748	5.09E-09	8.3	0.692	5.86E-09	8.2	0.742
1.0	4.19E-11	10.4	0.229	1.01E-08	8.0	3.10	1.84E-08	7.7	3.98
2.0	4.95E-12	11.3	0.260	6.12E-09	8.2	4.18	1.03E-08	8.0	5.39
7.0	7.24E-12	11.1	0.372	3.26E-09	8.5	6.55	5.46E-09	8.3	8.44
14.0	1.24E-11	10.9	0.501	1.31E-09	8.9	7.88	2.63E-09	8.6	10.3
28.0	1.80E-11	10.7	0.722	5.29E-10	9.3	9.08	1.58E-09	8.8	12.4
42.0	1.62E-11	10.8	0.883	3.36E-10	9.5	9.81	1.32E-09	8.9	13.9
49.0	1.47E-11	10.8	0.950	2.33E-10	9.6	10.1	1.43E-09	8.8	14.5
63.0	1.13E-11	10.9	1.06	1.52E-10	9.8	10.5	8.53E-10	9.1	15.4
90.0	1.05E-11	11.0	1.22	1.11E-10	10.0	11.0	5.91E-10	9.2	16.7
140.0	4.95E-12	11.3	1.40	1.14E-10	9.9	11.9	4.68E-10	9.3	18.4
406.0	2.55E-12	11.6	1.84	5.94E-11	10.2	14.0	2.84E-10	9.5	23.1
Average (from 28 d)	1.12E-11	11.0		2.19E-10	9.8		9.33E-10	9.1	

	T14-2 for ^{99}Tc			T14-2 for NO_3^-			T14-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.86E-10	9.7	0.132	9.08E-11	10.0	0.0919	5.30E-09	8.3	0.703
1.0	3.20E-10	9.5	0.557	4.06E-11	10.4	0.243	4.70E-09	8.3	2.33
2.0	3.02E-10	9.5	0.798	7.29E-11	10.1	0.362	3.63E-09	8.4	3.17
7.0	3.24E-10	9.5	1.54	6.53E-11	10.2	0.694	4.03E-09	8.4	5.78
14.0	5.32E-11	10.3	1.81	6.21E-11	10.2	0.983	2.13E-09	8.7	7.47
28.0	7.41E-14	13.1	1.82	3.35E-11	10.5	1.28	1.10E-09	9.0	9.19
42.0	2.28E-14	13.6	1.83	3.29E-11	10.5	1.51	1.06E-09	9.0	10.5
49.0	4.60E-14	13.3	1.83	6.19E-11	10.2	1.65	9.94E-10	9.0	11.0
63.0	6.59E-14	13.2	1.84	3.33E-11	10.5	1.83	8.17E-10	9.1	11.9
90.0	7.64E-14	13.1	1.85	2.16E-11	10.7	2.07	6.00E-10	9.2	13.2
140.0	4.51E-14	13.3	1.87	1.32E-11	10.9	2.35	5.00E-10	9.3	14.9
406.0	5.01E-14	13.3	1.93	4.01E-12	11.4	2.91	3.28E-10	9.5	20.0
Average (from 28 d)	5.44E-14	13.3		2.86E-11	10.7		7.71E-10	9.1	

	T15-2 for ^{99}Tc			T15-2 for NO_3^-			T15-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	5.76E-12	11.2	0.0231	2.89E-10	9.5	0.164	4.59E-09	8.3	0.652
1.0	5.27E-11	10.3	0.195	1.57E-09	8.8	1.10	1.44E-08	7.8	3.50
2.0	9.37E-11	10.0	0.329	2.36E-09	8.6	1.77	1.53E-08	7.8	5.20
7.0	9.44E-11	10.0	0.727	2.12E-09	8.7	3.66	1.28E-08	7.9	9.84
14.0	8.31E-12	11.1	0.833	1.65E-09	8.8	5.14	8.79E-09	8.1	13.3
28.0	1.55E-13	12.8	0.853	8.79E-10	9.1	6.67	5.14E-09	8.3	17.0
42.0	1.39E-13	12.9	0.868	6.10E-10	9.2	7.65	4.51E-09	8.3	19.6
49.0	2.43E-13	12.6	0.876	5.06E-10	9.3	8.04	3.84E-09	8.4	20.7
63.0	2.15E-13	12.7	0.891	3.43E-10	9.5	8.62	2.21E-09	8.7	22.2
90.0	1.45E-13	12.8	0.910	2.78E-10	9.6	9.48	1.67E-09	8.8	24.3
140.0	6.25E-14	13.2	0.930	1.94E-10	9.7	10.6	1.25E-09	8.9	27.0
406.0	3.32E-14	13.5	0.980	1.16E-10	9.9	13.6	8.32E-10	9.1	35.0
Average (from 28 d)	1.42E-13	12.9		4.18E-10	9.5		2.78E-09	8.6	

	T16-2 for ^{99}Tc			T16-2 for NO_3^-			T16-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	9.20E-11	10.0	0.0922	4.18E-10	9.4	0.196	4.70E-09	8.3	0.659
1.0	1.22E-09	8.9	0.921	2.58E-09	8.6	1.40	1.97E-08	7.7	3.98
2.0	1.09E-09	9.0	1.38	2.74E-09	8.6	2.12	1.59E-08	7.8	5.72
7.0	5.46E-10	9.3	2.33	2.04E-09	8.7	3.97	1.15E-08	7.9	10.1
14.0	6.03E-11	10.2	2.62	1.47E-09	8.8	5.37	7.28E-09	8.1	13.2
28.0	1.93E-12	11.7	2.69	8.61E-10	9.1	6.89	4.73E-09	8.3	16.8
42.0	2.38E-12	11.6	2.75	5.59E-10	9.3	7.82	3.80E-09	8.4	19.2
49.0	2.30E-12	11.6	2.78	4.41E-10	9.4	8.19	2.85E-09	8.5	20.2
63.0	3.15E-12	11.5	2.83	3.37E-10	9.5	8.76	1.89E-09	8.7	21.5
90.0	2.29E-12	11.6	2.91	2.68E-10	9.6	9.60	1.49E-09	8.8	23.5
140.0	1.09E-12	12.0	2.99	1.92E-10	9.7	10.7	1.03E-09	9.0	26.0
406.0	2.88E-13	12.5	3.14	1.11E-10	10.0	13.6	6.56E-10	9.2	33.1
Average (from 28 d)	1.92E-12	11.8		3.96E-10	9.5		2.35E-09	8.7	

	T17-2 for ^{99}Tc			T17-2 for NO_3^-			T17-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.92E-10	9.7	0.133	4.24E-10	9.4	0.197	6.32E-09	8.2	0.761
1.0	1.72E-09	8.8	1.11	3.32E-09	8.5	1.56	2.48E-08	7.6	4.47
2.0	5.98E-10	9.2	1.45	2.73E-09	8.6	2.27	1.23E-08	7.9	6.00
7.0	1.38E-10	9.9	1.92	2.42E-09	8.6	4.28	1.03E-08	8.0	10.1
14.0	5.13E-13	12.3	1.95	1.21E-09	8.9	5.54	5.80E-09	8.2	12.9
28.0	1.39E-13	12.9	1.97	4.13E-10	9.4	6.59	2.64E-09	8.6	15.5
42.0	2.17E-13	12.7	1.99	1.94E-10	9.7	7.14	1.78E-09	8.7	17.2
49.0	4.71E-13	12.3	2.00	1.57E-10	9.8	7.35	1.29E-09	8.9	17.8
63.0	2.64E-13	12.6	2.02	9.03E-11	10.0	7.65	7.05E-10	9.2	18.7
90.0	2.27E-13	12.6	2.04	6.89E-11	10.2	8.07	4.83E-10	9.3	19.8
140.0	1.57E-13	12.8	2.07	3.57E-11	10.4	8.54	2.87E-10	9.5	21.1
406.0	2.14E-13	12.7	2.20	2.51E-11	10.6	9.92	2.26E-10	9.6	25.2
Average (from 28 d)	2.41E-13	12.6		1.41E-10	10.0		1.06E-09	9.1	

