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Chemical Degradation of SuperLig®639 Ion Exchange Resin

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September 2003

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Test specification: None
Test plan: TP-RPP-WTP-091, Rev. 0
Test exceptions: None
R&T focus area: Pretreatment
Test Scoping Statement(s): B-54

Battelle, Pacific Northwest Division
Richland, Washington 99352

Completeness of Testing

This report describes the results of work and testing specified by TP-RPP-WTP-091, Rev. 0. The work and any associated testing followed the quality assurance requirements outlined in the Test Specification/Plan. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Test plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

_____ _____

Gordon H. Beeman, Manager Date
WTP R&T Support Project

Summary

Battelle, Pacific Northwest Division (PNWD) is contracted to Bechtel National Inc. (BNI) on the River Protection Project – Waste Treatment Plant (RPP-WTP) project to perform research and development activities. Unit operations of the WTP process include the separation of ^{137}Cs and ^{99}Tc by ion exchange from the liquid portion of the waste. SuperLig® 644 (SL-644) and SuperLig® 639 (SL-639) ion exchange resins were selected by the project to perform ^{137}Cs and ^{99}Tc separations, respectively.

Objectives

The primary objective of this task was to determine the degradation in SL-639 resin performance over repeated cycles of waste processing and elution in a column system. The SL-639 resin underwent 26 cycles of waste processing and elution to accomplish this objective. Secondary objectives included:

- preliminary assessment of some hazardous waste characteristics of the resin to support future development of a spent resin disposal pathway.
- determination of the impact of low-activity waste (LAW) processing rate and Tc and NO_3^- concentrations on the resin-breakthrough performance.

This investigation was conducted according to the test plan prepared by Arm (2001), superseding that prepared by Blanchard (2001), in response to the test requirements for investigating ion exchange resin chemical degradation delineated by Barnes et al. (2002) in Section 5.3 of the Research and Technology Plan and test scoping statement B-54. The primary objective and preliminary determination of the hazardous waste characteristics were achieved. Although appropriate tests were executed, determination of the impact of LAW processing rate and Tc and NO_3^- concentrations on the resin breakthrough performance was not possible due to artificially poor performance in some cycles caused by LAW feed channeling through the bed.

Conduct of Testing

Tests were performed using a simulated LAW based on the LAW currently stored in Tank 241-AN-105. Except for the first and last cycles, the simulated LAW was processed first through a column containing SL-644 to test for the chemical degradation of that resin and to replicate the actual operation of the WTP. The first and last cycles processed simulated LAW with no pre-processing. The simulated AN-105 LAW recipe was modified to include the toxicity characteristic (TC) metals (Ag, As, Ba, Cd, Cr, Hg, Pb, and Se) at concentrations corresponding to the highest observed in actual LAW samples so that the hazardous waste characterization of the resin was determined for the worst-case conditions. The K, OH^-, Cs, Tc, and NO_3^- concentrations were also modified for conducting the parametric studies of the two chemical-degradation tests. The simulated LAW was traced with ^{95m}Tc so that process samples could be analyzed by gamma energy analysis (GEA).

The test apparatus consisted of an ion exchange column containing nominally 5 mL of SL-639 resin expanded in 0.25 M NaOH, a metering pump, pressure-relief valve, pressure gage, and three 3-way valves. Hot water was re-circulated through a glass jacket surrounding the column to provide the heating required during elution.

A cycle test commenced with conditioning the resin with 0.25 M NaOH. The simulated LAW was then processed followed by column rinses of 0.1 M NaOH and de-ionized (DI) water before the resin was eluted with DI water at 65°C.

Simulated LAW effluent samples were periodically collected by directing the flow into 20-mL vials to collect nominally 5 mL of sample. The bed height and effluent bottle mass were measured during sampling events. For most cycles, eluate was collected in a single bottle, and then the final 5 mL was collected separately for GEA to determine the ^{95m}Tc content. In order to ascertain the elution profile, samples of eluate were collected during Cycles 1, 2, 5, 10, 15, 20, 25, and 26 into 20-mL vials. Samples were analyzed by GEA for their ^{95m}Tc content.

Results and Performance against Objectives

No physical changes in the resin were inferred from the constancy of the resin bed height and color. Scanning electron microscopic analysis of the resin surface showed that it had become more rough and pitted. There was no significant loss of resin through dissolution.

