PNNL-26443
RPT-SWCS-009, Rev 0

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# Updated Liquid Secondary Waste Grout Formulation and Preliminary Waste Form Qualification

**July 2017**

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R Sahajpal

U.S. DEPARTMENT OF
ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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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 $^{99}$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 **$^{99}$Tc $D_{eff}$ ($10^{-9}$ 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 $^{99}$Tc(IV) to be $7.1 \times 10^{-9}$ M – $1.1 \times 10^{-8}$ 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, $Na_2SO_4 \cdot 10H_2O$), 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 µg/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 $^{99}$Tc(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 µg/L) did not converge on a single final concentration value. An overall average value range for solubility of $^{99}$Tc(IV) can be reported as $7.1 \times 10^{-9}$ M – $1.1 \times 10^{-8}$ 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(°C) = T(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, $10^{-6}$) |

# Contents

# Figures

# Tables

# 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 [$Ca_6Al_2(SO_4)_3(OH)_{12} \bullet 26(H_2O)$] 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 µS/cm standard, and then checked with a range of potassium chloride standard solutions, ranging from 100 µS/cm to 10,000 µS/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 Kα radiation ($\lambda$ = 1.5418 Å with 40 kV and 15 mA) source. The bulk samples were homogenized by grinding in an agate mortar and pestle, then ~10 wt% $TiO_2$ 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 2θ. 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 $TiO_2$ standard.

### 2.2.2 Single-Particle Digital Autoradiography (iQID)

Single-particle digital autoradiography experiments assessed the spatial distribution of $^{99}Tc$ 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 × 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 $^{127}I$ (as a surrogate of $^{129}I$) was added to the simulant and then $^{99}Tc$ 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)] |
|---|---|---|
| *Radionuclides* | | |
| | 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 $^{127}I$ and $^{99}Tc$ concentrations in the prepared simulant were increased to levels much higher than target concentration values (Table 3.2) to ensure that $^{127}I$ and $^{99}Tc$ 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 $^{127}I$ and $^{99}Tc$, respectively. $^{127}I$ was added to the entire 25-kg batch of simulant. The amount of $^{99}Tc$ needed was preliminarily calculated and added to a 10.9 kg subsample of batch simulant using a ~10,000 ppm $^{99}Tc$ $NH_4TcO_4$ stock solution. The actual $^{99}Tc$ 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 |
| $(NH_4)_2SO_4$ | 53.22 |
| $Na_2SO_4$•$10H_2O$ | 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 |
| $(NH_4)_2SO_4$ | 4244.20 |
| $Na_2SO_4$•$10H_2O$ | 5565.70 |
| Density ($g/cm^3$) | 1.22 |
| Wt% total solids | 30.04 |

## 3.3 Simulant Analysis Results

The $^{99}$Tc-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, $^{127}$I, and $^{99}$Tc 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 $^{127}$I concentration was not identified. In addition, the measured result for $^{99}$Tc 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 $^{127}$I and $^{99}$Tc 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 ($Sn_xCa_y(PO_4)(OH,Cl,F)$) (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 [$Ca(OH)_2$], 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 [$Ca(OH)_2$], 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 µm pellets. The pellets were crushed with a mortar and pestle to a size < 300 µm 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.

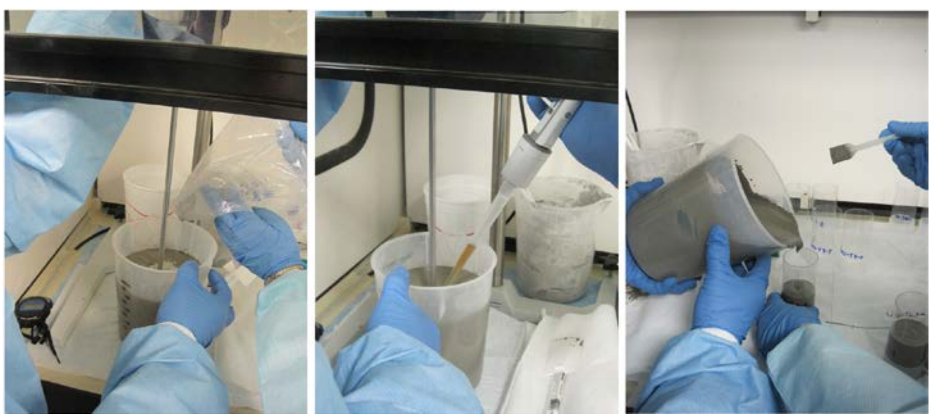

**Figure 4.1**. Homogeneous Grout Slurry Mixing (left), Adding MG 3030 (middle), and Filling Form with Grout Slurry (right)

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 × 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.

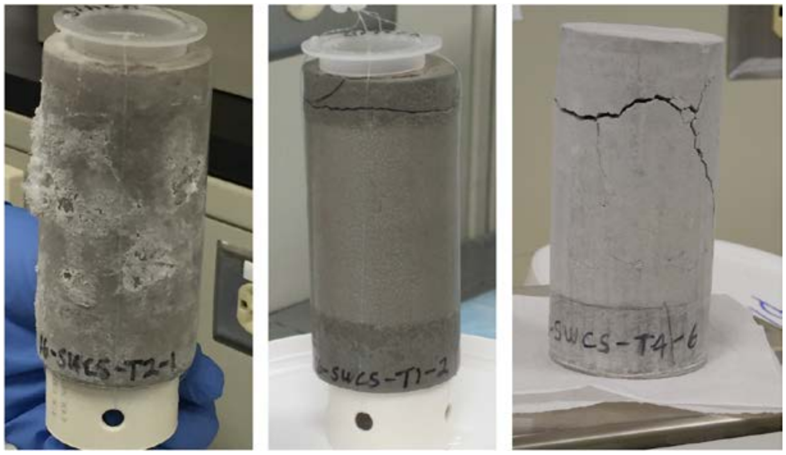

**Figure 4.2**. 28-Day Cured T2 Monolith with White Precipitates on the Surface (left), 28-Day Cured T1 Monolith with Cracks (middle), and 60-Day Cured T4 Grout Monolith with Cracks (right)

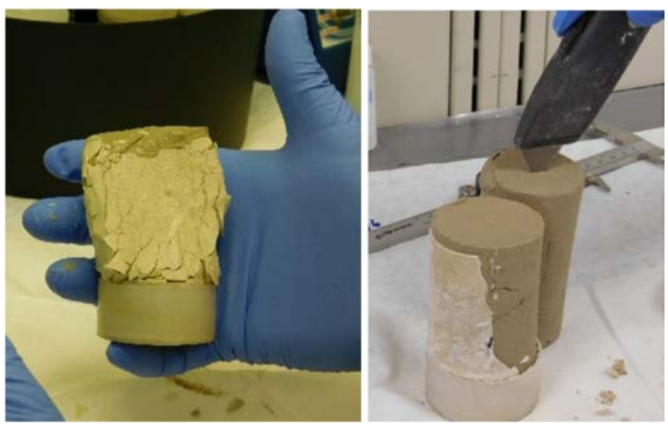

**Figure 4.3**. 28-Day Cured T5 Monolith for the Current Cast Stone Formulation (left) and 60-Day Cured T5 Monolith for the Current Cast Stone Formulation (right)

### 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, $Na_2SO_4 \cdot 10H_2O$) 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, $SO_4^{2-}$ = 241 g/L (See Table 3.5), is much higher than that of WTP-treated off-gas condensate, $SO_4^{2-}$ = 122 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.

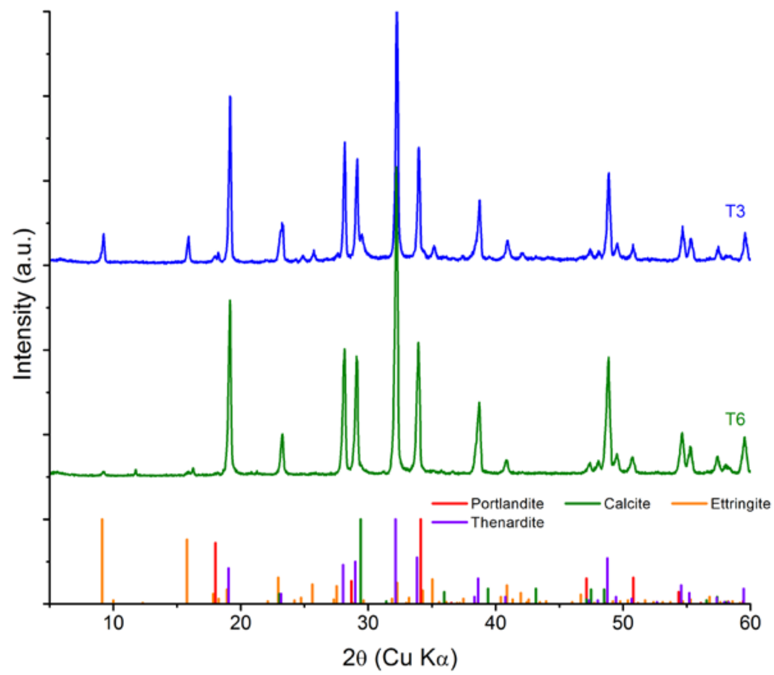


**Figure 4.4**. XRD Patterns of White Precipitates Formed on T3 and T6 60-Day Cured Monoliths. XRD patterns of thenardite ($Na_2SO_4$) and mirabilite (hydrated thenardite, $Na_2SO_4 \bullet 10H_2O$) are identical.

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 [$Ca_6Al_2(SO_4)_3(OH)_{12} \bullet 26H_2O$] 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 [$CaSO_4 \bullet 2H_2O$] 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.