	T18-2 for ^{99}Tc			T18-2 for NO_3^-			T18-2 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.31E-10	9.9	0.110	2.83E-10	9.5	0.161	3.99E-09	8.4	0.605
1.0	5.65E-10	9.2	0.671	1.05E-09	9.0	0.928	8.38E-09	8.1	2.77
2.0	4.18E-10	9.4	0.952	1.65E-09	8.8	1.49	7.62E-09	8.1	3.97
7.0	1.35E-10	9.9	1.43	1.96E-09	8.7	3.29	8.84E-09	8.1	7.81
14.0	2.20E-12	11.7	1.48	1.16E-09	8.9	4.53	5.57E-09	8.3	10.5
28.0	1.24E-12	11.9	1.54	4.34E-10	9.4	5.61	2.57E-09	8.6	13.1
42.0	1.74E-12	11.8	1.59	2.10E-10	9.7	6.18	1.86E-09	8.7	14.8
49.0	2.43E-12	11.6	1.62	1.54E-10	9.8	6.39	1.28E-09	8.9	15.5
63.0	3.33E-12	11.5	1.67	1.17E-10	9.9	6.73	8.35E-10	9.1	16.4
90.0	1.63E-12	11.8	1.74	7.42E-11	10.1	7.17	5.48E-10	9.3	17.6
140.0	6.21E-13	12.2	1.80	4.28E-11	10.4	7.68	3.42E-10	9.5	19.0
406.0	2.73E-13	12.6	1.94	2.46E-11	10.6	9.05	2.44E-10	9.6	23.3
Average (from 28 d)	1.61E-12	11.9		1.51E-10	10.0		1.10E-09	9.1	

Table A.10. Diffusivity and LI Values of ^{99}Tc , NO_3^- and Na^+ in VZPW. Values highlighted in yellow represent new data from the extended leaching period beyond previously reported leaching (Um et al. 2016).

T1-4 for ^{99}Tc				T1-4 for NO_3^-			T1-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)
0.08	2.51E-12	11.6	0.0153	-	-	-	8.65E-09	8.1	0.898
1.0	3.40E-12	11.5	0.0592	-	-	-	8.20E-09	8.1	3.05
2.0	3.34E-12	11.5	0.0845	-	-	-	6.72E-10	9.2	3.41
7.0	1.46E-12	11.8	0.134	-	-	-	3.73E-09	8.4	5.93
14.0	8.18E-14	13.1	0.145	-	-	-	2.40E-09	8.6	7.72
28.0	3.46E-15	14.5	0.148	-	-	-	2.35E-09	8.6	10.2
42.0	2.08E-15	14.7	0.150	-	-	-	3.44E-09	8.5	12.6
49.0	1.09E-14	14.0	0.151	-	-	-	4.28E-10	9.4	12.9
63.0	5.13E-15	14.3	0.154	-	-	-	1.61E-09	8.8	14.2
90.0	1.23E-15	14.9	0.155	-	-	-	7.68E-10	9.1	15.6
140.0	3.42E-15	14.5	0.160	-	-	-	1.03E-09	9.0	18.1
406.0	1.05E-14	14.0	0.189	-	-	-	4.00E-10	9.4	23.7
Average (from 28 d)	5.25E-15	14.4		-	-	-	1.43E-09	9.0	
“-” indicates “not measured”				¹ Cumulative release					

T2-4 for ^{99}Tc				T2-4 for NO_3^-			T2-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)
0.08	4.02E-10	9.4	0.194	8.67E-11	10.1	0.0901	1.15E-08	7.9	1.04
1.0	8.55E-11	10.1	0.415	5.71E-11	10.2	0.270	3.54E-09	8.5	2.46
2.0	3.79E-11	10.4	0.500	3.79E-10	9.4	0.541	2.97E-09	8.5	3.21
7.0	2.83E-11	10.5	0.720	1.19E-08	7.9	5.05	5.37E-09	8.3	6.24
14.0	1.89E-11	10.7	0.879	1.50E-08	7.8	9.55	5.57E-09	8.3	8.98
28.0	3.08E-13	12.5	0.908	7.52E-09	8.1	14.1	3.61E-09	8.4	12.1
42.0	1.96E-14	13.7	0.913	1.28E-08	7.9	18.6	3.24E-09	8.5	14.4
49.0	1.00E-14	14.0	0.915	6.70E-08	7.2	23.1	1.06E-09	9.0	14.9
63.0	1.34E-14	13.9	0.919	2.06E-08	7.7	27.6	2.93E-09	8.5	16.6
90.0	1.01E-14	14.0	0.924	7.52E-09	8.1	32.1	1.46E-09	8.8	18.6
140.0	2.04E-14	13.7	0.935	3.28E-09	8.5	36.6	1.48E-09	8.8	21.6
406.0	6.54E-14	13.2	1.01	1.63E-11	10.8	37.7	6.30E-10	9.2	28.6
Average (from 28 d)	6.39E-14	13.6		1.70E-08	8.3		2.06E-09	8.8	

	T3-4 for ^{99}Tc			T3-4 for NO_3^-			T3-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	7.45E-11	10.1	0.0833	2.02E-09	8.7	0.434	2.52E-08	7.6	1.53
1.0	5.41E-11	10.3	0.258	4.79E-10	9.3	0.955	1.30E-08	7.9	4.25
2.0	8.39E-11	10.1	0.385	3.18E-09	8.5	1.74	1.68E-08	7.8	6.04
7.0	3.65E-11	10.4	0.634	6.94E-10	9.2	2.82	1.25E-08	7.9	10.6
14.0	2.33E-12	11.6	0.690	3.51E-11	10.5	3.04	1.06E-08	8.0	14.4
28.0	2.09E-14	13.7	0.697	3.09E-10	9.5	3.95	6.04E-09	8.2	18.4
42.0	1.80E-15	14.7	0.699	9.65E-11	10.0	4.34	5.77E-09	8.2	21.4
49.0	9.46E-15	14.0	0.701	5.62E-11	10.3	4.47	2.80E-09	8.6	22.4
63.0	2.90E-15	14.5	0.702	1.55E-10	9.8	4.86	4.88E-09	8.3	24.6
90.0	1.06E-15	15.0	0.704	3.44E-11	10.5	5.16	3.40E-09	8.5	27.6
140.0	3.02E-15	14.5	0.708	7.65E-12	11.1	5.38	2.87E-09	8.5	31.8
406.0	6.37E-15	14.2	0.730	7.63E-11	10.1	7.81	1.69E-09	8.8	43.2
Average (from 28 d)	6.51E-15	14.4		1.05E-10	10.2		3.92E-09	8.4	