There was no significant deterioration in the breakthrough and elution performance of the SL-639 resin after 26 cycles of simulated LAW processing and elution. The column distribution coefficient was ~280 through Cycle 26 for consistent conditions. The concentration of Tc in the eluate reduced to 1% of its concentration in the simulated LAW feed when less than 20 bed volumes of eluate had been generated. Olson (2001) describes the WTP Tc removal system consisting of three columns operating in a carousel fashion with elution being performed after a column processes LAW in the lead position. A design-cycle, therefore, consists of 3 loading operations and one elution compared to a test-cycle of single loading and elution operations. Therefore, a bed would require replacement no more frequently than after every 9th design-cycle (equivalent to 27 test-cycles) on the basis of these results and assuming the worse case that any degradation occurs only when processing LAW. The current design assumption documented by Olson (2001) that replacement occurs after the 10th design-cycle appears likely, therefore, to be consistent with these results.

Poor elution and breakthrough performance in some cycles was attributed to LAW feed channeling through the bed as a result of bubbles in the bed generated as air came out of solution when the eluant was heated inside the column. This may have been avoided if the eluant had been pre-heated in a ventilated and stirred vessel before it was fed to the column. The poor performance in some cycles precluded determination of the impact of LAW processing rate on breakthrough performance. However, results were obtained that indicated both NO_3^- and NO_2^- appear to compete with TcO_4^- for ion exchange sites. .

The modified Toxicity Characteristic Leach Procedure (TCLP) indicates that the spent resin would not exhibit toxicity characteristics if a formal TCLP were performed. However, this result may not be appropriate for regulatory purposes or submissions since the TCLP had to be modified from the standard EPA SW-846 method due to the small sample size restricting quality control to less than required by the method. Further testing using TCLP methods approved by the Washington State Department of Ecology would need to be completed with both actual and simulated wastes to develop a disposal pathway and identify disposal methods.

Chemical analysis of the leached resin and TCLP leachate showed the spent resin contained Tc at a concentration of 0.69 μg/g or 5.86 mCi/m^3. This value is below the Hanford Site Solid Waste Acceptance Criteria (McDowell (2002)) category 1 limit (23 mCi/m^3).

Quality Requirements

PNWD implemented the RPP-WTP quality requirements in a quality assurance project plan (QAPjP) as approved by the RPP-WTP quality assurance (QA) organization. As delineated in the test plan prepared by Blanchard (2001) and then the superseding plan prepared by Arm (2001), test preparation activities and the first half of the first of 26 test cycles were conducted in accordance with PNWD's quality assurance project plan, CHG-QAPjP, Rev.0, which invoked PNWD's Standards Based Management System (SBMS), compliant with DOE Order 414.1A Quality Assurance and 10 CFR 830, Energy/Nuclear Safety Management, Subpart A -- Quality Assurance Requirements. Due to a change in the contract QA requirements, the remainder of the cycle tests and analytical activities were conducted in accordance with PNWD's quality assurance project plan, RPP-WTP-QAPjP, Rev.0, which invoked NQA-1-1989 Part I, Basic and Supplementary Requirements, and NQA-2a-1990, Part 2.7. These quality requirements were implemented through PNWD's Waste Treatment Plant Support Project Quality Assurance Requirements and Description Manual (WTPSP). The change in QA requirements did not affect the analytical methods or data.

PNWD addressed verification activities by conducting an Independent Technical Review of the final data report in accordance with procedure QA-RPP-WTP-604. This review verified that the reported results were traceable, that inferences and conclusions were soundly based, and the reported work satisfied the Test Plan objectives. The review procedure is part of PNWD's WTPSP Manual.

Issues

These tests raised the necessity of pre-heating eluant in laboratory tests in a stirred and ventilated vessel before feeding it to the column to assure that no air comes out of solution in the resin bed. Air bubbles would cause feed reagents to by-pass ion exchange material (channel through the column) and reduce performance.

References

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McDowell AK. 2002. *Hanford Site Solid Waste Acceptance Criteria*, HNF-EP-0063, Fluor Hanford, Richland, Washington.