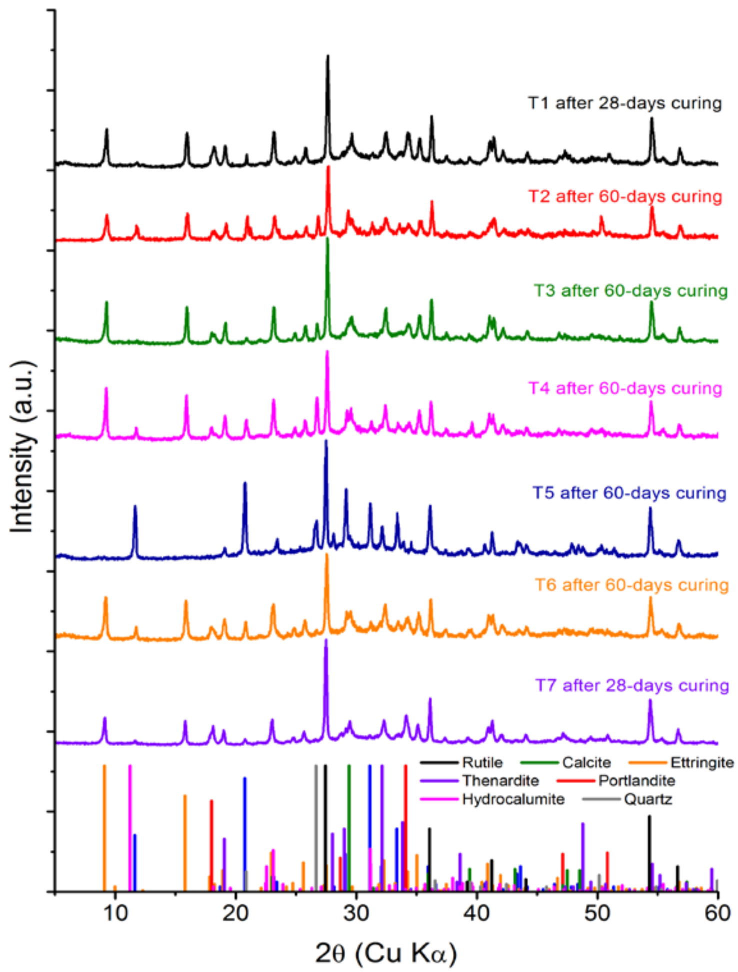


**Figure 4.5**. XRD Patterns of Monoliths with Different Curing Durations (28 and 60 Days)

**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 [$Ca_6Al_2(SO_4)_3(OH)_{12}{\bullet}26H_2O$], portlandite [$Ca(OH)_2$], calcite [$CaCO_3$], larnite [$Ca_2SiO_4$], thenardite [$Na_2SO_4$], hydrocalumite [$Ca_4Al_2(OH)_{12}(OH)_2{\bullet}6H_2O)$], gypsum [$CaSO_4{\bullet}2H_2O$], and quartz [$SiO_2$]
b. CSH : calcium silicon hydrated amorphous phase
c. Non-$^{99}$Tc-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 ± 3 °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 ± 3 °C using Equation (4.1) below:

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

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 − [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 $^{99}$Tc-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-013 [2], “Preparation of Secondary Waste Grout Monolith Specimens,” and has the same formulation as T1, but was not spiked with $^{99}$Tc. 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 ($HNO_3$) 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 $HNO_3$ concentrations were prepared using $HNO_3$ 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 $HNO_3$ 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 $HNO_3$ because of the small amount of $HNO_3$ 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 $^{99}$Tc 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-fractioned 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<br>mS/cm | $E_h$[(a)]<br>mV | [$^{99}Tc$]<br>µg/g | [$^{127}I$]<br>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 (µg/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 µg/g) and maximum (5.860 µg/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 µg/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 µg/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 |
|---|---|---|---|---|---|---|---|
| | µg/L | µg/L | µg/L | µg/L | µg/L | µg/L | µg/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 µg/L).

Released $^{127}I$ remained generally constant, between 35 and 40 µg/g, over the tested pH range (Table 5.2 and Figure 5.1D), except with an approximate 14 to 18 µg/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 µg/g) beyond the initial concentration (35.5 µg/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 $10^4$ µg/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 $Fe(OH)_3(s)$ precipitation, as previously mentioned. Finally, Mg concentrations steadily increase with decreasing pH as the solid material dissolves, releasing cations into solution.

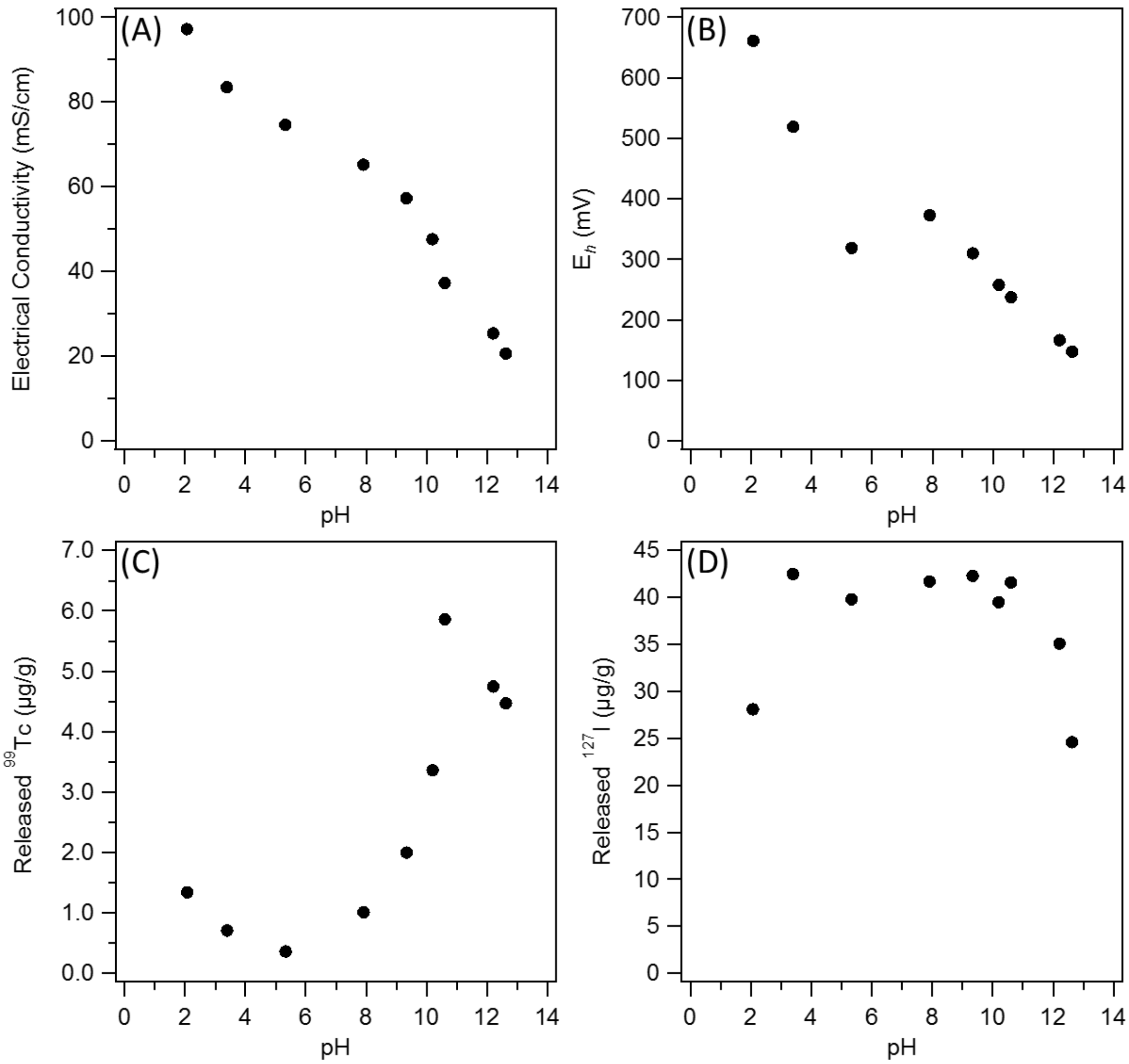


**Figure 5.1**. Secondary Waste Monolith T1 EPA Method 1313 Results for (A) Electrical Conductivity, (B) $E_h$, (C) Released $^{99}$Tc, and (D) Released $^{127}$I as a Function of final pH.

# 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 $9 \pm 1$ mL/cm$^2$. 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., $^{99}$Tc, $^{127}$I, $NO_3^-$, and $Na^+$) and overall chemical composition. Analytical methods used include ICP-OES for cation concentrations, ICP-MS for $^{99}$Tc and $^{127}$I concentrations, and IC for anion concentrations.

Initial concentrations, C(0), of the constituents of interest in the pre-leached LSWGs, specifically $^{99}$Tc, $^{127}$I, $NO_3^-$, and $Na^+$, are given in Table 6.1. Initial $^{99}$Tc, $^{127}$I, $NO_3^-$, 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 $^{99}$Tc and relatively negligible $^{127}$I, $NO_3^-$, or $Na^+$ sources in the dry ingredients. Although the spiked $^{127}$I concentration is much higher than the actual $^{129}$I concentration in the Hanford waste stream, the highest $^{127}$I loading in this report (~0.05 wt%, Table 6.1) is lower than the $^{127}$I concentration limit (0.14 wt%) determined to impact the loading sensitivity of $^{127}$I leaching (Serne et al. 2015). However, excess $^{127}$I may affect the geochemical behavior of $^{127}$I, 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.

$$D_{eff} = 10000 * D_{obs(i)} = \pi\left[\frac{M_{ti}}{2\rho C_0\,(\sqrt{t_i}-\sqrt{t_{i-1}})}\right]^2 \quad (6.1)$$

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 (mg/kg-dry)
- $\rho$ = grout dry bulk density (kg-dry/$m^3$), 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 $\beta$ is a defined constant (1.0 $cm^2/s$) from ANSI/ANS-16.1 (ANSI/ANS 2003). A low diffusivity results in a larger LI.

$$LI_i = \frac{1}{n}\sum_1^n\left[\log\left(\frac{\beta}{D_i}\right)\right]_n \quad (6.2)$$

## 6.2 Results and Discussion

The calculated effective diffusivity coefficients ($D_{eff}$) and LI values for $^{99}Tc$, $^{127}I^-$, $NO_3^-$, 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 µg/L) and IC for $NO_3^-$ (<12.5 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 $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | T3-5 for $^{99}Tc$ LI [-] | T3-6 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | T3-6 for $^{99}Tc$ LI [-] | T3-5 for $^{127}I$ $D_{eff}$ ($cm^2/s$) | T3-5 for $^{127}I$ LI [-] | T3-6 for $^{127}I$ $D_{eff}$ ($cm^2/s$) | T3-6 for $^{127}I$ LI [-] | T3-5 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | T3-5 for $NO_3^-$ LI [-] | T3-6 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | T3-6 for $NO_3^-$ LI [-] | T3-5 for $Na^+$ $D_{eff}$ ($cm^2/s$) | T3-5 for $Na^+$ LI [-] | T3-6 for $Na^+$ $D_{eff}$ ($cm^2/s$) | T3-6 for $Na^+$ 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 $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | T4-5 for $^{99}Tc$ LI [-] | T4-6 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | T4-6 for $^{99}Tc$ LI [-] | T4-5 for $^{127}I$ $D_{eff}$ ($cm^2/s$) | T4-5 for $^{127}I$ LI [-] | T4-6 for $^{127}I$ $D_{eff}$ ($cm^2/s$) | T4-6 for $^{127}I$ LI [-] | T4-5 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | T4-5 for $NO_3^-$ LI [-] | T4-6 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | T4-6 for $NO_3^-$ LI [-] | T4-5 for $Na^+$ $D_{eff}$ ($cm^2/s$) | T4-5 for $Na^+$ LI [-] | T4-6 for $Na^+$ $D_{eff}$ ($cm^2/s$) | T4-6 for $Na^+$ 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 $0.5 \pm 0.15$).