	T4-4 for ^{99}Tc			T4-4 for NO_3^-			T4-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	3.53E-10	9.5	0.182	-	-		7.16E-09	8.1	0.820
1.0	6.61E-10	9.2	0.796	-	-		6.79E-09	8.2	2.79
2.0	8.07E-10	9.1	1.19	-	-		8.90E-09	8.1	4.10
7.0	5.68E-10	9.2	2.18	-	-		6.29E-09	8.2	7.38
14.0	1.32E-10	9.9	2.60	-	-		7.17E-09	8.1	10.5
28.0	3.78E-13	12.4	2.63	-	-		2.23E-09	8.7	13.0
42.0	1.71E-15	14.8	2.63	-	-		4.87E-09	8.3	15.7
49.0	8.96E-15	14.0	2.63	-	-		7.96E-10	9.1	16.2
63.0	2.75E-15	14.6	2.64	-	-		4.59E-09	8.3	18.4
90.0	1.06E-15	15.0	2.64	-	-		1.20E-09	8.9	20.2
140.0	1.23E-14	13.9	2.65	-	-		1.25E-09	8.9	23.0
406.0	4.71E-14	13.3	2.71	-	-		6.37E-10	9.2	30.0
Average (from 28 d)	6.46E-14	14.0		-	-		2.23E-09	8.8	
“-” indicates “not measured”				¹ Cumulative release					

	T5-4 for ^{99}Tc			T5-4 for NO_3^-			T5-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.36E-10	9.9	0.112	1.94E-09	8.7	0.424	1.15E-08	7.9	1.03
1.0	7.40E-11	10.1	0.316	1.57E-10	9.8	0.721	6.92E-09	8.2	3.00
2.0	7.98E-11	10.1	0.439	1.51E-10	9.8	0.891	1.19E-08	7.9	4.51
7.0	2.43E-11	10.6	0.641	2.89E-09	8.5	3.10	4.71E-09	8.3	7.32
14.0	7.10E-12	11.1	0.739	1.35E-08	7.9	7.34	6.36E-09	8.2	10.2
28.0	5.44E-13	12.3	0.777	6.75E-09	8.2	11.6	5.03E-09	8.3	13.9
42.0	2.97E-14	13.5	0.784	3.10E-09	8.5	13.8	5.40E-09	8.3	16.8
49.0	2.51E-14	13.6	0.786	9.62E-11	10.0	14.0	1.89E-09	8.7	17.6
63.0	1.52E-14	13.8	0.790	4.99E-09	8.3	16.2	1.05E-08	8.0	20.8
90.0	1.41E-14	13.9	0.796	6.75E-09	8.2	20.4	2.07E-09	8.7	23.1
140.0	9.96E-14	13.0	0.821	2.95E-09	8.5	24.6	2.67E-09	8.6	27.1
406.0	1.16E-11	10.9	1.77	1.46E-11	10.8	25.7	1.29E-09	8.9	37.1
Average (from 28 d)	1.77E-12	13.0		3.52E-09	8.9		4.11E-09	8.5	

	T6-4 for ^{99}Tc			T6-4 for NO_3^-			T6-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.39E-10	9.9	0.113	6.41E-10	9.2	0.244	9.68E-09	8.0	0.0947
1.0	5.93E-10	9.2	0.691	1.69E-09	8.8	1.22	2.25E-08	7.6	4.51
2.0	1.18E-09	8.9	1.16	1.70E-09	8.8	1.79	3.18E-08	7.5	6.97
7.0	7.89E-10	9.1	2.32	1.49E-09	8.8	3.37	1.99E-08	7.7	12.8
14.0	3.00E-10	9.5	2.95	1.35E-09	8.9	4.71	1.37E-08	7.9	17.0
28.0	1.52E-11	10.8	3.15	4.51E-10	9.3	5.81	9.08E-09	8.0	22.0
42.0	5.24E-14	13.3	3.16	3.40E-10	9.5	6.54	7.23E-09	8.1	25.3
49.0	1.50E-14	13.8	3.16	4.46E-10	9.4	6.91	5.21E-09	8.3	26.6
63.0	4.05E-14	13.4	3.17	1.69E-10	9.8	7.31	9.64E-09	8.0	29.7
90.0	1.17E-14	13.9	3.18	7.48E-11	10.1	7.76	4.75E-09	8.3	33.2
140.0	2.36E-14	13.6	3.19	2.12E-10	9.7	8.90	3.84E-09	8.4	38.1
406.0	7.66E-14	13.1	3.26	4.21E-10	9.4	14.6	2.60E-09	8.6	52.2
Average (from 28 d)	2.20E-12	13.1		3.02E-10	9.6		6.05E-09	8.3	

	T7-4 for ^{99}Tc			T7-4 for NO_3^-			T7-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.71E-10	9.8	0.127	2.17E-09	8.7	0.451	1.38E-08	7.9	1.14
1.0	8.34E-11	10.1	0.345	5.71E-11	10.2	0.631	8.38E-09	8.1	3.32
2.0	4.83E-11	10.3	0.441	2.85E-08	7.5	2.98	3.78E-09	8.4	4.18
7.0	1.79E-11	10.7	0.617	1.19E-08	7.9	7.49	1.93E-08	7.7	9.93
14.0	1.06E-11	11.0	0.736	1.50E-08	7.8	12.0	4.51E-09	8.3	12.4
28.0	2.00E-13	12.7	0.759	7.52E-09	8.1	16.5	3.21E-09	8.5	15.3
42.0	8.89E-15	14.1	0.763	1.28E-08	7.9	21.0	2.27E-09	8.6	17.2
49.0	1.15E-14	13.9	0.765	6.70E-08	7.2	25.5	3.59E-09	8.4	18.3
63.0	2.18E-14	13.7	0.770	2.06E-08	7.7	30.0	4.41E-09	8.4	20.4
90.0	2.08E-14	13.7	0.777	7.52E-09	8.1	34.5	1.47E-09	8.8	22.4
140.0	3.78E-14	13.4	0.792	3.28E-09	8.5	39.1	1.31E-09	8.9	25.2
406.0	2.53E-13	12.6	0.933	1.63E-11	10.8	40.2	7.41E-10	9.1	32.8
Average (from 28 d)	7.91E-14	13.4		1.69E-08	8.3		2.43E-09	8.7	

	T8-4 for ^{99}Tc			T8-4 for NO_3^-			T8-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	1.32E-10	9.9	0.111	6.22E-10	9.2	0.241	1.06E-08	8.0	1.00
1.0	6.58E-10	9.2	0.723	2.92E-09	8.5	1.53	2.75E-08	7.6	4.96
2.0	8.05E-10	9.1	1.12	1.42E-09	8.8	2.05	2.47E-08	7.6	7.14
7.0	3.97E-10	9.4	1.94	1.37E-09	8.9	3.58	2.44E-08	7.6	13.6
14.0	9.91E-11	10.0	2.31	3.07E-10	9.5	4.23	1.14E-08	7.9	17.5
28.0	4.90E-12	11.3	2.42	4.37E-10	9.4	5.31	8.17E-09	8.1	22.2
42.0	6.76E-14	13.2	2.43	8.25E-11	10.1	5.67	5.51E-09	8.3	25.2
49.0	4.39E-14	13.4	2.43	1.62E-10	9.8	5.90	7.59E-09	8.1	26.7
63.0	1.17E-14	13.9	2.44	6.56E-12	11.2	5.98	8.65E-09	8.1	29.6
90.0	5.40E-15	14.3	2.44	7.26E-11	10.1	6.42	3.58E-09	8.4	32.7
140.0	9.75E-15	14.0	2.45	1.77E-10	9.8	7.47	3.91E-09	8.4	37.6
406.0	5.13E-14	13.3	2.51	4.50E-10	9.3	13.4	2.76E-09	8.6	52.3
Average (from 28 d)	7.27E-13	13.3		1.98E-10	10.0		5.74E-09	8.3	