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Acronyms, Abbreviations, and Definitions

AV	apparatus volume
BNI	Bechtel National, Inc.
BV	bed volume
CPM	counts per minute
CVAA	cold vapor atomic absorption
DI	de-ionized
EPA	U.S. Environmental Protection Agency
FMI	Fluid Metering, Inc.
GEA	gamma energy analysis
HLW	high-level waste
HP	hot persulfate
IC	ion chromatography
ICP-AES	inductively coupled plasma – atomic emission spectrometry
ICP-MS	inductively coupled plasma – mass spectrometry
LAW	low activity waste
LSC	liquid scintillation counting
PNWD	Battelle, Pacific Northwest Division
QA	quality assurance
QAPjP	Quality Assurance Project Plan
RPP-WTP	River Protection Project – Waste Treatment Plant
SEM	scanning electron microscopy
SL	SuperLig®
SRTC	Savannah River Technology Center
SVOA	semi-volatile organic analysis

TC	toxicity characteristic
TCLP	toxicity characteristic leach procedure
TIC	total inorganic carbon
TOC	total organic carbon
TWINS	Tank Waste Information Network System
VOA	volatile organic analysis
WTPSP	Waste Treatment Plant Support Project Quality Assurance Requirements and Description Manual

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1.0 Introduction

1.1 Background

Battelle, Pacific Northwest Division (PNWD) is contracted to Bechtel National Inc. (BNI) on the River Protection Project – Waste Treatment Plant (RPP-WTP) project to perform research and development activities. The purpose of the RPP-WTP project is to design, construct, and commission a plant to treat and immobilize high level waste (HLW) and low activity waste (LAW) stored in underground storage tanks at the Hanford Site. Unit operations of the LAW treatment process include the separation of ^{137}Cs and ^{99}Tc by ion exchange from the liquid portion of the waste. SuperLig®644 (SL-644) and SuperLig®639 (SL-639) ion exchange resins were selected by the project to perform ^{137}Cs and ^{99}Tc separations, respectively, and are available from IBC Advanced Technologies, Inc., American Fork, Utah.

The degradation in performance of an ion exchange resin over repeated cycles of waste processing and elution is an important characteristic required for design and operational purposes. The rate of degradation will determine the useful life of the resin and thereby the rate of its consumption and the quantity of spent resin for disposal. Performance degradation is directly attributable to the changes in the resin structure caused by chemical and radiolytic attack. The chemical degradation of the SL-639 and SL-644 resins was investigated in a parallel suite of tests. This report documents the testing, results, and analysis of the SL-639 chemical degradation task.

1.2 Objectives

The primary objective of this task was to determine the degradation in resin performance over repeated cycles of waste processing and elution in a column system. The SL-639 resin underwent 26 cycles of waste processing and elution to accomplish this objective. Secondary objectives include:

- preliminary assessment of some hazardous waste characteristics of the resin to support future development of a spent resin disposal pathway.
- determination of the impact of the LAW processing rate and Tc and NO_3^- concentrations on the resin breakthrough performance.

This investigation was conducted according to the test plan prepared by Arm (2001), superseding that prepared by Blanchard (2001), in response to the test requirements to investigate ion exchange resin degradation delineated by Barnes et al. (2002) in Section 3.7.2.3 of the Research and Technology Plan and test scoping statement B-54.

1.3 Purpose

This report documents testing, results, and analyses associated with the SL-639 chemical-degradation investigation. The purpose of the investigation was to provide information for an assessment of the degradation in resin performance over repeated cycles of waste processing and elution and spent-resin disposal. The report is intended to aid the RPP-WTP project in decisions regarding the design and operation of the Tc ion exchange system in the WTP.

1.4 Quality Assurance

PNWD implemented the RPP-WTP quality requirements in a quality assurance project plan (QAPjP) as approved by the RPP-WTP quality assurance (QA) organization. As delineated in the test plan prepared by Blanchard (2001) and then the superseding plan prepared by Arm (2001), test preparation activities and the first half of the first of 26 test cycles were conducted in accordance with PNWD's quality assurance project plan, CHG-QAPjP, Rev.0, which invoked PNWD's Standards Based Management System (SBMS), compliant with DOE Order 414.1A Quality Assurance and 10 CFR 830, Energy/Nuclear Safety Management, Subpart A -- Quality Assurance Requirements. Due to a change in the contract QA requirements, the remainder of the cycle tests and analytical activities were conducted in accordance with PNWD's quality assurance project plan, RPP-WTP-QAPjP, Rev.0, which invoked NQA-1-1989 Part I, Basic and Supplementary Requirements, and NQA-2a-1990, Part 2.7. These quality requirements were implemented through PNWD's Waste Treatment Plant Support Project Quality Assurance Requirements and Description Manual (WTPSP). The change in QA requirements did not affect the analytical methods or data. Note that the TCLP sample analysis was not subject to the WTP QAPjP for environmental / regulatory data due to the research nature of the test.