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 ~$10^{-7.9}$ (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 (~$10^{-12.0}$) (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, $Na_2SO_4 \cdot 10H_2O$ (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 $0.5 \pm 0.15$) 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 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $^{99}Tc$ $D_{eff}$ [cm$^2$/s] | F[(a)] | $I^-$ $D_{eff}$ [cm$^2$/s] | F | $NO_3^-$ $D_{eff}$ [cm$^2$/s] | F | $Na^+$ $D_{eff}$ [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 $D_{eff}$ [$cm^2/s$] | F[(a)] | $I^-$ $D_{eff}$ [$cm^2/s$] | F | $NO_3^-$ $D_{eff}$ [$cm^2/s$] | F | $Na^+$ $D_{eff}$ [$cm^2/s$] | 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, $^{99}$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, $^{99}$Tc $D_{eff}$ values after 28-day leaching still show relatively low $D_{eff}$ values, with a range of $10^{-9}$ to $10^{-14}$ $cm^2/s$, which is much lower than average $D_{eff}$ values for nonreactive $NO_3^-$, ~$10^{-9}$ $cm^2/s$ (Table 6.7). Only T3 monoliths, cured 28 or 60 days, showed relatively high $^{99}$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 $^{99}$Tc $D_{eff}$ values compared to the other LSWG formulations. T1 and T2 monoliths showed the lowest $^{99}$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.

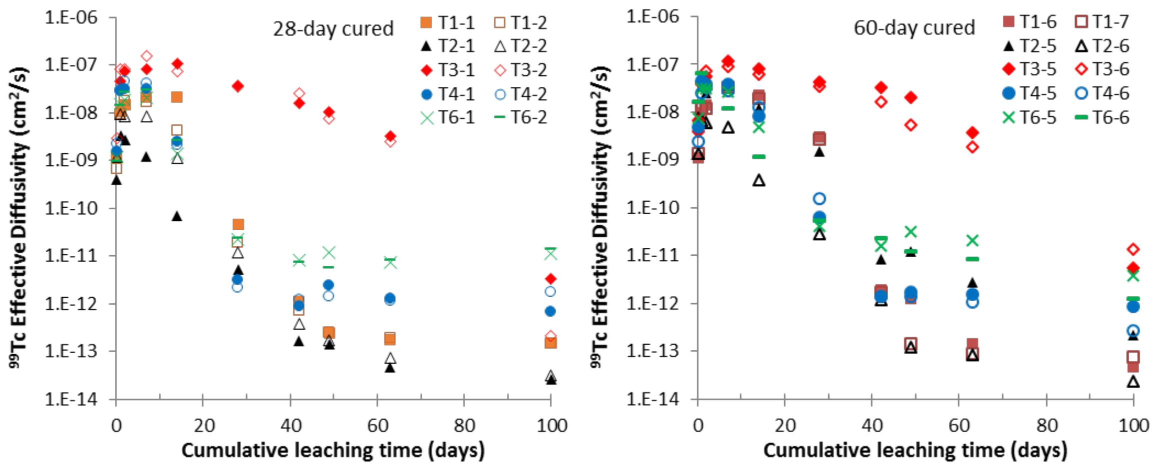


**Figure 6.2**. Effective Diffusivity Values of $^{99}$Tc from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in DIW (left: 28 days; right: 60 days)

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 $^{99}$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.

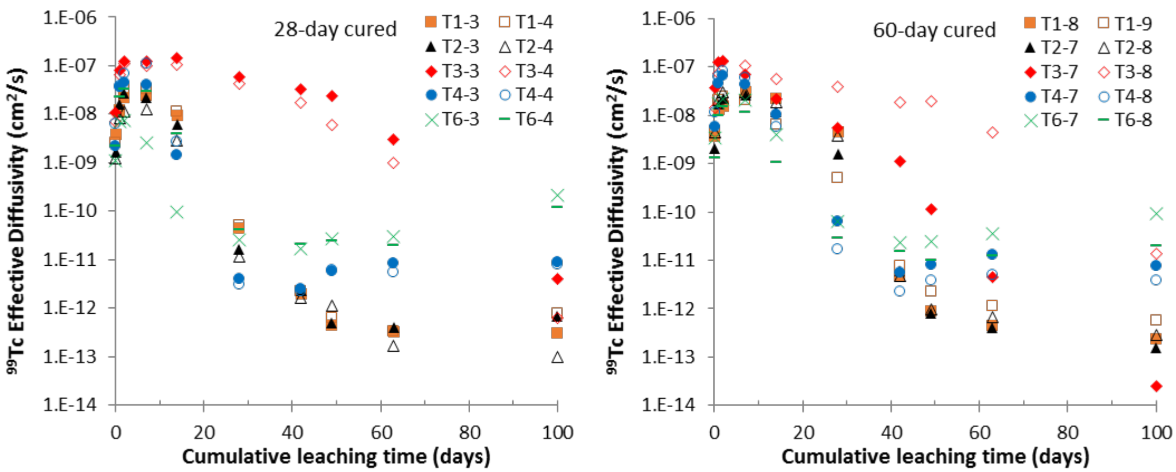


**Figure 6.3**. Effective Diffusivity Values of $^{99}$Tc from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in VZPW (left: 28 days; right: 60 days)

### 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.

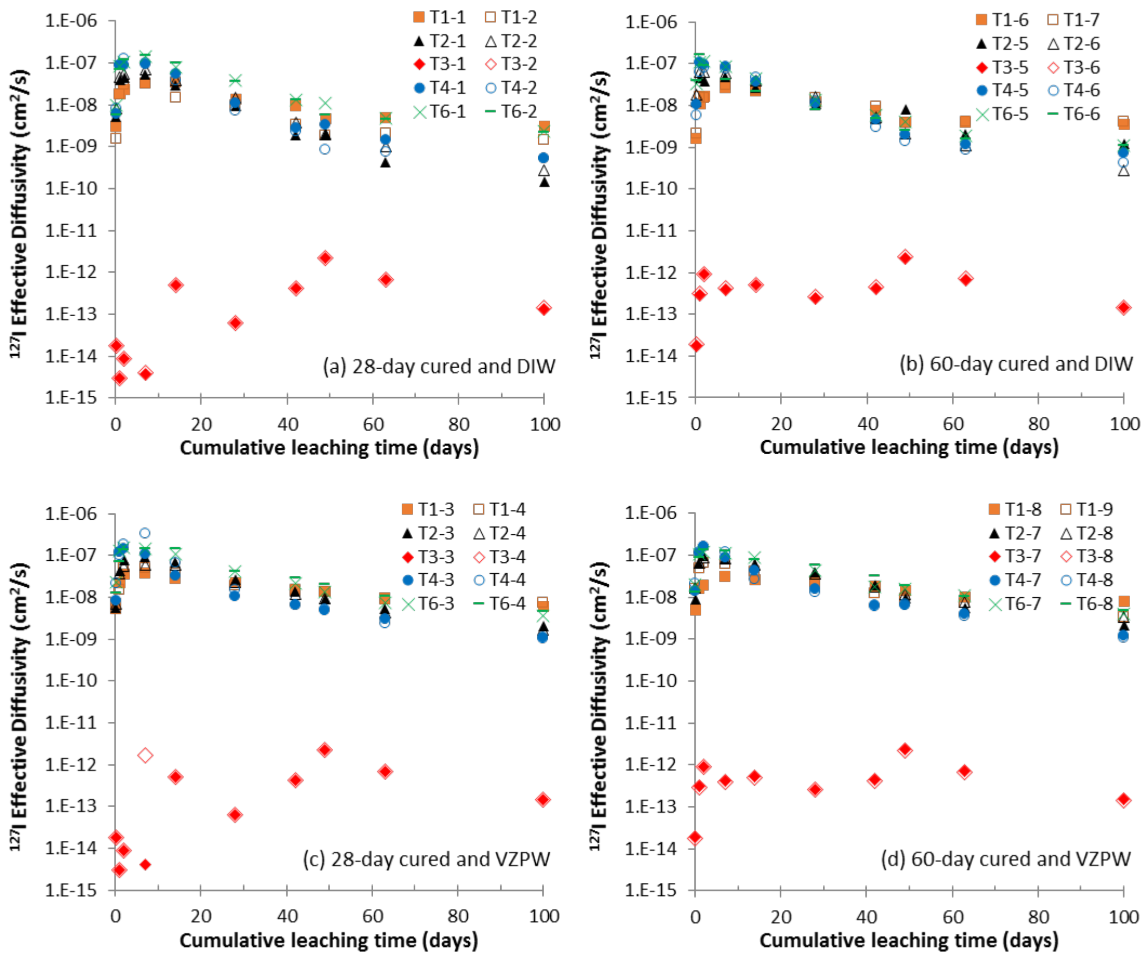


**Figure 6.4**. Effective Diffusivity Values of $^{127}$I from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in DIW or VZPW

### 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.

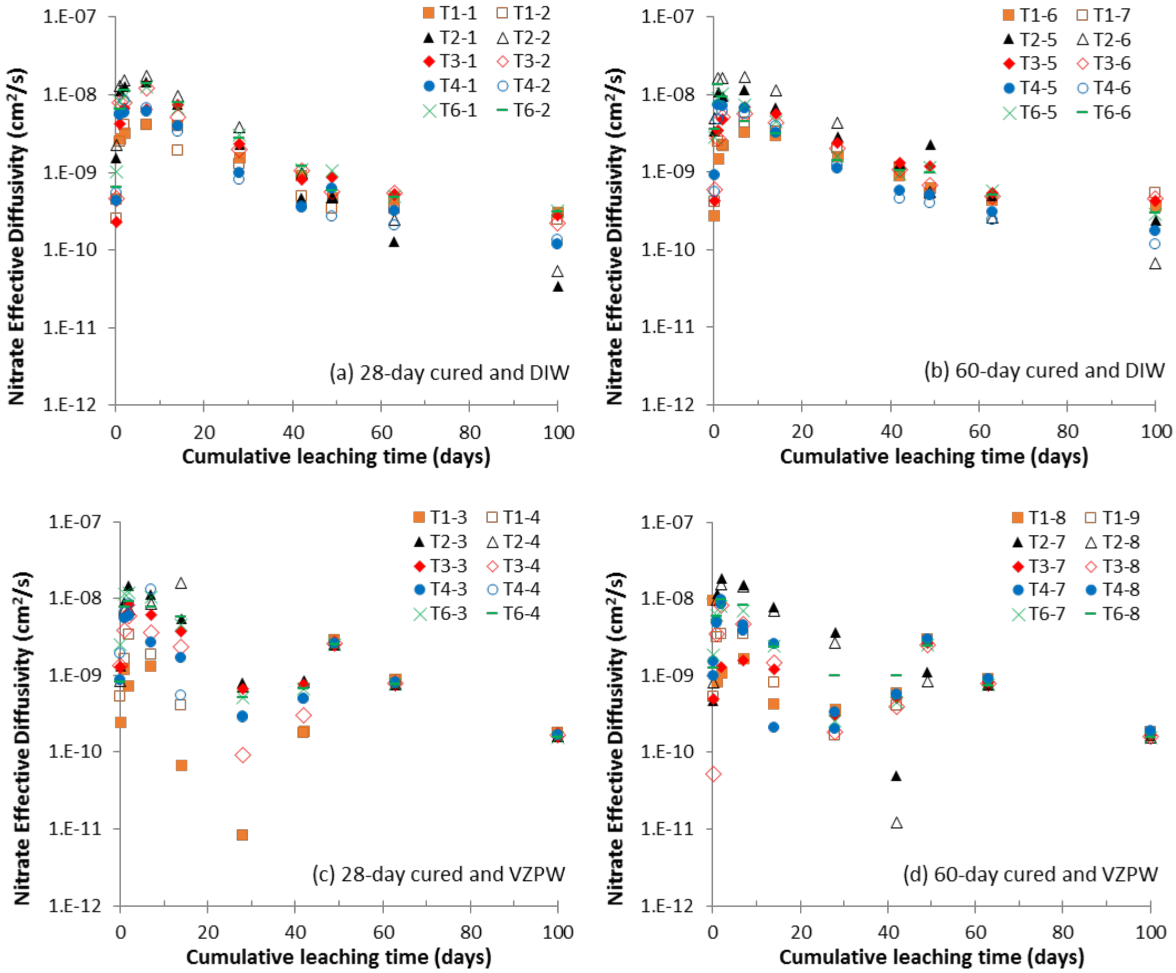


**Figure 6.5**. Effective Diffusivity Values of Nitrate from the Monoliths Prepared with Different Curing Times for the Cumulative 100-Day Leaching in DIW or VZPW