	T9-4 for ^{99}Tc			T9-4 for NO_3^-			T9-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)
0.08	8.35E-12	11.1	0.0278	-	-		1.48E-08	7.8	1.17
1.0	1.50E-11	10.8	0.119	-	-		1.33E-08	7.9	3.90
2.0	3.53E-12	11.5	0.145	-	-		8.01E-10	9.1	4.29
7.0	4.38E-14	13.4	0.154	-	-		3.90E-08	7.4	12.4
14.0	8.90E-15	14.1	0.157	-	-		1.03E-09	9.0	13.6
28.0	1.61E-15	14.8	0.159	-	-		1.16E-09	8.9	15.3
42.0	2.06E-15	14.7	0.161	-	-		3.88E-10	9.4	16.1
49.0	1.08E-14	14.0	0.163	-	-		1.15E-09	8.9	16.7
63.0	3.32E-15	14.5	0.165	-	-		1.92E-09	8.7	18.1
90.0	1.21E-15	14.9	0.167	-	-		3.58E-10	9.4	19.0
140.0	2.79E-15	14.6	0.171	-	-		6.24E-10	9.2	21.0
406.0	1.30E-14	13.9	0.202	-	-		3.62E-10	9.4	26.3
Average (from 28 d)	4.97E-15	14.5		-	-		8.50E-10	9.2	
“-” indicates “not measured”				¹ Cumulative release					

	T10-4 for ^{99}Tc			T10-4 for NO_3^-			T10-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)	D_{eff} (cm^2/s)	LI [-]	Release ¹ (%)
0.08	4.71E-10	9.3	0.209	7.47E-10	9.1	0.263	1.46E-08	7.8	1.16
1.0	1.09E-09	9.0	0.991	1.65E-09	8.8	1.23	2.01E-08	7.7	4.53
2.0	8.93E-10	9.0	1.40	1.01E-09	9.0	1.67	1.72E-08	7.8	6.34
7.0	1.02E-10	10.0	1.82	2.92E-10	9.5	2.37	1.60E-08	7.8	11.5
14.0	2.54E-13	12.6	1.84	2.43E-10	9.6	2.94	5.18E-09	8.3	14.2
28.0	1.04E-14	14.0	1.84	7.20E-11	10.1	3.38	3.41E-09	8.5	17.2
42.0	4.63E-15	14.3	1.84	1.10E-09	9.0	4.69	1.53E-09	8.8	18.7
49.0	9.71E-15	14.0	1.85	1.60E-08	7.8	6.88	3.00E-09	8.5	19.7
63.0	2.98E-15	14.5	1.85	4.92E-09	8.3	9.08	2.20E-09	8.7	21.1
90.0	1.09E-15	15.0	1.85	1.80E-09	8.7	11.3	1.35E-09	8.9	23.0
140.0	9.74E-16	15.0	1.85	7.86E-10	9.1	13.5	1.13E-09	8.9	25.7
406.0	3.34E-15	14.5	1.87	3.91E-12	11.4	14.0	6.27E-10	9.2	32.6
Average (from 28 d)	4.74E-15	14.5		3.53E-09	9.2		1.89E-09	8.8	

	T11-4 for ^{99}Tc			T11-4 for NO_3^-			T11-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	6.11E-12	11.2	0.0240	6.14E-10	9.2	0.241	2.29E-09	8.6	0.466
1.0	3.20E-11	10.5	0.159	9.77E-09	8.0	2.61	1.42E-08	7.8	3.32
2.0	4.17E-11	10.4	0.250	2.68E-09	8.6	3.33	6.96E-09	8.2	4.48
7.0	2.62E-11	10.6	0.462	1.81E-09	8.7	5.10	6.06E-09	8.2	7.71
14.0	1.56E-12	11.8	0.508	1.29E-09	8.9	6.42	3.98E-09	8.4	10.0
28.0	7.99E-15	14.1	0.513	1.04E-09	9.0	8.11	2.04E-09	8.7	12.4
42.0	1.74E-15	14.8	0.514	2.90E-10	9.5	8.79	2.30E-09	8.6	14.3
49.0	7.66E-15	14.1	0.516	2.58E-10	9.6	9.07	1.87E-09	8.7	15.1
63.0	4.03E-15	14.4	0.518	1.17E-10	9.9	9.41	1.60E-08	7.8	19.1
90.0	1.31E-15	14.9	0.520	5.91E-11	10.2	9.81	7.46E-10	9.1	20.5
140.0	3.76E-16	15.4	0.521	3.72E-11	10.4	10.3	4.41E-10	9.4	22.2
406.0	6.47E-16	15.2	0.529	2.66E-11	10.6	11.7	4.67E-10	9.3	28.2
Average (from 28 d)	3.39E-15	14.7		2.62E-10	9.9		3.41E-09	8.8	

	T12-4 for ^{99}Tc			T12-4 for NO_3^-			T12-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	3.29E-11	10.5	0.0558	-	-		3.25E-09	8.5	0.555
1.0	1.81E-10	9.7	0.378	-	-		2.07E-08	7.7	4.01
2.0	2.59E-10	9.6	0.602	-	-		1.03E-08	8.0	5.42
7.0	1.85E-10	9.7	1.17	-	-		3.19E-09	8.5	7.76
14.0	2.75E-11	10.6	1.36	-	-		1.35E-09	8.9	9.12
28.0	2.38E-13	12.6	1.39	-	-		8.71E-10	9.1	10.7
42.0	3.12E-15	14.5	1.39	-	-		6.06E-10	9.2	11.6
49.0	8.95E-15	14.0	1.39	-	-		1.01E-09	9.0	12.2
63.0	4.84E-15	14.3	1.39	-	-		5.06E-08	7.3	19.3
90.0	1.94E-15	14.7	1.39	-	-		3.48E-11	10.5	19.6
140.0	6.32E-16	15.2	1.40	-	-		3.89E-11	10.4	20.1
406.0	1.02E-15	15.0	1.40	-	-		1.21E-10	9.9	23.2
Average (from 28 d)	3.70E-14	14.3		-	-		7.61E-09	9.3	
“-” indicates “not measured”				¹ Cumulative release					

	T13-4 for ^{99}Tc			T13-4 for NO_3^-			T13-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	3.05E-11	10.5	0.0535	4.21E-09	8.4	0.628	4.48E-09	8.3	0.648
1.0	2.63E-11	10.6	0.176	2.10E-08	7.7	4.08	2.06E-08	7.7	4.07
2.0	2.45E-13	12.6	0.183	3.86E-09	8.4	4.94	8.70E-09	8.1	5.37
7.0	6.45E-13	12.2	0.216	4.30E-09	8.4	7.65	6.51E-09	8.2	8.70
14.0	7.99E-14	13.1	0.226	6.03E-10	9.2	8.56	2.62E-09	8.6	10.6
28.0	3.94E-14	13.4	0.237	6.99E-10	9.2	9.93	1.35E-09	8.9	12.5
42.0	3.37E-14	13.5	0.244	1.17E-10	9.9	10.4	1.27E-09	8.9	13.9
49.0	2.94E-14	13.5	0.247	8.13E-11	10.1	10.5	3.14E-10	9.5	14.2
63.0	2.80E-14	13.6	0.252	9.98E-11	10.0	10.8	1.71E-08	7.8	18.3
90.0	1.67E-14	13.8	0.259	8.21E-11	10.1	11.3	2.76E-10	9.6	19.2
140.0	4.85E-15	14.3	0.264	3.01E-11	10.5	11.7	2.46E-10	9.6	20.4
406.0	1.70E-14	13.8	0.301	1.78E-11	10.7	12.9	3.33E-10	9.5	25.5
Average (from 28 d)	2.41E-14	13.7		1.61E-10	10.1		2.98E-09	9.1	