PNWD addressed verification activities by conducting an Independent Technical Review of the final data report in accordance with procedure QA-RPP-WTP-604. This review verified that the reported results were traceable, that inferences and conclusions were soundly based, and the reported work satisfied the Test Plan objectives. The review procedure is part of PNWD's WTPSP Manual.

2.0 Test Design and Operation

This section describes the preparation of simulated LAW, the preparation of reagents, the preparation and storage of the selected ion exchange resin, the ion exchange column test setup, and the modified Toxicity Characteristic Leach Procedure (TCLP) that was used.

2.1 Simulated LAW Preparation

Tests were performed using a simulated LAW since using actual waste would have proved unacceptably expensive and impractical from a supply standpoint for the scale of the test.

The LAW currently stored in Tank 241-AN-105 was selected to simulate and test since it is scheduled for processing in the WTP and its composition is typical of the expected Envelope A LAW that will constitute the majority of the feed to the WTP. Except for the first and last cycles, the simulated LAW was processed first through a column containing SL-644 to test for the chemical degradation of that resin and to replicate the actual operation of the WTP. The first and last cycles processed simulated LAW with no pre-processing. Therefore, the simulated LAW was prepared with both SL-644 and SL-639 chemical degradation tests in mind.

The simulated AN-105 LAW recipe provided by Eibling and Nash (2001) was modified to include the toxicity characteristic (TC) metals (Ag, As, Ba, Cd, Cr, Hg, Pb, and Se) at concentrations corresponding to the highest observed in actual LAW samples so that hazardous waste characterization of the resins is determined for the worst-case conditions. In addition, U was added at a concentration corresponding to the highest observed in actual LAW samples, since Kurath and Wagner (2000) have shown that a significant quantity remains on the SL-644 resin after elution. The applicable TC metal and U concentrations were determined by interrogating the Tank Waste Information Network System (TWINS). Only samples from the LAW currently scheduled for processing in the WTP (Tanks AN-102, AN-103, AN-104, AN-105, AN-107, AP-101, AW-101, AZ-101, AZ-102, and SY-101) were examined, and the highest concentrations, with respect to Na, were selected for the modified recipe.

The NO_3^- and Tc concentration parametric study required selection of three concentrations for each of these constituents. The AN-105 LAW recipe concentration of NO_3^- detailed by Eibling and Nash (2001) was selected as baseline. The remaining concentrations were required to be symmetric about the baseline to provide minimum and maximum values. Concentrations bounding the range of potential values were determined by again interrogating the TWINS. As before, only samples from the LAW currently scheduled for processing in the WTP were examined. Appropriate values for the minimum and maximum values were then selected given the need for symmetry and the bounding concentrations.

In addition, parallel SL-644 resin-degradation tests required the K and OH^- concentrations to be varied in a parametric study. The KNO_3, NaOH, $NaNO_3$, and $NaNO_2$ concentrations were therefore optimized to fulfill the requirements of each test. The $NaNO_2$ concentration was adjusted to maintain a consistent total Na concentration.

The baseline Tc concentration was selected to provide 50% breakthrough when the equivalent of 250 bed volumes (BVs) of waste had been processed through the SL-639 column in the first cycle. A baseline value of 0.312 mM (0.52 mCi/L) was determined early in the test, and an appropriate minimum concentration was formulated. A maximum value was not selected since the baseline value corresponded to the highest observed in the LAW (Tank AZ-102 analyzed by Hassan et al. [2001]). In addition, the Tc concentration was progressively increased in a series of cycles up to the approximate maximum value observed in actual LAW samples.

The baseline recipe was used for Batches 1 through 4 and 9, and this is provided in Table 2-1. Table 2-2 details the K, OH^-, NO_2^-, and NO_3^- concentrations in each batch prepared for the parametric study; other constituents, except Tc, were the same as in the baseline recipe. The minimum Tc concentration used in the parametric study was 0.0485 mM (0.08 mCi/L). The Tc concentration used for each cycle is provided in the operations descriptions provided later in the report. The solutions were contacted with litmus paper and indicated a pH in the range 13 to 14, as expected.