### 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, $Na_2SO_4 \cdot 10H_2O$), 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 [$Ca_6Al_2(SO_4)_3(OH)_{12}{\bullet}26H_2O$] 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 [$Ca_6Al_2(SO_4)_3(OH)_{12}\bullet 26H_2O$], portlandite [$Ca(OH)_2$], calcite [$CaCO_3$], larnite [$Ca_2SiO_4$], brucite [$Mg(OH)_2$], hydrocalumite [$Ca_4Al_2(OH)_{12}(OH)_2\bullet 6H_2O)$], dolomite [$CaMg(CO_3)_2$], gypsum [$CaSO_4\bullet 2H_2O$], and quartz [$SiO_2$]

(b) CSH: calcium silicon hydrated amorphous phase

(-) not detected

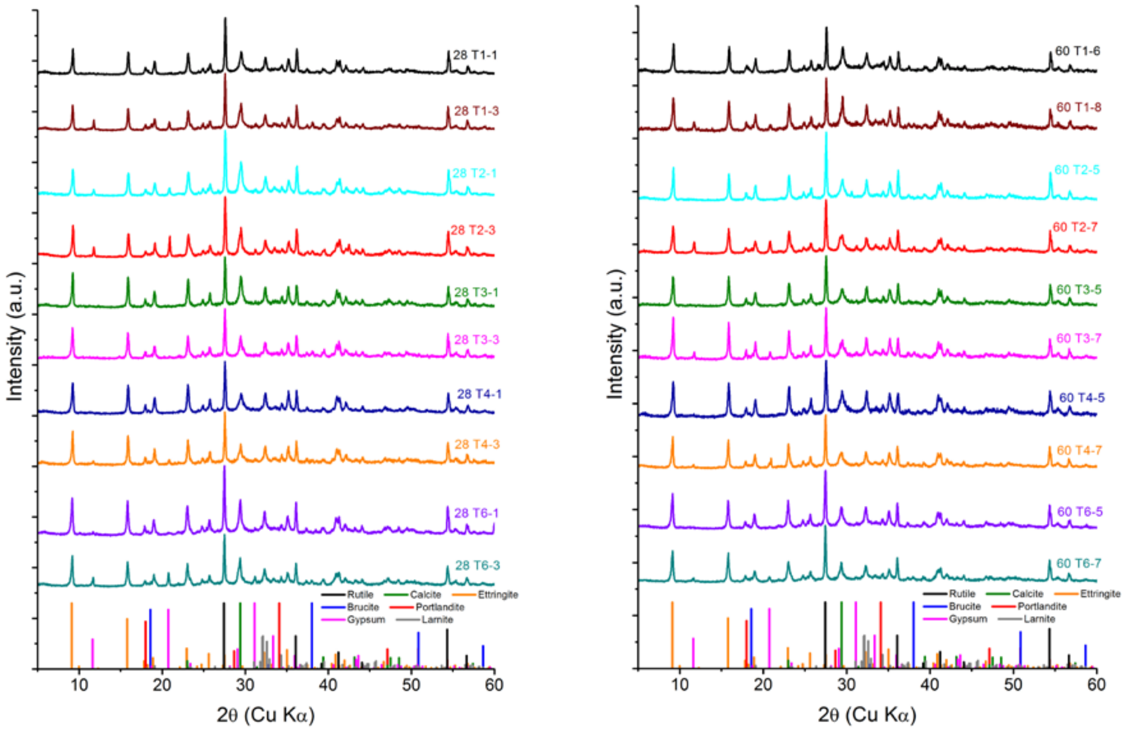


**Figure 6.6**. XRD Patterns of 100-Day Leached White Precipitates Formed on the 28-Day Cured (left) and 60-Day Cured (right) Monoliths after 100-Day Leaching

# 7.0 $^{99}$Tc Desorption $K_d$ Measurements

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

## 7.1 Methods and Materials

For all $^{99}$Tc sorption and desorption tests, non-$^{99}$Tc-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 $^{99}$Tc Sorption and Desorption $K_d$ using Three Aliquots of Non-$^{99}$Tc-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 $N_2$ (98%) and $H_2$ (2%) gases and with a palladium catalyst to maintain an $O_2$-free environment (<20 ppm $O_2$). 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 $^{99}$Tc Sorption Phase Using non-$^{99}$Tc-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 $^{99}$Tc 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 $^{99}$Tc 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 $N_2$ (98%) and $H_2$ (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 $^{99}$Tc using $NaTcO_4$ (or $NH_4TcO_4$) stock solution to achieve a final concentration of 1 ppb $^{99}$Tc.

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 $Ca(OH)_2$ 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 $Ca(OH)_2$ 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:

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

where $C_i$ is the initial aqueous total $^{99}Tc$ concentration (µg/mL) in the supernatant determined from the control samples, $C_t$ is the final aqueous equilibrated $^{99}Tc$ concentration (µg/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 $Ca(OH)_2$-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 $Ca(OH)_2$-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 $Ca(OH)_2$-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 $^{99}$Tc 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 $^{99}$Tc $K_d$ was calculated using Equation (7.2),

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

where $C_s$ is the final $^{99}$Tc concentration (µg/g) on the solid after the desorption test. $C_s$ is determined by taking the difference between the initially sorbed $^{99}$Tc mass on the solids after the sorption phase of the test and the final $^{99}$Tc mass in the desorption solution at steady state. $C_t$ is the final aqueous $^{99}$Tc concentration for the desorption test (µg/mL), and $m_r$ is the remaining $^{99}$Tc mass (µg) in the sorption tube before starting the desorption experiment. $m_r$ was calculated by multiplying the desorption aqueous total $^{99}$Tc 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 $^{99}$Tc mass on the solid at the start of the desorption experiment. To determine the total $^{99}$Tc mass on the solid at the start of the desorption experiment, the average total $^{99}$Tc concentration determined from the sorption control samples was multiplied by the starting sorption supernatant volume, and any $^{99}$Tc 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 $^{99}$Tc Sorption on Non-$^{99}$Tc-Spiked Monolith Crushed Material

All $^{99}$Tc sorption tests were conducted inside an anoxic chamber to maintain reducing conditions. The pH and $E_h$ values of the initial $^{99}$Tc (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 $^{99}$Tc (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 $^{99}$Tc concentrations measured in the supernatant collected from sorption supernatants after 30 days of testing are presented in Figure 7.1. The initial concentration of $^{99}$Tc present in solution, 1.19 µg/L, is the average concentration calculated from the measured $^{99}$Tc concentrations for the three control samples and is close to the target $^{99}$Tc concentration of 1.0 µg/L. Furthermore, this concentration and the absence of visible precipitates, e.g., black $TcO_2$(s), suggests that $^{99}$Tc remains soluble in the control samples and that the reducing conditions used are not low enough to facilitate $TcO_2$(s) precipitation. For all sorption samples containing T7 monolith powders, the measured $^{99}$Tc concentration in the supernatant was below 0.066 µg/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 ± 1 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 µg/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 | |
| KS-S2-D30 | 12.6 | −431 | 166 | KD-S2-D30 | 12.5 | 146.2 | 21.4 | 21.7 ± 0.6 |
| 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 | |
| KS-S2-D60 | 12.6 | −440 | 166 | KD-S2-D60 | 12.4 | 156.9 | 22.3 | 22.1 ± 0.8 |
| 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 | |
| KS-S2-D120 | 12.7 | −436 | 166 | KD-S2-D120 | 12.2 | 159.2 | 28.1 | 24.0 ± 3.6 |
| 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 | |
| KS-S2-D150 | 12.6 | −425 | 166 | KD-S2-D150 | 12.2 | 162.9 | 35.7 | 35.0 ± 0.9 |
| 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.

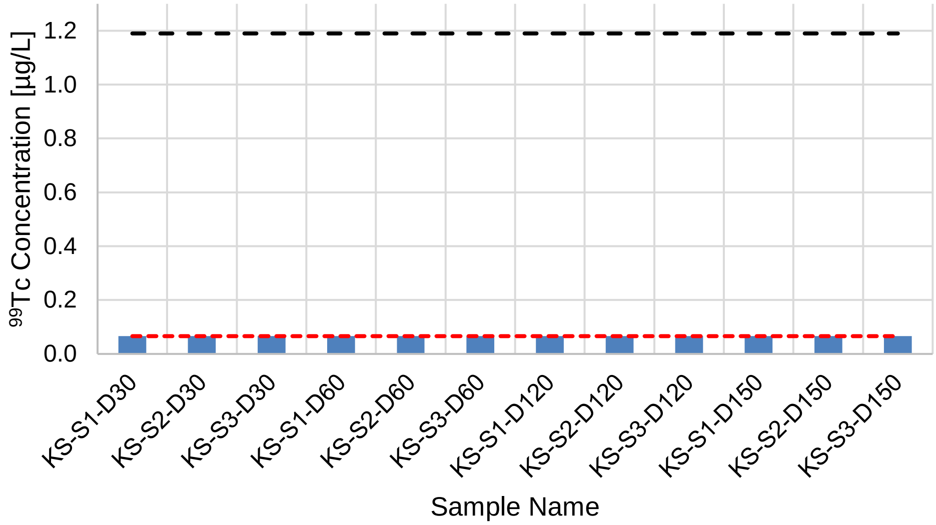


**Figure 7.1**. $^{99}$Tc Concentrations in the Supernatants after 30-Day Sorption Testing. The black dashed line indicates the average initial $^{99}$Tc concentration [µg/L] in the supernatant at the start of sorption testing determined from the average concentration values for control samples (KS-C1,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

### 7.2.2 $^{99}$Tc Desorption $K_d$s using $^{99}$Tc Sorbed Monolith Powders

The wet slurry remaining from the $^{99}$Tc sorption phase of testing was used for $^{99}$Tc 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, $^{99}$Tc concentrations above the EQL level were measured and are shown in Figure 7.2. These values were used to determine individual sample $^{99}$Tc desorption $K_d$ values and average $K_d$ values for each desorption testing period, which are reported in Table 7.1. Interestingly, the average $^{99}$Tc 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 $^{99}$Tc desorption $K_d$ after 120 days implies that less $^{99}$Tc partitions into the aqueous phase and that some $^{99}$Tc 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 $^{99}$Tc 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 $^{99}$Tc desorption, and possible resorption, reaches equilibrium. Finally, the average $^{99}$Tc 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.