	T14-4 for ^{99}Tc			T14-4 for NO_3^-			T14-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	7.70E-11	10.1	0.0844	9.19E-07	6.0	9.22	1.51E-09	8.8	0.374
1.0	1.36E-10	9.9	0.361	1.51E-07	6.8	18.4	8.98E-09	8.0	2.62
2.0	8.28E-11	10.1	0.486	4.46E-07	6.4	27.7	5.23E-09	8.3	3.62
7.0	5.97E-11	10.2	0.803	5.05E-08	7.3	36.9	4.48E-09	8.3	6.36
14.0	1.81E-11	10.7	0.959	6.38E-08	7.2	46.1	2.29E-09	8.6	8.11
28.0	3.21E-14	13.5	0.968	3.19E-08	7.5	55.3	1.31E-09	8.9	9.98
42.0	6.40E-15	14.2	0.971	5.42E-08	7.3	64.5	3.97E-09	8.4	12.5
49.0	1.03E-14	14.0	0.973	2.84E-07	6.5	73.8	1.87E-09	8.7	13.2
63.0	1.17E-14	13.9	0.976	8.72E-08	7.1	83.0	2.23E-07	6.7	28.0
90.0	9.70E-15	14.0	0.981	3.19E-08	7.5	92.2	2.48E-08	7.6	36.1
140.0	2.94E-14	13.5	0.995	1.39E-08	7.9	100.1	3.67E-10	9.4	37.6
406.0	8.31E-14	13.1	1.07	6.92E-11	10.2	100.4	4.67E-10	9.3	43.6
Average (from 28 d)	2.61E-14	13.7		7.19E-08	7.7		3.66E-08	8.4	

	T15-4 for ^{99}Tc			T15-4 for NO_3^-			T15-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	2.05E-11	10.7	0.0436	5.09E-10	9.3	0.217	1.14E-08	7.9	1.03
1.0	1.21E-10	9.9	0.305	2.45E-09	8.6	1.39	3.46E-08	7.5	5.44
2.0	1.25E-10	9.9	0.459	8.02E-10	9.1	1.78	1.75E-08	7.8	7.27
7.0	8.75E-11	10.1	0.844	5.42E-10	9.3	2.74	1.76E-08	7.8	12.7
14.0	9.26E-12	11.0	0.955	1.71E-10	9.8	3.22	1.10E-08	8.0	16.6
28.0	6.37E-14	13.2	0.968	3.12E-10	9.5	4.13	6.86E-09	8.2	20.8
42.0	1.17E-14	13.9	0.972	1.51E-09	8.8	5.67	6.02E-09	8.2	23.9
49.0	3.60E-14	13.4	0.976	1.57E-08	7.8	7.85	6.38E-09	8.2	25.3
63.0	8.92E-15	14.0	0.979	1.31E-09	8.9	8.98	4.79E-08	7.3	32.1
90.0	1.33E-14	13.9	0.985	2.83E-12	11.5	9.07	1.86E-09	8.7	34.4
140.0	3.09E-14	13.5	0.998	1.98E-11	10.7	9.41	2.87E-09	8.5	38.6
406.0	6.44E-14	13.2	1.07	1.34E-10	9.9	12.6	2.30E-09	8.6	51.9
Average (from 28 d)	3.27E-14	13.6		2.72E-09	9.6		1.06E-08	8.3	

	T16-4 for ^{99}Tc			T16-4 for NO_3^-			T16-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	2.79E-10	9.6	0.160	1.86E-10	9.7	0.131	6.86E-09	8.2	0.796
1.0	1.24E-09	8.9	0.993	2.67E-09	8.6	1.35	2.65E-08	7.6	4.65
2.0	1.09E-09	9.0	1.45	1.00E-09	9.0	1.79	1.79E-08	7.7	6.49
7.0	5.62E-10	9.3	2.42	8.90E-10	9.1	3.01	1.55E-08	7.8	11.6
14.0	6.49E-11	10.2	2.71	1.16E-10	9.9	3.41	9.31E-09	8.0	15.1
28.0	5.23E-13	12.3	2.75	3.16E-10	9.5	4.32	5.70E-09	8.2	19.0
42.0	9.81E-15	14.0	2.75	3.04E-09	8.5	6.51	6.30E-09	8.2	22.2
49.0	9.17E-15	14.0	2.75	4.83E-09	8.3	7.71	3.97E-09	8.4	23.2
63.0	3.31E-15	14.5	2.76	4.90E-11	10.3	7.92	4.24E-08	7.4	29.7
90.0	2.25E-15	14.6	2.76	2.87E-12	11.5	8.01	1.58E-09	8.8	31.7
140.0	4.16E-15	14.4	2.76	3.79E-11	10.4	8.49	2.65E-09	8.6	35.7
406.0	8.67E-14	13.1	2.85	1.25E-10	9.9	11.6	2.02E-09	8.7	48.2
Average (from 28 d)	9.12E-14	13.8		1.20E-09	9.8		9.23E-09	8.3	

	T17-4 for ^{99}Tc			T17-4 for NO_3^-			T17-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	4.31E-10	9.4	0.200	5.21E-10	9.3	0.220	9.90E-09	8.0	0.959
1.0	8.64E-10	9.1	0.898	8.59E-11	10.1	0.440	1.81E-08	7.7	4.16
2.0	5.73E-10	9.2	1.23	1.71E-09	8.8	1.01	1.40E-08	7.9	5.79
7.0	8.15E-11	10.1	1.60	1.39E-10	9.9	1.50	1.15E-08	7.9	10.2
14.0	1.91E-13	12.7	1.62	3.62E-11	10.4	1.72	5.73E-09	8.2	13.0
28.0	1.59E-15	14.8	1.62	1.81E-11	10.7	1.94	3.40E-09	8.5	16.0
42.0	1.84E-15	14.7	1.62	9.30E-10	9.0	3.15	2.88E-09	8.5	18.1
49.0	9.63E-15	14.0	1.62	1.61E-08	7.8	5.35	1.52E-09	8.8	18.8
63.0	2.96E-15	14.5	1.62	1.98E-10	9.7	5.79	2.89E-08	7.5	24.1
90.0	1.08E-15	15.0	1.62	6.52E-10	9.2	7.11	9.97E-10	9.0	25.7
140.0	4.72E-16	15.3	1.63	7.90E-10	9.1	9.31	9.24E-10	9.0	28.1
406.0	8.28E-17	16.1	1.63	3.93E-12	11.4	9.86	4.78E-10	9.3	34.2
Average (from 28 d)	2.52E-15	14.9		3.12E-09	9.3		5.59E-09	8.7	

	T18-4 for ^{99}Tc			T18-4 for NO_3^-			T18-4 for Na^+		
Cumulative Leach Time (days)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)	D_{eff} (cm ² /s)	LI [-]	Release ¹ (%)
0.08	4.20E-10	9.4	0.197	3.42E-10	9.5	0.177	5.17E-09	8.3	0.690
1.0	1.03E-09	9.0	0.954	1.41E-09	8.9	1.06	1.33E-08	7.9	3.41
2.0	1.41E-09	8.9	1.47	1.26E-09	8.9	1.55	1.41E-08	7.9	5.05
7.0	2.92E-10	9.5	2.17	4.23E-11	10.4	1.82	9.18E-09	8.0	8.97
14.0	3.92E-13	12.4	2.19	1.48E-12	11.8	1.86	5.89E-09	8.2	11.8
28.0	1.14E-15	14.9	2.20	2.67E-11	10.6	2.13	3.50E-09	8.5	14.8
42.0	6.56E-15	14.2	2.20	9.88E-10	9.0	3.37	2.94E-09	8.5	17.0
49.0	1.00E-14	14.0	2.20	1.65E-08	7.8	5.59	1.95E-09	8.7	17.7
63.0	3.07E-15	14.5	2.20	2.45E-10	9.6	6.08	2.97E-08	7.5	23.1
90.0	1.12E-15	14.9	2.20	6.90E-10	9.2	7.43	1.24E-09	8.9	24.9
140.0	4.90E-16	15.3	2.21	8.10E-10	9.1	9.65	9.16E-10	9.0	27.3
406.0	1.17E-16	15.9	2.21	4.02E-12	11.4	10.2	5.22E-10	9.3	33.6
Average (from 28 d)	3.21E-15	14.8		2.76E-09	9.5		5.83E-09	8.6	

Table A.11. Quantitative XRD Data Showing the Mineral Composition of the 406 d Leached Samples. An internal TiO₂ standard was included to facilitate the quantification.