Table 2-1. Simulated AN-105 LAW Component List

		Final Target Concentration	
Species	**Main Reagent Used**	**(mg/L)**	**(M)**
Metals			
Aluminum	Sodium aluminate	19,900	7.36E-1
Arsenic	Sodium arsenate	51.8	6.91E-4
Barium	Barium nitrate	26.5	1.93E-4
Cadmium	Cadmium nitrate	3.74	3.33E-5
Calcium	Calcium nitrate	20.0	4.99E-4
Cesium	Cesium nitrate	16.2	1.22E-4
Chromium	Sodium chromate	1,620	3.12E-2
Lead	Lead nitrate	80.8	3.90E-4
Magnesium	Magnesium nitrate	2.70	1.11E-4
Mercury	Mercuric (I) nitrate	0.263	1.31E-6
Molybdenum	Potassium molybdate	41.0	4.27E-4
Potassium	Potassium nitrate	3,720	9.51E-2
Selenium	Selenium dioxide	52.9	6.70E-4
Silicon	Sodium meta-silicate	106	3.76E-3
Silver	Silver nitrate	22.3	2.07E-4
Sodium	Various	123,000	5.34E00
Uranium	Uranyl nitrate	260	1.10E-3
Zinc	Zinc nitrate	5.05	7.72E-5
Cations			
Ammonium	Ammonium acetate	60	3.33E-3
Boron	Boric acid	25.5	2.36E-3
Anions			
Carbonate	Sodium carbonate	6,240	1.04E-1
Chloride	Sodium chloride	4,540	1.28E-1
Fluoride	Sodium fluoride	95	5.00E-3
Hydroxide	Sodium hydroxide	29,200	1.72E00
Nitrate	Sodium nitrate	82,500	1.33E00
Nitrite	Sodium nitrite	55,700	1.21E00
Phosphate	Sodium phosphate	280	3.00E-3
Sulfate	Sodium sulfate	390	4.01E-3
Organic Compounds			
Glycolic acid	Glycolic acid	830	1.09E-2
Acetate	Sodium and ammonium acetate	1020	1.75E-2
Formate	Sodium formate	1410	3.20E-2
Oxalate	Sodium oxalate	310	3.47E-3

Table 2-2. K, OH^-, NO_2^- and NO_3^- Concentrations in Simulated AN-105 LAW Batches

	Target Concentration (M)			
Species	**Batch 5**	**Batch 6**	**Batch 7**	**Batch 8**
K	0.008	0.008	0.80	0.80
OH^-	2.20	1.20	2.20	1.20
NO_3^-	0.50	0.50	1.36	1.36
NO_2^-	1.46	2.46	0.58	1.60

Batches of 5 L and 5.5 L were prepared for the column tests, and each batch was filtered following a week of mixing. The volume of material required for the next cycle was then extracted and further filtered. The requisite quantity of $CsNO_3$ was added, and the cycle batch was spiked with ^{137}Cs tracer to facilitate gamma emission analysis (GEA) immediately before processing through the SL-644 column. The effluent from the SL-644 test was stored for up to 5 weeks when it was filtered, supplemented with the required quantity of ^{99}Tc, and spiked with ^{95m}Tc to enable GEA before processing in the SL-639 column.

The simulated AN-105 LAW feeds to Cycles 5, 10, 15, 20, and 25, were analyzed by

- ion chromatography (IC)
- inductively coupled plasma – atomic emission spectrometry (ICP-AES)
- inductively coupled plasma – mass spectrometry (ICP-MS)
- carbon oxidation using hot persulfate (HP) for total organic and inorganic carbon (TOC and TIC)
- carbon oxidation using a furnace for total carbon and TOC
- cold vapor atomic absorption (CVAA) spectroscopy for mercury.

Table 2-3 compares the target constituent concentrations with those determined by the appropriate analysis methods for the simulated LAW feeds. Batches 1, 2, and 8 served as feeds for Cycles 5, 1, and 25, respectively, while Batch 4 served as feed for Cycles 10, 15, and 20. Note that analysis for Hg was not performed on any of the feeds to the SL-639 column but only in the feed to the SL-644 column.

The presence of a significant quantity of black precipitate after a week of mixing the freshly prepared simulated LAW indicates that not all of the reagents dissolved entirely. This is particularly true for the TC metals since they were added at quantities to maximize their concentration in the simulated LAW rather than to simulate the contents of any particular tank. Na and Al appear to be the major constituents of the precipitate, probably as sodium aluminate, with some K. Presumably the added sodium aluminate exceeded the solubility limit of the compound in the simulated LAW. Of the TC metals, Ag, Ba, and Hg were at concentrations a factor of ~100 below their targets, although the others (As, Cr, Pb, and Se) were at concentrations close to their targets given the analytical errors.