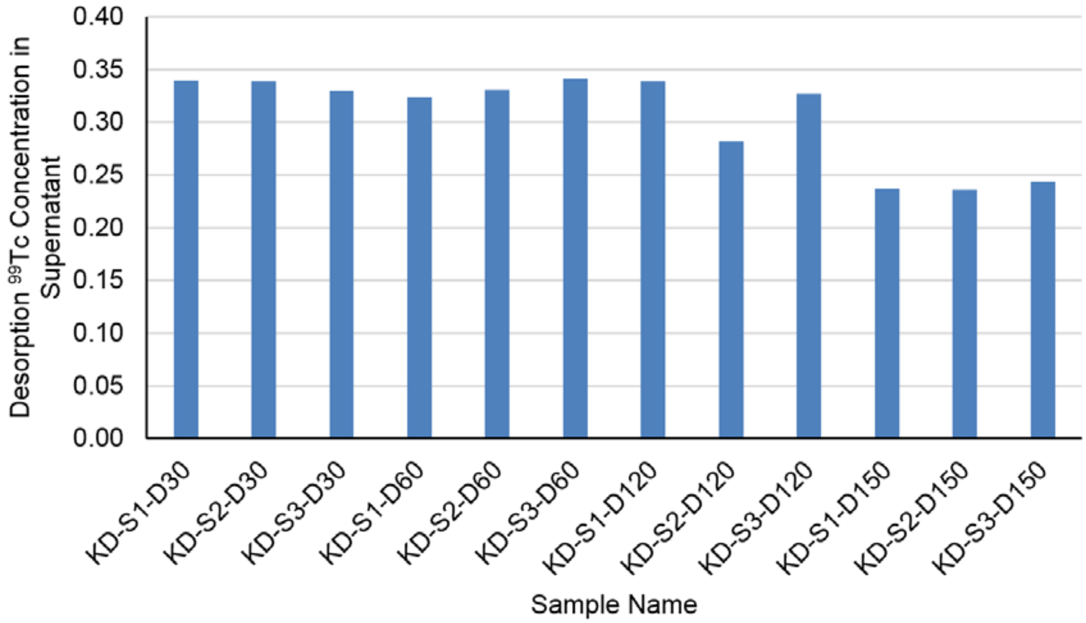


**Figure 7.2**. $^{99}$Tc Concentrations (µg/L) Measured in the Filtered Supernatants Collected after Desorption Testing Periods. Sample names containing D60, D120, and D150 correspond with actual testing times equal to 54, 90, and 120 days, respectively.

# 8.0 $^{99}$Tc Solubility Measurements

This section presents $^{99}$Tc (mol/L) solubility measurements for size-reduced non-$^{99}$Tc-spiked (T7) and $^{99}$Tc-spiked (T1) monolith material contacted with simulated pore water solutions spiked with various concentrations of $^{99}$Tc. 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 $^{99}$Tc concentration is controlled by the solubility of a $^{99}$Tc(IV)-bearing solid phase, then the $^{99}$Tc equilibrium concentration should be independent of the initial $^{99}$Tc 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-$^{99}$Tc-spiked (T7) and crushed $^{99}$Tc-spiked (T1) LSWG were used to provide a direct comparison between $^{99}$Tc solubility in the presence and absence of $^{99}$Tc within the cured LSWG. The aqueous $^{99}$Tc concentrations in the supernatant collected from each batch test are expected to converge to a single $^{99}$Tc concentration after achieving steady state, despite different starting aqueous $^{99}$Tc concentrations, under reducing and fixed pH conditions (Estes et al. 2012).

## 8.1 Methods and Materials

### 8.1.1 Material Preparation

All $^{99}$Tc batch solubility experiments were conducted in an anoxic chamber filled with a mixture of $N_2$ (98%) and $H_2$ (2%) gases, and with two palladium catalysts that convert $O_2$(g) to water via reaction with $H_2$(g). After curing for 28 days, LSWG monoliths T1 ($^{99}$Tc spiked) and T7 (non-$^{99}$Tc 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 $^{99}$Tc-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 $^{99}$Tc(VII). Specifically, three solutions were prepared with $^{99}$Tc(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 $^{99}$Tc stock solution to 1,250 mL of pre-equilibrated saturated $Ca(OH)_2$ solutions, respectively.

### 8.1.2 $^{99}$Tc Solubility Measurements

In 50 mL centrifuge tubes, 40 mL of $^{99}$Tc(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 $^{99}$Tc-spiked solution prepared and each monolith, T1 and T7. Triplicate reaction tubes for each crushed LSWG, each starting $^{99}$Tc concentration, and each reaction time were prepared. In addition, triplicate control samples (three for each of the three initial $^{99}$Tc concentrations, for a total of nine) consisting of 40 mL of the 2.0, 20, and 200 ppb $^{99}$Tc(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 $^{99}$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 µg/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 $^{99}$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 $^{99}$Tc(VII) to $^{99}$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 µg/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 µg/L, the $^{99}$Tc aqueous concentrations in the filtrates collected after 120 reaction days were 1.04, 1.24, and 1.23 µg/L, respectively, with an average value of 1.17 ± 0.11 µg/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 µg/L, for respective starting $^{99}$Tc aqueous concentrations 2.0, 20, and 200 µg/L, with an average value of 1.01 ± 0.24 µg/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 µg/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 µg/L, all the $^{99}$Tc aqueous concentrations in the filtrates were below the $^{99}$Tc detection limit for ICP-MS (0.033 µg/L) except the first sampling after 30 reaction days. For the batch experiment with a starting $^{99}$Tc aqueous concentration equal to 20 µg/L, nearly constant, low aqueous $^{99}$Tc concentrations of 0.08–0.1 µg/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 µg/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 µg/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 µg/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 $Ca(OH)_2$ contacting solution with initial $^{99}$Tc aqueous concentrations of 2.0 and 20 µg/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 µg/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 $0.71 \pm 0.07$ µg/L ($7.1 \pm 0.65 \times 10^{-9}$ 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 $\sim 1.1 \pm 0.12 \times 10^{-8}$ M, despite the different initial $^{99}$Tc concentrations (2.0, 20, and 200 µg/L). For the experiments with LSWG T7, the average value of $7.1 \pm 0.65 \times 10^{-9}$ M could also be considered to be controlled by the solubility of a $^{99}$Tc(IV)-bearing solid phase. An overall average value range for solubility of $^{99}$Tc(IV) can be reported as $7.1 \times 10^{-9}$ M to $1.1 \times 10^{-8}$ 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 $4.8 \times 10^{-9}$ 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 µg/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 $^{99}$Tc(IV) can be reported as $\sim 1.7 \pm 0.6 \times 10^{-9}$ M, which is lower than the $\sim 10^{-8}$ 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.

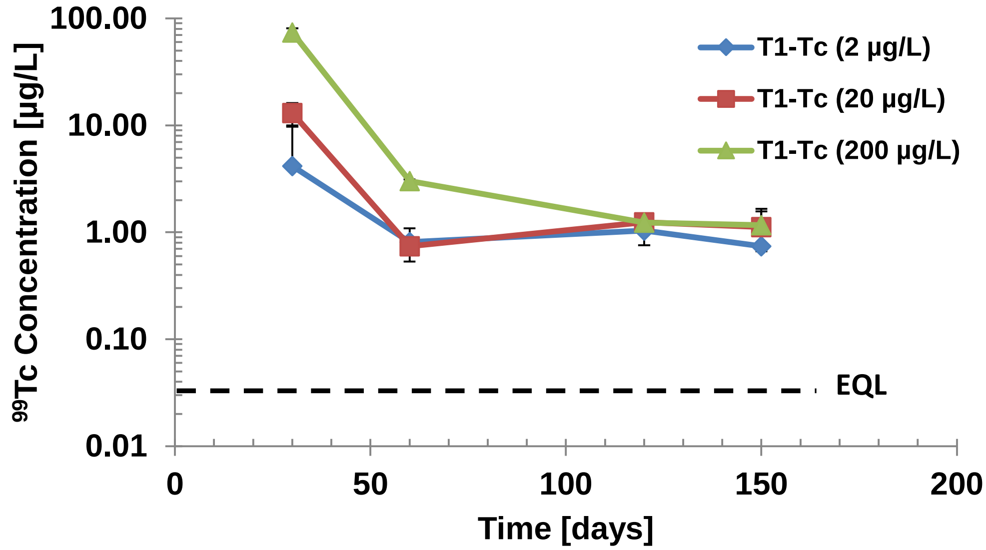


**Figure 8.1**. Average Aqueous $^{99}$Tc Concentrations for Different Sorption Reaction Times using T1 ($^{99}$Tc spiked) LSWG Monolith Material. The blue, red, and green symbols indicate sorption reactions spiked with initial $^{99}$Tc concentrations of 2.0, 20, and 200 µg/L, respectively. The error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

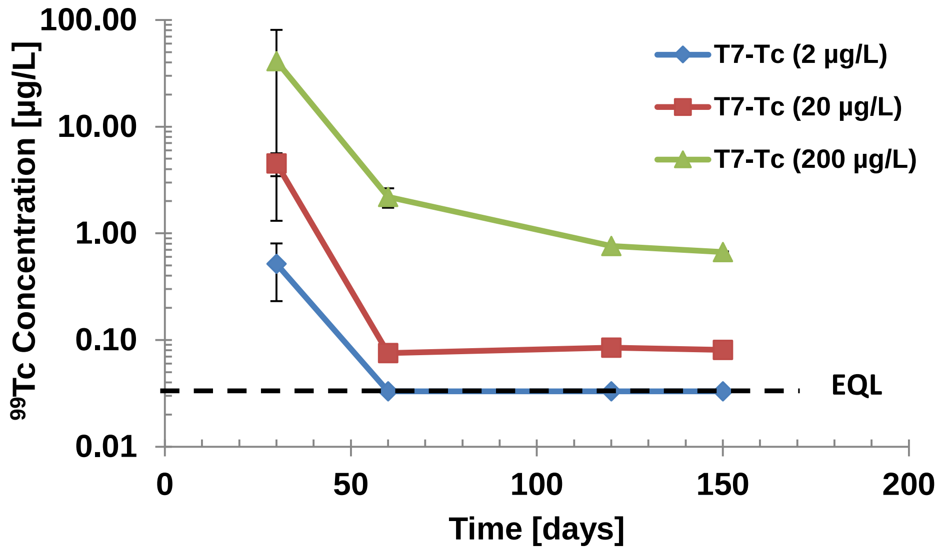


**Figure 8.2**. Average Aqueous $^{99}$Tc Concentrations for Different Sorption Reaction Times using T7 (non-$^{99}$Tc spiked) LSWG Monolith Material. The blue, red, and green symbols indicate sorption reactions spiked with initial $^{99}$Tc concentrations of 2.0, 20, and 200 µg/L, respectively. The 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 $^{99}Tc(IV)$-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 [$Ca_6Al_2(SO_4)_3(OH)_{12}\bullet 26(H_2O)$], 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, $Na_2SO_4 \bullet 10H_2O$), 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 [$Ca_6Al_2(SO_4)_3(OH)_{12} \bullet 26H_2O$] 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 ($CaSO_4 \bullet 2H_2O$) 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 $[Ca_6Al_2(SO_4)_3(OH)_{12}\bullet 26H_2O]$ 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 µg/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 µg/L), indicating a solubility control likely by a $^{99}Tc(IV)$-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 $^{99}Tc(IV)$-bearing solid phase; however, equilibrium aqueous $^{99}Tc$ concentrations for the different initial