Sample	Ettringite	Brucite	Gypsum	Calcite	Vaterite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
15 T1-2	14%			13%		4.70%	11.0%	0.90%	2.20%	1.00%	52%
15 T1-4	23%	8.90%	3.00%	5.00%		4.00%	1.40%				55%
15 T2-2	8.80%			5.70%		4.40%	11.0%	1.60%			68%
15 T2-4	29%	9.90%	3.20%	5.50%	3.10%	3.60%					46%
15 T3-2	14%			6.50%		2.60%	6.40%	0.70%	1.10%	0.30%	69%
15 T3-4	23%	2.10%	1.20%	5.90%		4.30%	5.70%	0.80%	1.10%		59%
15 T4-2	13%			8.40%		3.00%	6.70%	0.50%	1.40%	0.90%	66%
15 T4-4	23%	4.70%	0.70%	6.60%		3.80%	5.10%	0.70%	1.30%		54%
15 T5-2	10%			8.40%		3.20%	9.30%	4.20%		0.60%	64%
15 T5-4	31%	8.20%		6.40%	5.10%	3.50%					46%
15 T6-2	18%			8.90%		3.50%	4.80%			1.00%	64%
15 T6-4	27%	4.40%		5.50%		3.30%	1.20%			0.10%	58%
15 T7-2	10%			6.80%		3.90%	11.0%	3.10%	1.60%	1.20%	62%
15 T7-4	26%	6.40%	1.30%	5.80%	3.10%	2.90%	1.40%			0.30%	53%
15 T8-2	19%			11%		3.90%	4.40%			0.70%	60%
15 T8-4	28%	3.00%		6.20%		4.00%	2.60%			1.00%	55%
15 T9-2	12%			8.50%		3.00%	3.40%	1.30%			72%
15 T9-4	24%	4.00%		5.20%		3.10%	1.40%	0.80%	1.30%		61%
15 T10-2	16%			7.40%		2.20%	2.70%		1.30%	0.40%	70%
15 T10-4	23%	4.00%		5.10%		2.20%	1.00%			0.30%	65%
15 T11-2	19%			4.50%		2.80%				3.90%	70%
15 T11-4	18%			5.90%		3.50%				3.30%	69%
15 T12-2	14%			5.80%		2.90%				3.20%	75%
15 T12-4	19%	1.10%		6.60%		2.60%				1.70%	69%
15 T13-2	13%			3.20%		1.80%				3.50%	79%
15 T13-4	14%			3.50%		2.10%				4.90%	75%
15T14-2	11%		1.20%	6.70%		3.40%	8.10%	1.30%			69%
15T14-4	27%	8.60%	3.30%	5.60%		4.20%	3.20%	0.70%			48%
15T15-2	13%			6.10%		3.90%	8.20%			1.10%	68%

Sample	Ettringite	Brucite	Gypsum	Calcite	Vaterite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
15T15-4	26%	5.90%	1.80%	4.90%		4.70%	4.60%			0.30%	52%
15T16-2	16%			6.40%		3.90%	6.80%				67%
15T16-4	21%	3.40%	1.50%	3.70%		2.50%	3.00%			0.50%	64%
15T17-2	21%		1.20%	8.70%		2.90%	4.50%			0.70%	61%
15T17-4	21%	5.80%	1.80%	4.70%		2.70%	1.00%				63%
15T18-2	18%			9.50%		2.40%	3.00%	0.70%	1.30%	1.70%	63%
15T18-4	22%	3.10%	1.50%	4.00%		2.60%	1.30%			0.40%	65%

Table A.12. Comparison of the Mineralogical Makeup of Available Monolith Samples after Curing, 140 d Leaching, and 406 d Leaching

T3 - WTP Simulant - 20:35:45 HL:OPC:BFS - 0.5 Water-to-Dry-Mix Ratio										
Sample	Ettringite	Brucite	Gypsum	Calcite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
T3 Cured	14.0%			6.8%	4.4%	11.0%				64.0%
T3-1 140 d	21.0%			6.7%	4.5%	8.6%				58.0%
T3-2 406 d	14.0%			6.5%	2.6%	6.4%	0.7%	1.1%	0.3%	69.0%
T3-3 140 d	20.0%	5.2%	3.1%	4.2%	4.3%	4.7%				
T3-4 406 d	23.0%	2.1%	1.2%	5.9%	4.3%	5.7%	0.8%	1.1%		59.0%
T6 - WTP Simulant - 20:35:45 HL:OPC:BFS - 0.6 Water-to-Dry-Mix Ratio										
Sample	Ettringite	Brucite	Gypsum	Calcite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
T6 Cured	17.0%			5.4%	4.5%	9.7%				63.0%
T6-1 140 d	21.0%			6.7%	4.5%	9.3%				59.0%
T6-2 406 d	18.0%			8.9%	3.5%	4.8%			1.0%	64.0%
T6-3 140 d	25.0%	3.4%	3.5%	5.9%	4.9%	3.9%			0.3%	53.0%
T6-4 406 d	27.0%	4.4%		5.5%	3.3%	1.2%			0.1%	58.0%
T11 - WTP Simulant - 20:35:45 OPC:FA:BFS - 0.6 Water-to-Dry-Mix Ratio										
Sample	Ettringite	Brucite	Gypsum	Calcite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
T11 Cured	15.0%			4.5%	4.1%				20.0%	75.0%
T11-1 140 d	19.0%			4.9%	3.8%				4.1%	68.0%
T11-2 406 d	19.0%			4.5%	2.8%				3.9%	70.0%
T11-3 140 d	24.0%			6.0%	4.8%				11.0%	55.0%
T11-4 406 d	18.0%			5.9%	3.5%				3.3%	69.0%
T13 - WTP Simulant - 8:45:47 OPC:FA:BFS - 0.6 Water-to-Dry-Mix Ratio										
Sample	Ettringite	Brucite	Gypsum	Calcite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
T13 Cured	12.0%			4.2%	2.0%				4.1%	78.0%
T13-1 140 d	16.0%			3.0%	3.0%				3.1%	75.0%
T13-2 406 d	13.0%			3.2%	1.8%				3.5%	79.0%
T13-3 140 d	17.0%			2.9%	2.4%				3.6%	74.0%
T13-4 406 d	14.0%			3.5%	2.1%				4.9%	75.0%

T12 - ERDF Leachates - 20:35:45 OPC:FA:BFS - 0.6 Water-to-Dry-Mix Ratio

Sample	Ettringite	Brucite	Gypsum	Calcite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Amorphous/Unidentified
T12 Cured	14.0%			3.7%	2.4%				1.5%	78.0%
T12-1 140 d	14.0%			4.1%	4.0%				3.0%	75.0%
T12-2 406 d	14.0%			5.8%	2.9%				3.2%	75.0%
T12-3 140 d	17.0%			5.0%	4.1%				4.2%	70.0%
T12-4 406 d	19.0%	1.1%		6.6%	2.6%				1.7%	69.0%

Table A.13. Comparison of the XRD Results of Samples Taken from the Outer Wall (OUT) and Inner Core (IN) of Monoliths Following 406 d Leaching. The DIW Deposit sample was a white powder collected from the outermost surface of the T3-2 sample.