The Tc concentrations in the feeds to Cycles 15, 20 and 25 were ~30% lower than in the feeds to cycles 5 and 10. This was due to the chemical composition used to determine the quantity of the stock Tc solution used in cycles 5 and 10 being incorrect since the concentrations in the feeds to the remaining cycles are very close to the target concentration. The error propagated to the simulated LAW concentration because the volume of Tc stock solution added to the simulated LAW was determined based on its Tc composition and the concentration desired in the simulated LAW. The reported Tc concentrations estimated in the feeds to cycles 1 through 4 and 6 through 9 are corrected for the discrepancy.

Table 2-3. Comparison of Analyzed and Target Simulated AN-105 LAW Compositions

		Concentration (mg/L)[1]						
Analyte	**Analysis Method**	**Target**	**Cycle 1 Batch 2**	**Cycle 5 Batch 1**	**Cycle 10 Batch 4**	**Cycle 15 Batch 4**	**Cycle 20 Batch 4**	**Cycle 25 Batch 8**
Ag	ICP-AES	22.3	<0.625	<0.625	<0.625	<0.625	<0.625	<0.625
Al	ICP-AES	19,900	15,600	15,600	15,400	16,000	16,400	15,600
As	ICP-AES	51.8	64.2	*60*	*60*	*62*	*62*	*59*
B[13]	ICP-AES	25.5	82.1	39.8[7]	39.7	36.6	37.2[11]	25.5[11]
Ba	ICP-AES	26.5	*0.39*	*0.43*	<0.25	*0.49*	*0.53*	*0.50*
Ca	ICP-AES	20.0	<6.25	<6.25	<6.25	<6.25	<6.25	<6.25
Cd	ICP-AES	3.74	*1.3*	*0.97*	*1.1*	*0.82*	*1.0*	*1.1*
Cl	IC	4,540	6,300	5,700	5,500	5,800	4,600	4,500
Cr	ICP-AES	1,620	1,470	1,430	1,420	1,460	1,480	1,400
F[6, 12]	IC	95	1,000	1,000	1,000	1,000	800	800
Hg	CVAA	0.263	[4]	4.46E-3[2]	[4]	[4]	[4]	[4]
K	ICP-AES	3,720	3,070	3,030	3,000	3,080	3,260	3,250
Mg	ICP-AES	2.70	<2.5	<2.5	<2.5	<2.5	*3.6*	*3.4*
Mo	ICP-AES	41.0	40.4	39.0	38.6	40.0	40.1[11]	37.9[11]
Na	ICP-AES	123,000	113,000[9]	111,000[8]	110,000[9]	113,000[9]	115,000	111,000
P	ICP-AES	280	125	122	127	125	131	90.0
Pb	ICP-AES	80.8	56.7	41.4	51.6	55.4	54.8	49.1
Se	ICP-AES	52.9	*51*	*49*	*49*	*50*	*49*	*46*
Si	ICP-AES	106	156	138[7]	*120*	110	127[11]	*110*[11]
Tc	ICP-MS	30.0	(4)	42.225	40.925	27.850	29.4[14]	28.1[14]
U	ICP-AES	260	<50	<50	<50	<50	<50	<50
Zn	ICP-AES	5.05	*5.0*	*4.7*	*4.7*	*4.7*	17.7[5]	17.1[5]
C_2O_4[12]	IC	310	<500	<500	<500	<500	300	200
NO_2^-	IC	55,700	56,900	56,200	56,900	57,800	57,500	57,300
NO_3^-	IC	82,500	82,900	82,300	81,900	83,800	83,400	83,000
PO_4^{-}[12]	IC	280	<500	1,400	1,400	1,300	1,400	1,400
SO_4^{-}[12]	IC	400	2,600	2,400	2,300	2,600	1,100	1,100
TIC	HP	1,250 (as CO_3^-)	1,450	1,610	1,640	1,680	1,670	1,580
Total Carbon	Furnace	3,400	2,420	2,710	2,680	2,640	2,640	2,720
TOC	HP	1,150	1,120	1,140	1,070	1,120	970	1,220
	Furnace		35[10]	175[10]	<94[10]	43[10]	200[10]	<170[10]
	Furnace Total Carbon – HP TIC[3]		970	1,100	1,040	960	1,120	1,140