$^{99}$Tc concentrations (2.0, 20, and 200 μg/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 $^{99}$Tc(IV) solids as $7.1 \times 10^{-9}$ M to $1.1 \times 10^{-8}$ 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 $4.8 \times 10^{-9}$ 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 | $7.1 \times 10^{-9}$ M – $1.1 \times 10^{-8}$ 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 ($Ca_6Al_2(SO_4)_3(OH)_{12}•26H_2O$), calcite ($CaCO_3$), and larnite ($Ca_2SiO_4$). The HL-based samples all contained portlandite ($Ca(OH)_2$) except T2-4 and T5-4. Leached monoliths that contained brucite ($Mg(OH)_2$) 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 µg/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 $^{99}$Tc(IV) can be reported as ~$1.7 \pm 0.6 \times 10^{-9}$ M, which is lower than the ~$10^{-8}$ 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 $^{99}$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 $^{99}$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.

| 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-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 |

| 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-T4-3 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 |

| 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-T6-1 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.

| 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-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 $1.16 \times 10^{-11}$ cm$^2$/s. This diffusivity is larger than the 140-day sampling value ($9.96 \times 10^{-14}$) and within the range of diffusivities measured before 7-days leaching. For the 406-day T5-4 sampling, the lowest $NO_3^-$ diffusivity ($1.46 \times 10^{-11}$ cm$^2$/s) and $Na^+$ diffusivity ($1.29 \times 10^{-9}$ cm$^2$/s) resulted compared to the other sampling intervals. An increase in $^{99}$Tc diffusivity was also observed for the T7-4 sample, increasing to $2.53 \times 10^{-13}$ cm$^2$/s at 406 days compared with $3.74 \times 10^{-14}$ cm$^2$/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 $NO_3^-$ ($1.63 \times 10^{-11}$ cm$^2$/s) and $Na^+$ ($7.41 \times 10^{-10}$ cm$^2$/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 ($6.54 \times 10^{-14}$ cm$^2$/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 ($5.13 \times 10^{-14}$ cm$^2$/s, largest diffusivity past 42 days) and T16-4 ($8.67 \times 10^{-14}$ cm$^2$/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 $0.5 \pm 0.15$). 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.

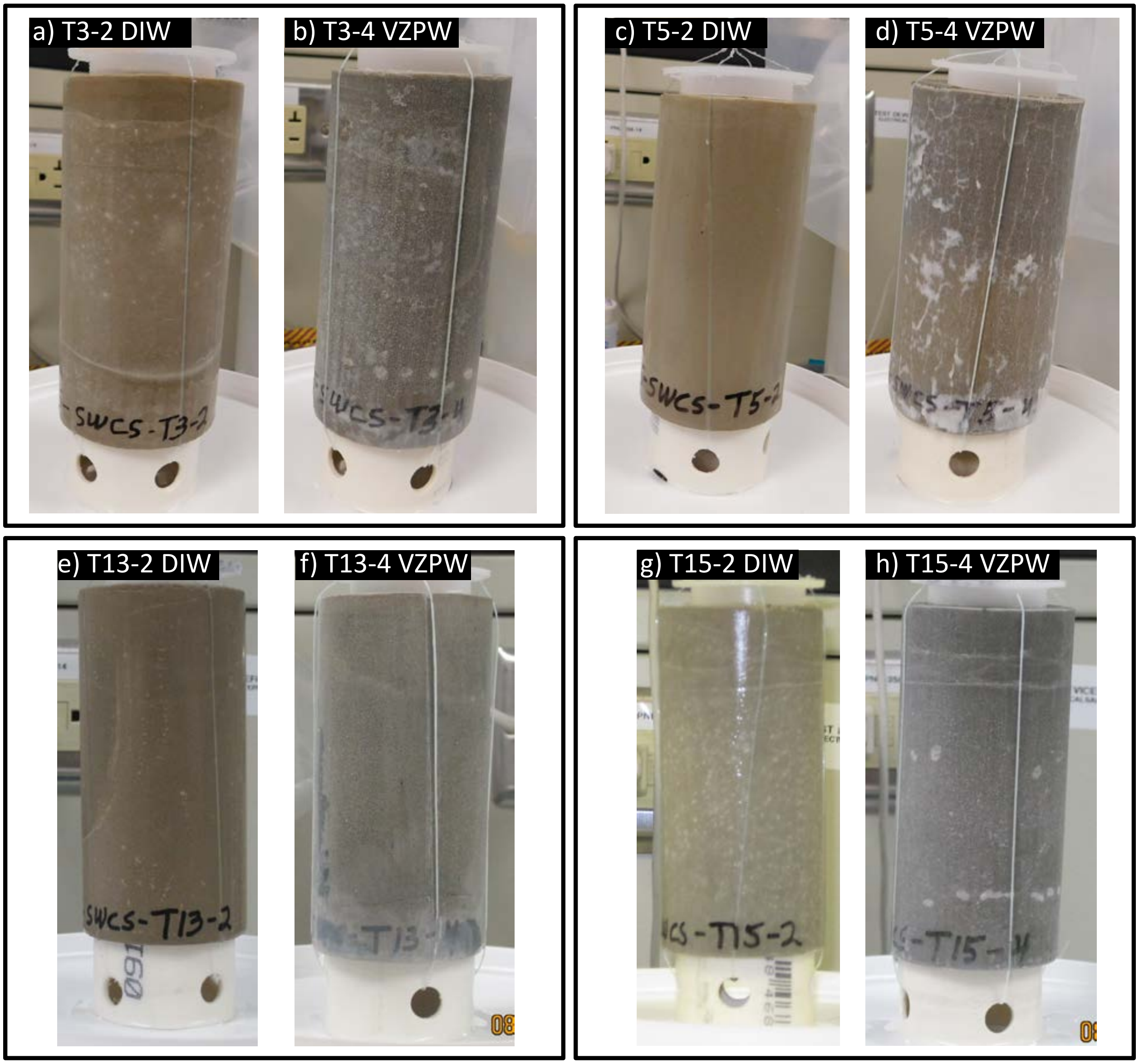


**Figure A.1**. Photographs of Select Monoliths Following the 406-day Extended Leaching. Both the DIW- and VZPW-Leached Samples are displayed.

## 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.

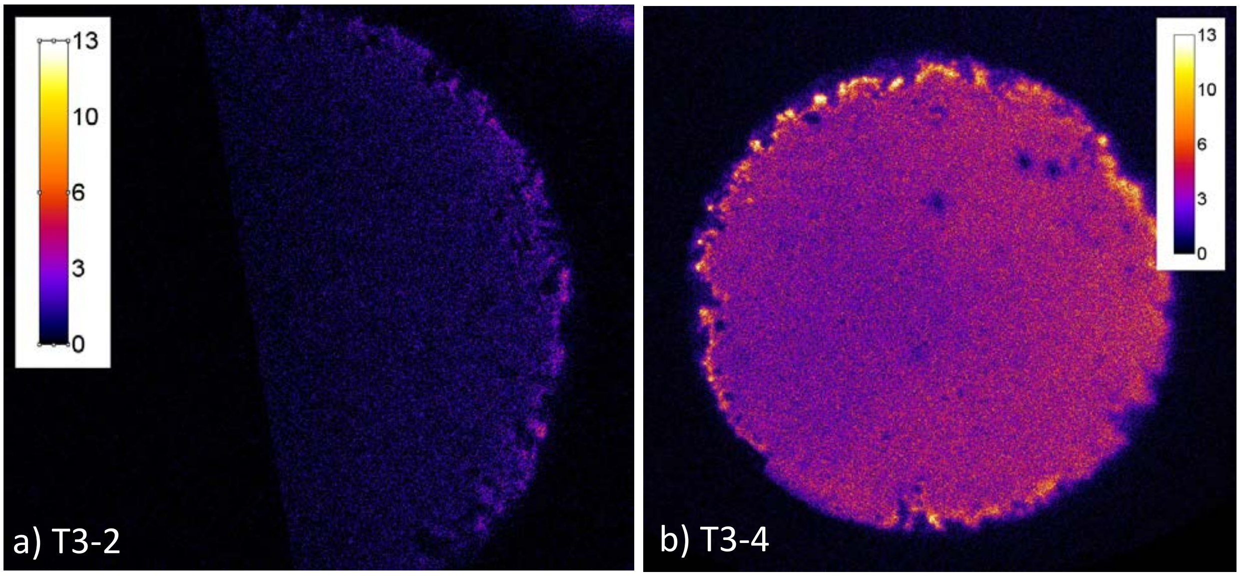


**Figure A.2**. Radiography Images Produced by the iQID System of Cross Sections of the (a) T3-2 (DIW) and (b) T3-4 (VZPW) Samples Following 406 d Leach Testing. The duration of collection was 60 h. The scale bar represents the number of β-decays detected at a particular pixel.

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.

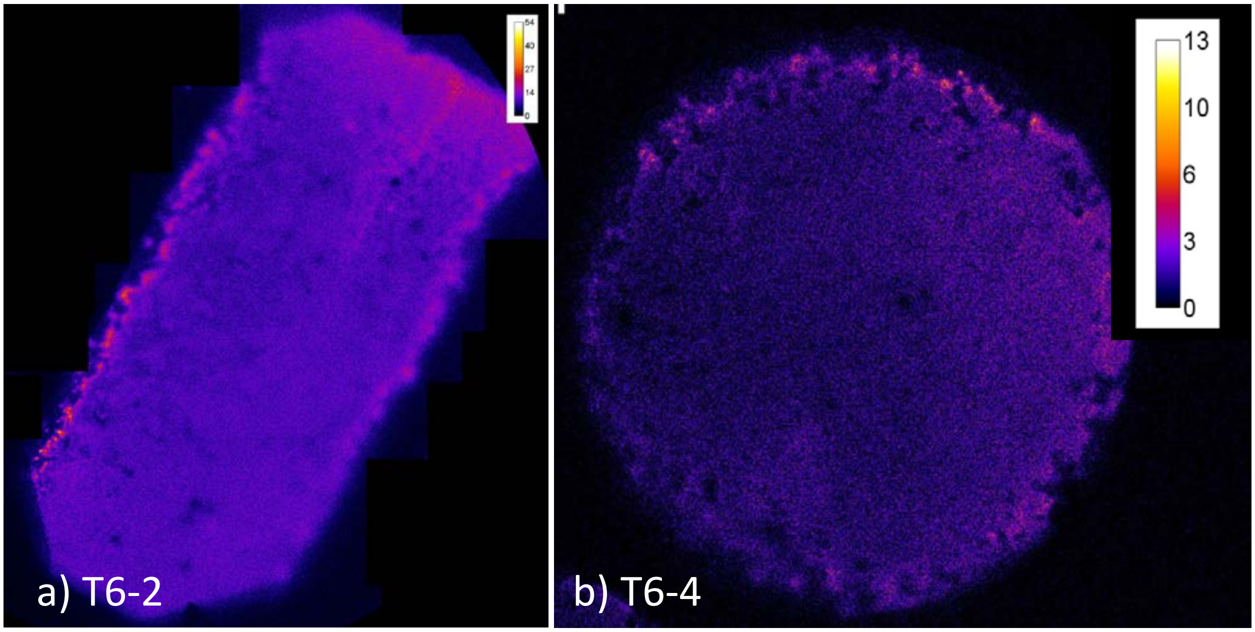


**Figure A.3**. Radiography Images Produced by the iQID System of (a) Vertical Section of T6-2 (DIW) and (b) Horizontal Cross Section of T6-4 (VZPW) Samples Following 406 d Leach Testing. The duration of collection was 60 h. The scale bar represents the number of β-decays detected at a particular pixel.