Sample	Ettringite	Calcite	Larnite	Portlandite	Hydrocalumite	Hydrotalcite	Quartz	Brucite	Amorphous/Unidentified
T3-2 In	11.0%	2.1%	4.8%	8.6%	0.4%	0.9%	0.1%		72.0%
T3-2 Out	14.0%	3.3%	1.6%	5.8%	0.4%	0.5%	0.5%		74.0%
T11-2 In	15.0%	3.1%	2.0%				1.0%		79.0%
T11-2 Out	15.0%	3.1%	1.9%				1.6%		79.0%
T3-4 In	13.0%	2.8%	2.7%	7.3%	0.5%	0.6%			73.0%
T3-4 Out	15.0%	2.4%	2.0%	2.4%	0.3%	0.3%	0.5%	6.2%	69.0%
DIW Deposit	4.1%	17.0%			0.3%	0.4%	0.7%		78.0%

A.5.5 References

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A.6 Extended ^{99}Tc Solubility for FY 2015 Cementitious Monoliths Update: Additional Analysis on ^{99}Tc Solubility Measurements using Monoliths T19, T20, and T21 Leached for 121, 210, and 370 days.

This section presents additional extended data analysis to determine ^{99}Tc solubility (mol/L) under reducing conditions using crushed samples of monoliths T19, T20, and T21 (corresponding to monolith Tests #3, #6, and #11, respectively) with different initial ^{99}Tc concentrations (2.5, 10, and 25 $\mu\text{g/L}$) in pre-equilibrated saturated $\text{Ca}(\text{OH})_2$ solution for three extended reaction times (121, 210, and 370 days). The tests were started on 9/28/2015 and the ^{99}Tc concentrations at 14, 30, and 51 days have been already reported in Um et al. (2016), in which the detailed material preparation and measurement procedure are also provided. More details of ^{99}Tc solubility can be also found in Section 8 of this report.

A.6.1 Results and Discussion

The solubility of ^{99}Tc in the three non- ^{99}Tc -spiked crushed monoliths (T19, T20, and T21) with the F1 (0.3–2 mm) size fraction were continued for 121, 210, and 370 days under reducing conditions inside the anoxic chamber. The measured average E_h value for filtrates was ~ -400 mV (Appendix A.14), indicating that reducing conditions prevailed, likely due to the presence of unreacted BFS in the crushed monolith and H_2 (2%) inside the anoxic chamber during the entire solubility test. No precipitates or significant ^{99}Tc losses were observed in any of control samples (the saturated $\text{Ca}(\text{OH})_2$ solution with no crushed monolith material) prepared with initial spiked ^{99}Tc concentrations of 2.5, 10, and 25 $\mu\text{g/L}$ while inside the chamber. This demonstrates that the ^{99}Tc remained soluble over the entire course of the solubility experiments and reductive precipitation of $^{99}\text{Tc}(\text{IV})$ did not occur in the controls, indicating the reducing conditions in the anoxic chamber were not sufficient to facilitate $^{99}\text{Tc}(\text{IV})$ precipitation in the absence of additional reductant or reductant-bearing solids.

The measured average aqueous ^{99}Tc concentration in filtrates collected from the crushed LSWG slurries for each reaction time (including the data collected in FY2015 at 14, 30, and 51 days) are shown in Figure A.8a, Figure A.8b, and Figure A.8c. Generally, the aqueous ^{99}Tc concentration in all filtrates isolated from T19, T20, and T21 crushed LSWG slurries rapidly decreased with increasing reaction time during early reaction periods (up to 51-day reaction). Then, the filtrates exhibited a gradual decrease (up to 121-day reaction) and finally a near concentration plateau for the remainder of the test period (121–370 days).

In the case of T19, for the additional data collected at 121, 210, and 370 days, Figure A.8a illustrates that for the batch experiment started with ^{99}Tc aqueous concentrations of 2.5 $\mu\text{g/L}$, all the ^{99}Tc aqueous concentrations in the filtrates were below the detection limit ICP-MS (0.033 $\mu\text{g/L}$) except the first sampling after 121 days, which had a near-detection-limit value of 0.04 $\mu\text{g/L}$. For the T19 batch experiment, with a starting ^{99}Tc aqueous concentration equal to 10 $\mu\text{g/L}$, nearly constant, low aqueous concentrations of ~ 0.05 – 0.07 $\mu\text{g/L}$ were observed for all 121, 210, and 370-day sampling intervals. For the T19 batch experiment started with the highest ^{99}Tc aqueous concentrations of 25 $\mu\text{g/L}$, a gradual decrease in ^{99}Tc aqueous concentration (0.11 to 0.06 $\mu\text{g/L}$) was observed throughout the 121–370 day reaction process. Figure A.8a shows that, for the additional reaction times, 121 to 370 days, the filtrate ^{99}Tc concentrations for the different starting ^{99}Tc concentrations (2.5, 10, and 25 $\mu\text{g/L}$) did not converge to a single value. The highest filtrate ^{99}Tc aqueous concentration values were 0.06–0.11 $\mu\text{g/L}$ from the batch experiment that started with the highest ^{99}Tc aqueous concentrations, 25 $\mu\text{g/L}$.

In the case of T20, the additional ^{99}Tc solubility data collected (at 121, 210, and 370 days), Figure A.8b illustrates that for the batch experiment started with ^{99}Tc aqueous concentrations of $2.5\ \mu\text{g/L}$, all the ^{99}Tc aqueous concentrations in the filtrates were below the detection limit of ICP-MS ($0.033\ \mu\text{g/L}$). For the T20 batch experiment with a starting ^{99}Tc aqueous concentrations of 10 and $25\ \mu\text{g/L}$, a narrow range of low aqueous concentrations of $\sim 0.03\text{--}0.06\ \mu\text{g/L}$ were observed in the filtrates for all 121, 210, and 370-day sampling intervals.

In the case of T21, the additional data collected at 121, 210, and 370 days, Figure A.8c illustrates that for the batch experiment started with ^{99}Tc aqueous concentrations of $2.5\ \mu\text{g/L}$, all the ^{99}Tc aqueous concentrations in the filtrates were near the detection limit of ICP-MS ($0.033\ \mu\text{g/L}$). For both T21 batch experiments with starting ^{99}Tc aqueous concentrations of 10 and $25\ \mu\text{g/L}$, the filtrate ^{99}Tc concentrations for the two different initial ^{99}Tc concentrations (10 and $25\ \mu\text{g/L}$) converged into a very narrow concentration range ($0.09\text{--}0.24\ \mu\text{g/L}$) during the entire 121–370 day test period. Within this extended test period, two averaged aqueous ^{99}Tc concentrations, corresponding to the two different initial ^{99}Tc concentrations of 10 and $25\ \mu\text{g/L}$, can be calculated, namely $0.14 \pm 0.06\ \mu\text{g/L}$ ($1.4 \pm 0.6 \times 10^{-9}\ \text{M}$) and $0.19 \pm 0.06\ \mu\text{g/L}$ ($1.9 \pm 0.6 \times 10^{-9}\ \text{M}$), respectively.