1. ICP-AES results in normal type have errors likely <15%, but those in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.
2. Result obtained before the batch was processed through the SL-644 column.
3. The furnace method typically produces the best total-carbon results while the best TIC results are obtained from the HP method. Thus, the best TOC result may be the difference between these measurements.
4. Not measured.
5. Observed Zn concentration in the blank did not satisfy QC acceptance criteria and this Zn concentration consequently likely up to 75% over-estimated.
6. F^- results from IC should be considered upper bounds due to significant analytical interference from organic compounds such as acetate.
7. Si and B analysis compromised by error in sample preparation manifesting in poor recoveries from spike samples.
8. Relative % difference of 7.3% between duplicates did not satisfy the QC acceptance criterion of 3.5%. No significant impact on results expected.
9. Relative % difference of 4.0% between duplicates did not satisfy the QC acceptance criterion of 3.5%. No significant impact on results expected.
10. TOC recoveries from the caustic matrix spike lower than the QC acceptance criterion makes this result doubtful. See also note 3.
11. B, Mo and Si achieved recoveries of 72%, 73% and 59%, respectively, from the matrix spike sample and so did not satisfy the QC acceptance criterion of >75%. No significant impact on results expected.
12. F^-, PO_4^-, SO_4^- and $C_2.O_4^-$ results should be considered qualitative since the high concentrations of NO_3^- and NO_2^- required the samples to be diluted by up to 10,000 times so that the anions were measured within their IC calibration range and to avoid the IC column becoming overloaded during analysis. The result for P obtained from ICP-AES is considered more accurate.
13. The reason for reported concentrations for B higher than targeted is not known. However, B is known to be somewhat ubiquitous since it is a constituent of glass.
14. Error may be as high as +/- 30%. These ICP-MS analyses were completed in early August, 2002. Subsequent independent verification analyses by LSC in late May, 2003, of the calibration and calibration verification standard materials gave concentrations 16% and 24% higher, respectively, than the assigned values for the standards. The Cycle 15 feed analysis was conducted on a different instrument by different operators using different standards; the agreement in the Tc concentrations for these runs suggests that the error is not this high.

2.2 Reagent Preparation

All reagents were "reagent grade." Sodium hydroxide solutions were prepared by dissolving the required mass of sodium hydroxide pellets in de-ionized (DI) water.

2.3 Ion Exchange Resin Preparation and Storage

SL-639 Tc ion exchange resin from Batch 010227CTC-9-23 was received in late March of 2001 and stored dry in a plastic bottle. The manufacturer reports the mean diameter of the beads as 0.5 mm. A sample of this batch of SL-639 resin was sieved to determine the particle-size distribution of the resin, and the results are reported in Table 2-4. The results show that the greatest weight fraction of this batch has a particle-size range of 600 to 1000 μm.

Table 2-4. Particle-Size Distribution of SL-639 Resin, Batch 010227CTC-9-23

ASTM Sieve Number	Particle Size (μm)	Mass of Resin (g)	% of total, (mass basis)
Sieve 18	Greater than 1000	0.0524	0.52
Sieve 30	1000–600	7.5324	75.3
Sieve 40	600–425	2.1655	21.7
Sieve 50	425–300	0.2190	2.19
Sieve 70	300–212	Very few beads	Not significant

The bulk dry density of the resin was determined to be 0.53 g/mL, but this reduced to 0.47 g/mL when wet.

2.4 Ion Exchange Column Test Setup

A process schematic of the apparatus is provided in Figure 2-1. The apparatus consists of an ion exchange column containing nominally 5 mL of SL-639 resin expanded in 0.25 M NaOH, a metering pump, pressure relief valve, pressure gage, and three 3-way valves. A total volume of 15 mL for the apparatus was determined.