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.

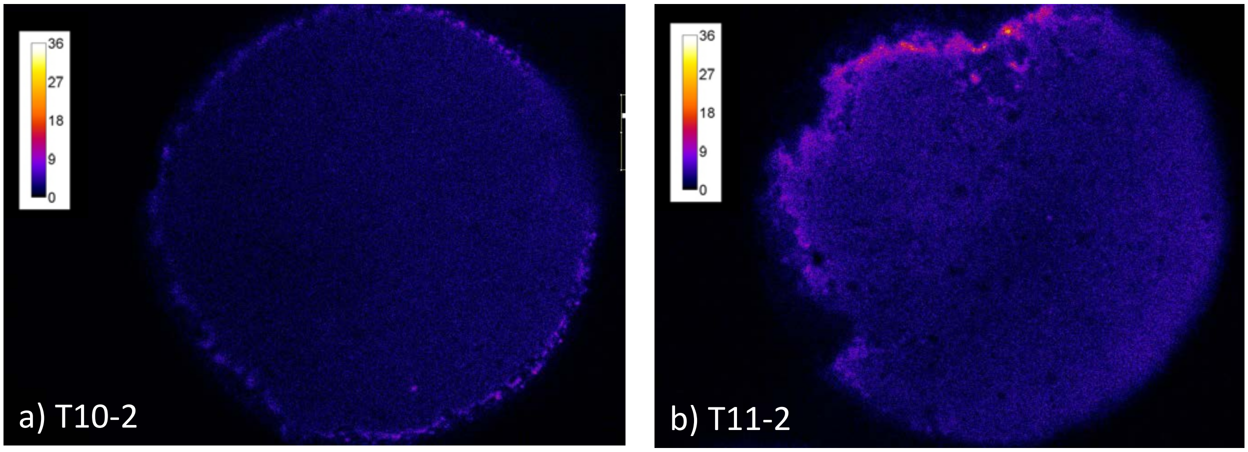


**Figure A.4**. Radiography Images Produced by the iQID System of Horizontal Cross Sections of (a) T10-2 (DIW) and (b) T11-2 (DIW) Samples Following 406-day Leach Testing. The duration of collection was 60 h. The scale bar represents the number of β-decays detected at a particular pixel.

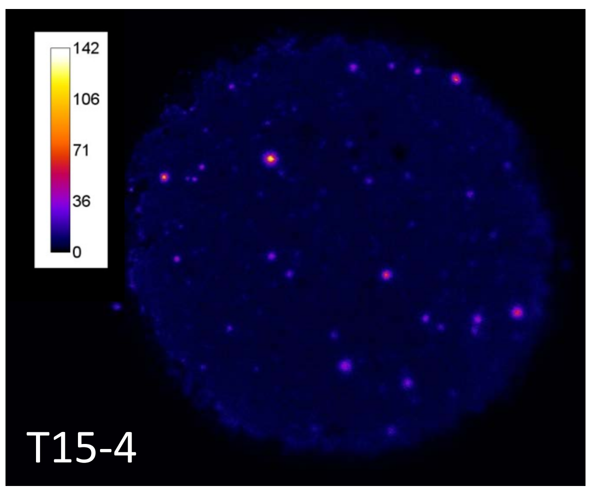


**Figure A.5**. Radiography Image Produced by the iQID System of Horizontal Cross Section of T15-4 (VZPW) Following 406-day Leach Testing. The T15 monolith included Sn(II)-treated apatite as a $^{99}Tc$ getter. The duration of collection was 60 h. The scale bar represents the number of β-decays detected 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 ($Ca_6Al_2(SO_4)_3(OH)_{12}•26H_2O$), calcite ($CaCO_3$), and larnite ($Ca_2SiO_4$). The HL-based monoliths all contained portlandite ($Ca(OH)_2$) except T2-4 and T5-4. The samples containing brucite ($Mg(OH)_2$) 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.

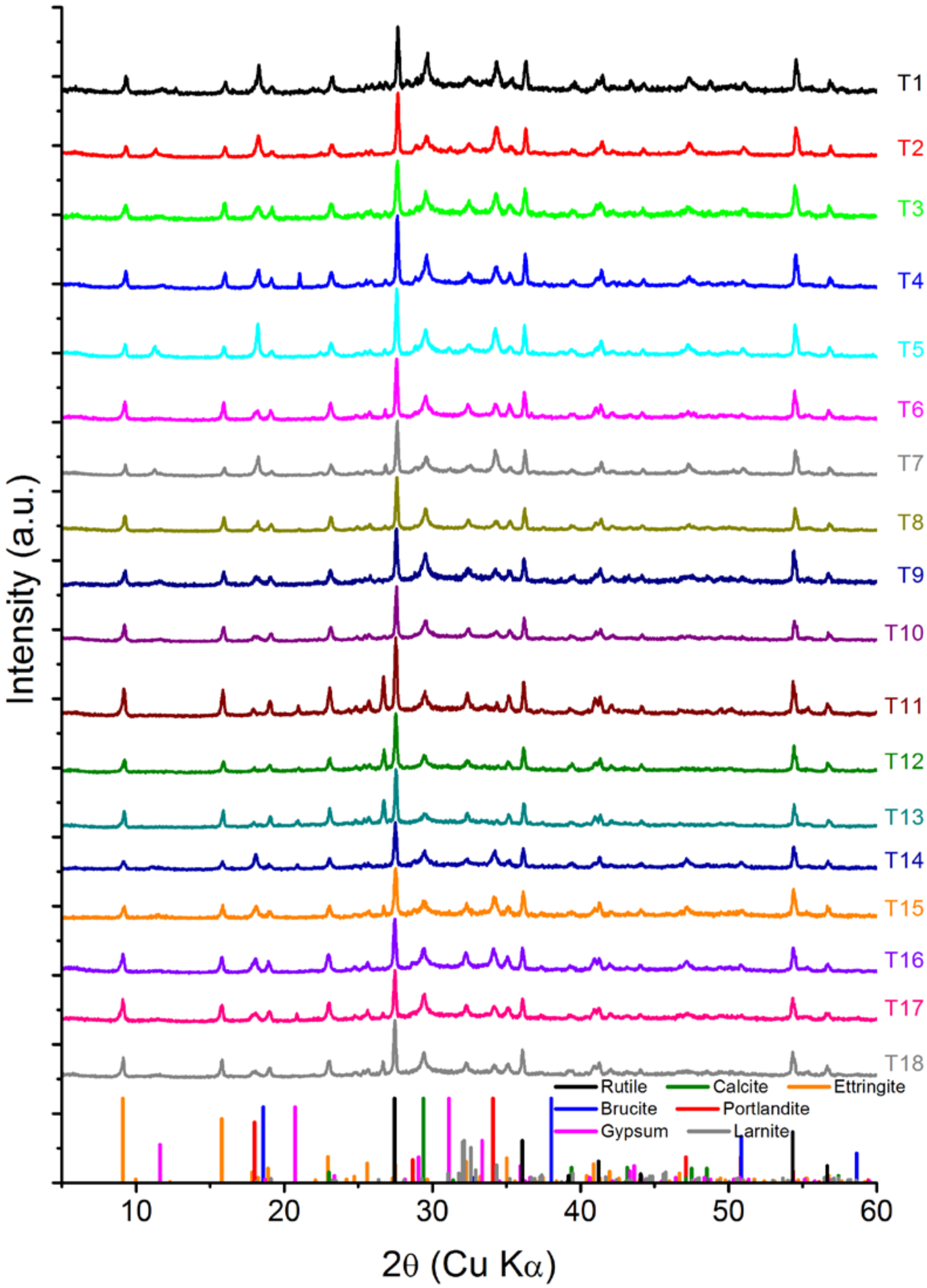


**Figure A.6**. XRD Patterns of the 18 Extended-Leached Samples in DIW. Numbers to the right of each spectrum are the test number of the monolith.