In summary, during the extended test period (121–370 days), for the experiments with LSWG T19 and T20, the ^{99}Tc concentrations in most of the filtrates were near or below the ICP-MS detection limit ($0.03\ \mu\text{g/L}$). In contrast, LSWG T21 filtrates show much higher concentration levels ($0.09\text{--}0.24\ \mu\text{g/L}$). This difference agrees well with Um et al. (2016), in which much lower sorption capacity was reported for T21 compared to T19 and T20. Therefore, for T19 and T20, which show higher ^{99}Tc sorption capacity, the spiked ^{99}Tc mass in the saturated $\text{Ca}(\text{OH})_2$ solution likely did not exceed the monolith's sorption capacity. Thus, almost 100% of the spiked ^{99}Tc in the saturated $\text{Ca}(\text{OH})_2$ solution was taken up by the grout after the long extended reaction days, resulting in almost undetectable ^{99}Tc concentrations in the filtrates. In such a scenario, the observed filtrate ^{99}Tc aqueous concentration could be lower than a true ^{99}Tc solubility control value. In contrast, for T21, although there was almost 100% uptake of the spiked ^{99}Tc in the saturated $\text{Ca}(\text{OH})_2$ solution that started with ^{99}Tc aqueous concentrations of $2.5\ \mu\text{g/L}$, the total amounts of ^{99}Tc in T21 batch slurries that started with ^{99}Tc aqueous concentrations of 10 and $25\ \mu\text{g/L}$ were probably sufficient to saturate the relatively lower sorption capacity of T21. The T21 filtrate aqueous ^{99}Tc concentrations leveled off to similar ^{99}Tc aqueous concentrations of $\sim 1.4 \pm 0.6$ to $1.9 \pm 0.6 \times 10^{-9}\ \text{M}$ despite the different initial ^{99}Tc concentrations (10 and $25\ \mu\text{g/L}$). An overall average solubility control based on an assumed $^{99}\text{Tc}(\text{IV})$ solid is $\sim 1.7 \pm 0.6 \times 10^{-9}\ \text{M}$ based on the results of this study. This value agrees well with values reported by Estes et al. (2012) and Um et al. (2016), who respectively reported solubility values of 10^{-9} to $10^{-8}\ \text{M}$ and $4.8 \times 10^{-9}\ \text{M}$ for empirical solubility experiments conducted under reducing conditions with several different cementitious waste forms.

Figure A.8. Average Aqueous ^{99}Tc Concentrations for Different Sorption Reaction Times up to 370 Days using T19 (a), T20 (b), and T21(c) crushed LSWG Material. The blue, red, and green symbols indicate aqueous ^{99}Tc concentrations at different reaction times with initial ^{99}Tc concentrations of 2.5, 10, and 25 $\mu\text{g/L}$, respectively. The error bars are the standard deviation of the average, calculated from triplicate sample measurements.

Table A.14. pH and E_h Results from the Extended ^{99}Tc Solubility Tests for Crushed T19, T20, and T21 Monoliths

Sample ID	pH	E_h (mV)	Sample ID	pH	E_h (mV)
SOL-T19-S1-Tc2.5-D210	12.5	-365.8	SOL-T19-S2-Tc10-D370	11.7	-493.7
SOL-T19-S2-Tc2.5-D210	12.5	-340.2	SOL-T19-S3-Tc10-D370	11.7	-498.9
SOL-T19-S3-Tc2.5-D210	12.6	-480.5	SOL-T19-C1-Tc10-D370	10.9	-424.8
SOL-T19-S1-Tc10-D210	12.5	-513.4	SOL-T19-S1-Tc25-D370	11.7	-493.7
SOL-T19-S2-Tc10-D210	12.6	-521.6	SOL-T19-S2-Tc25-D370	11.7	-504.5
SOL-T19-S3-Tc10-D210	12.6	-570.6	SOL-T19-S3-Tc25-D370	12.5	-397.2
SOL-T19-S1-Tc25-D210	12.6	-566.7	SOL-T19-C1-Tc25-D370	11.8	-318.3
SOL-T19-S2-Tc25-D210	12.6	-483.7	SOL-T20-S1-Tc2.5-D370	12.4	-438.0
SOL-T19-S3-Tc25-D210	12.5	-573.4	SOL-T20-S2-Tc2.5-D370	12.4	-445.7
SOL-T20-S1-Tc2.5-D210	12.5	-584.0	SOL-T20-S3-Tc2.5-D370	12.4	-449.6
SOL-T20-S2-Tc2.5-D210	12.5	-538.4	SOL-T20-C1-Tc2.5-D370	12.7	-379.0
SOL-T20-S3-Tc2.5-D210	12.5	-558.1	SOL-T20-S1-Tc10-D370	12.4	-460.9
SOL-T20-S1-Tc10-D210	12.6	-551.3	SOL-T20-S2-Tc10-D370	12.4	-470.7
SOL-T20-S2-Tc10-D210	12.5	-483.1	SOL-T20-S3-Tc10-D370	12.4	-472.7
SOL-T20-S3-Tc10-D210	12.5	-522.1	SOL-T20-C2-Tc10-D370	11.6	-414.9
SOL-T20-S1-Tc25-D210	12.6	-561.5	SOL-T20-S1-Tc25-D370	12.3	-380.5
SOL-T20-S2-Tc25-D210	12.5	-578.6	SOL-T20-S2-Tc25-D370	12.3	-402.8
SOL-T20-S3-Tc25-D210	12.5	-580.0	SOL-T20-S3-Tc25-D370	12.4	-410.6
SOL-T21-S1-Tc2.5-D210	12.1	-586.6	SOL-T20-C1-Tc25-D370	11.7	-328.3
SOL-T21-S2-Tc2.5-D210	12.1	-572.1	SOL-T21-S1-Tc2.5-D370	11.9	-378.2
SOL-T21-S3-Tc2.5-D210	12.0	-539.2	SOL-T21-S2-Tc2.5-D370	11.8	-399.8
SOL-T21-S1-Tc10-D210	12.0	-572.0	SOL-T21-S3-Tc2.5-D370	11.8	-411.3
SOL-T21-S2-Tc10-D210	12.1	-583.0	SOL-T21-C1-Tc2.5-D370	11.5	-374.3
SOL-T21-S3-Tc10-D210	12.0	-586.6	SOL-T21-S1-Tc10-D370	11.8	-420.5
SOL-T21-S1-Tc25-D210	12.1	-588.9	SOL-T21-S2-Tc10-D370	11.8	-427.9
SOL-T21-S2-Tc25-D210	12.0	-589.9	SOL-T21-S3-Tc10-D370	11.8	-438.8 ^(a)
SOL-T21-S3-Tc25-D210	12.0	-595.0	SOL-T21-C1-Tc10-D370	11.5	-337.6 ^(a)
SOL-T19-S1-Tc2.5-D370	11.6	-443.2	SOL-T21-S1-Tc25-D370	11.8	-272.0 ^(a)
SOL-T19-S2-Tc2.5-D370	11.6	-474.4	SOL-T21-S2-Tc25-D370	11.8	-321.2 ^(a)
SOL-T19-S3-Tc2.5-D370	11.6	-476.7	SOL-T21-S3-Tc25-D370	11.9	-332.0 ^(a)
SOL-T19-C1-Tc2.5-D370	10.8	-401.6	SOL-T21-C1-Tc25-D370	11.5	-305.3 ^(a)
SOL-T19-S1-Tc10-D370	11.6	-505.9			

Label format for ^{99}Tc solubility test: SOL-T19/20/21(for monolith number)-S1/2/3(for triplicates; C1/2/3 for the triplicate controls [no cementitious material present])-Tc2.5/10/25(for initial Tc concentration of 2.5, 10, or 25 ppb)-D14/30/51(for different reaction times)

(a): E_h values are for information purposes only because probe calibration checks were not performed after sample measurement, thus the values are uncertain.

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