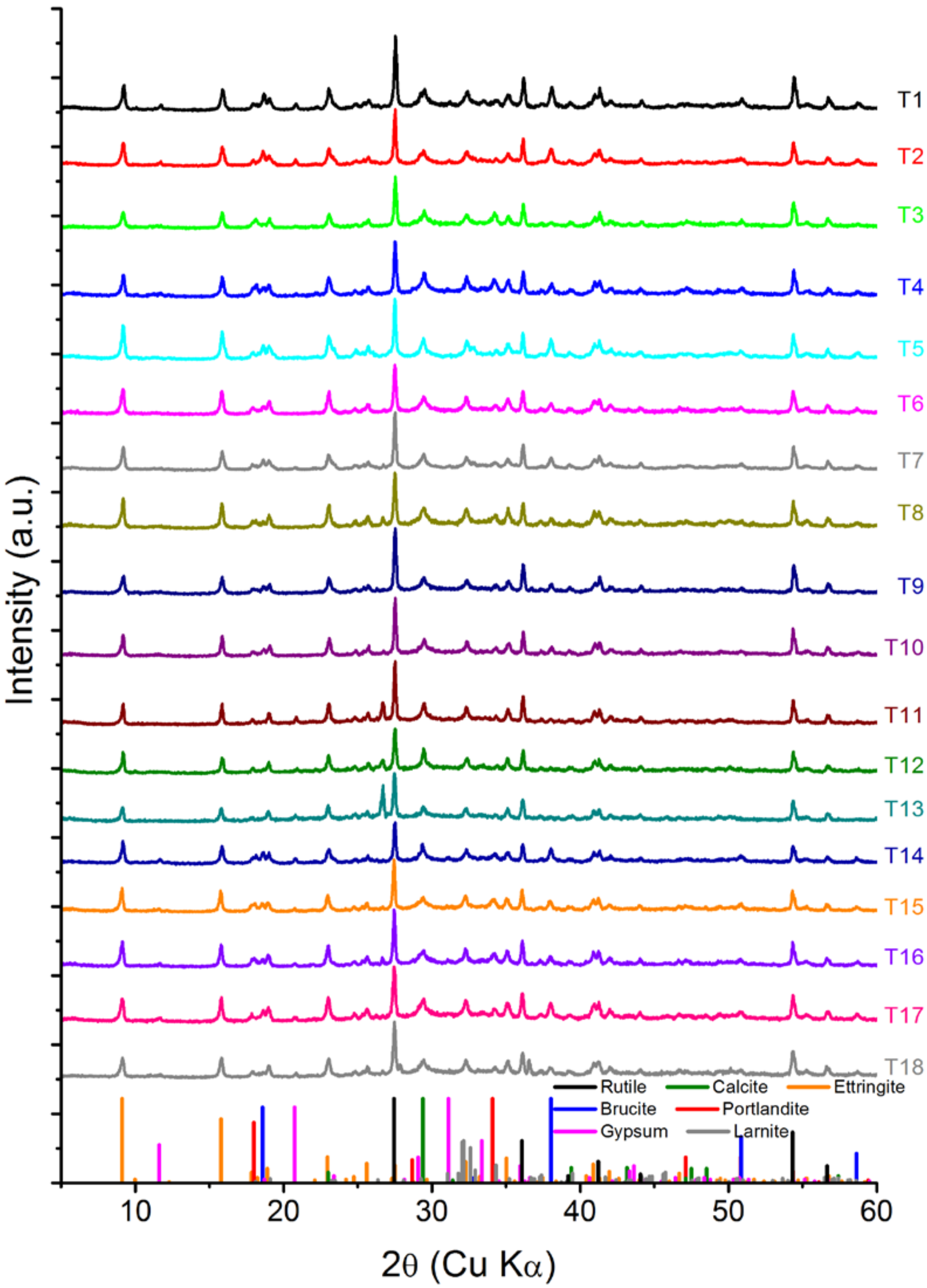


**Figure A.7**. XRD Patterns of the 18 Extended-Leached Samples in VZPW. Numbers to the right of each spectrum are the test number of the monolith.

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 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 $Mg(OH)_2$ 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 | |

| Cumulative Leach Time (days) | T7-2 for $^{99}Tc$ $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | T7-2 for $NO_3^-$ $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | T7-2 for $Na^+$ $D_{eff}$ (cm²/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 | |

| Cumulative Leach Time (days) | T8-2 for $^{99}Tc$ $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | T8-2 for $NO_3^-$ $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | T8-2 for $Na^+$ $D_{eff}$ (cm²/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) | $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | $D_{eff}$ (cm²/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) | $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | $D_{eff}$ (cm²/s) | LI [-] | Release[1] (%) | $D_{eff}$ (cm²/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 | | | | | |

| Cumulative Leach Time (days) | T13-2 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T13-2 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T13-2 for $Na^+$ $D_{eff}$ ($cm^2/s$) | 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 | |

| Cumulative Leach Time (days) | T14-2 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T14-2 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T14-2 for $Na^+$ $D_{eff}$ ($cm^2/s$) | 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 | |

| Cumulative Leach Time (days) | T17-2 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T17-2 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T17-2 for $Na^+$ $D_{eff}$ ($cm^2/s$) | 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 | |

| Cumulative Leach Time (days) | T18-2 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T18-2 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T18-2 for $Na^+$ $D_{eff}$ ($cm^2/s$) | 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 | |

| Cumulative Leach Time (days) | T3-4 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T3-4 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T3-4 for $Na^+$ $D_{eff}$ ($cm^2/s$) | 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 | |

| Cumulative Leach Time (days) | T4-4 for $^{99}Tc$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T4-4 for $NO_3^-$ $D_{eff}$ ($cm^2/s$) | LI [-] | Release[1] (%) | T4-4 for $Na^+$ $D_{eff}$ ($cm^2/s$) | 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 $TiO_2$ 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 µg/L) in pre-equilibrated saturated $Ca(OH)_2$ 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 $Ca(OH)_2$ solution with no crushed monolith material) prepared with initial spiked $^{99}Tc$ concentrations of 2.5, 10, and 25 µg/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 $^{99}Tc(IV)$ did not occur in the controls, indicating the reducing conditions in the anoxic chamber were not sufficient to facilitate $^{99}Tc(IV)$ 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 µg/L, all the $^{99}Tc$ aqueous concentrations in the filtrates were below the detection limit ICP-MS (0.033 µg/L) except the first sampling after 121 days, which had a near-detection-limit value of 0.04 µg/L. For the T19 batch experiment, with a starting $^{99}Tc$ aqueous concentration equal to 10 µg/L, nearly constant, low aqueous concentrations of ~0.05–0.07 µg/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 µg/L, a gradual decrease in $^{99}Tc$ aqueous concentration (0.11 to 0.06 µg/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 µg/L) did not converge to a single value. The highest filtrate $^{99}Tc$ aqueous concentration values were 0.06–0.11 µg/L from the batch experiment that started with the highest $^{99}Tc$ aqueous concentrations, 25 µg/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 µg/L, all the $^{99}Tc$ aqueous concentrations in the filtrates were below the detection limit of ICP-MS (0.033 µg/L). For the T20 batch experiment with a starting $^{99}Tc$ aqueous concentrations of 10 and 25 µg/L, a narrow range of low aqueous concentrations of ~0.03–0.06 µg/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 µg/L, all the $^{99}Tc$ aqueous concentrations in the filtrates were near the detection limit of ICP-MS (0.033 µg/L). For both T21 batch experiments with starting $^{99}Tc$ aqueous concentrations of 10 and 25 µg/L, the filtrate $^{99}Tc$ concentrations for the two different initial $^{99}Tc$ concentrations (10 and 25 µg/L) converged into a very narrow concentration range (0.09–0.24 µg /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 µg/L, can be calculated , namely 0.14 ± 0.06 µg/L ($1.4 \pm 0.6 \times 10^{-9}$ M) and 0.19 ± 0.06 µg /L ($1.9 \pm 0.6 \times 10^{-9}$ 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 µg/L). In contrast, LSWG T21 filtrates show much higher concentration levels (0.09–0.24 µg/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 $Ca(OH)_2$ solution likely did not exceed the monolith's sorption capacity. Thus, almost 100% of the spiked $^{99}Tc$ in the saturated $Ca(OH)_2$ 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 $Ca(OH)_2$ solution that started with $^{99}Tc$ aqueous concentrations of 2.5 µg/L, the total amounts of $^{99}Tc$ in T21 batch slurries that started with $^{99}Tc$ aqueous concentrations of 10 and 25 µg/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 ~$1.4 \pm 0.6$ to $1.9 \pm 0.6 \times 10^{-9}$ M despite the different initial $^{99}Tc$ concentrations (10 and 25 µg/L). An overall average solubility control based on an assumed $^{99}Tc(IV)$ solid is ~$1.7 \pm 0.6 \times 10^{-9}$ 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 $10^{-8}$ M and $4.8 \times 10^{-9}$ M for empirical solubility experiments conducted under reducing conditions with several different cementitious waste forms.

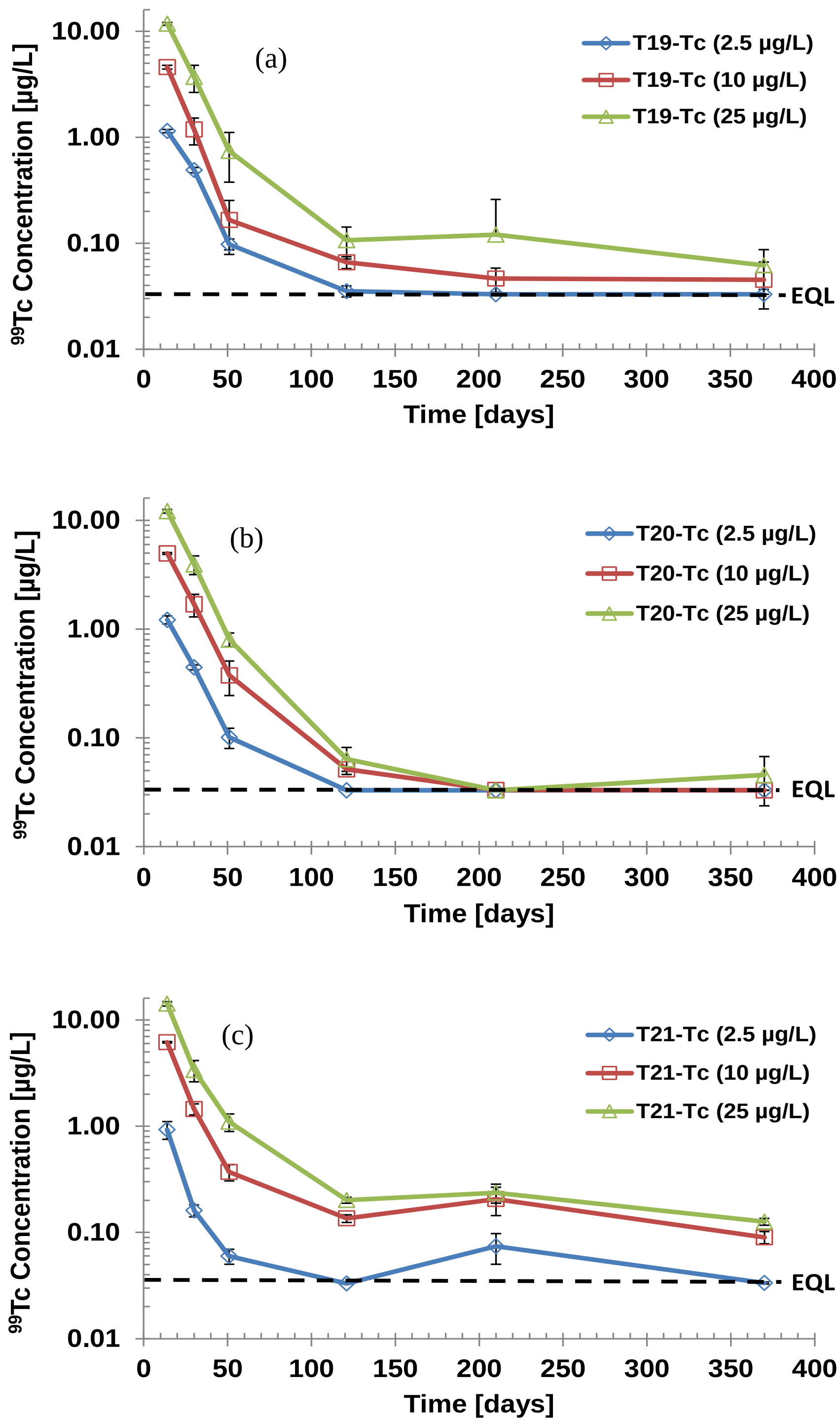


**Figure A.8**. Average Aqueous $^{99}$Tc Concentrations for Different Sorption Reaction Times up to 370 Days using T19 (a), T20 (b), and T21(c) crushed LSWG Material. The blue, red, and green symbols indicate aqueous $^{99}$Tc concentrations at different reaction times with initial $^{99}$Tc concentrations of 2.5, 10, and 25 µg/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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