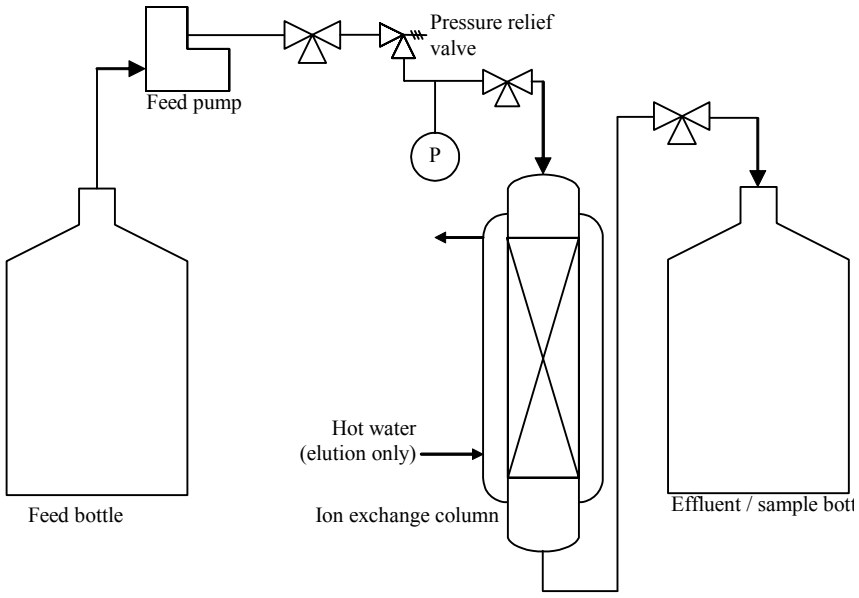

Figure 2-1. SL-639 Chemical Degradation Column Test Process Schematic

The column is a Spectrum Chromatography Spectra/Chrom® column manufactured from glass with plastic plungers on the ends that can be adjusted to control the distance between the top of the resin bed and the column feed. The headspace between the bed top and top plunger was packed with quartz wool to contain the bed since the resin is buoyant in LAW. Hot water can be recirculated through a glass jacket surrounding the column to provide the heating required during elution. The internal diameter of the column is 1.5 cm.

The pump was a Fluid Metering, Inc. (FMI) piston pump with the flow rate controlled from outside of the fumehood, using an FMI stroke rate controller. The controller was calibrated using water and the system could provide pumping rates between approximately 0.5 mL/h and 50 mL/h.

The pressure-relief valve was set to open at a pressure of 10 psi, which is below the maximum operating pressure of the column. Valves placed between the pump outlet and column were used to eliminate air from the system or isolate the column from the pump. A valve positioned between the column and effluent bottle was used to prevent the column from draining while the pump was stopped. The equipment and fittings were connected using $^{1}/_{16}$-in. internal diameter polyethylene plastic tubing.

2.5 Modified Toxicity Characteristic Leach Procedure

A TCLP was to be performed on the spent resin to provide a preliminary indication of its toxicity. However, the TCLP was modified from the official Environmental Protection Agency (EPA) SW-846 procedure to accommodate the very small sample of resin available. The deviations from the EPA SW-846 method are outlined below.

The SW-846 method requires that the leach, or extraction, fluid be selected according to the sample acidity. To choose the extraction fluid, according to the procedure, 1 g of sample is stirred with 20 mL of water. If the pH of the water is less than 5, then extraction Fluid #1 (a mixture of acetic acid and NaOH at a pH of 4.93) is used. Otherwise, 0.5 mL of 1 M HCl is added to the solution, and it is stirred. Then, if the pH is less than 5, Fluid #1 is used; otherwise, Fluid #2 (an acetic acid solution of pH 2.88) is used. There was insufficient sample to perform this test. However, there was little material adhering to the

sample that may have reacted and affected the pH of water or 1M HCl and the resin itself was considered inert in 1M HCl. Therefore, pHs of nearly neutral and <5 in water and 1 M HCl, respectively, were assumed to have been generated and extraction fluid #1 was selected.

Approximately 1 g of sample was available for testing, and this was much less than the 100 g required by the EPA SW-846 procedure. The extraction-fluid volume was proportionately scaled according the mass of available resin. No duplicate extractions were performed due to the limited sample size.

The results from the modified TCLP performed here, therefore, only provide a preliminary assessment of the toxicity characteristic of the spent resin and may not be appropriate for regulatory submissions as described by Arm (2001).

3.0 Test Operation

This section defines bed volume, describes resin conditioning, and describes cycle operation for Cycles 1 through 26.

3.1 Bed Volume (BV) Definition

Solution volumes and flow rates are reported relative to the volume of resin measured in 0.25 M NaOH, typically the conditioning operation at the beginning of each cycle. However, measurements of the bed height throughout the test showed that the bed volume was constant for all operations and reagents. The initial bed volume was 5 mL although this reduced to 4.6 mL after cycle 4 when resin was removed trapped in the quartz wool that was replaced. Bed diameter was 15 mm and initial height 28 mm.

3.2 Resin Conditioning

Dry SL-639 resin of mass 2.658 g and bed volume 5.0 mL was washed in DI water for 3 h in a beaker. The water was then de-canted from the resin that was further washed with 1 M NaOH for 2 h. The resin expanded in 1 M NaOH, occupied a volume of 5.7 mL, and 5 mL (2.33 g) were transferred to the column using DI water.

3.3 Cycle Operation

3.3.1 Test Schedule

Table 3-1 presents the test schedule. The schedule shows 26 cycles with cycles performed on nearly consecutive weeks with breaks for holidays. Every fifth cycle was performed under baseline conditions while different LAW feed compositions and flow rates were investigated in the intermediate cycles according to a partial factorial experimental design. The test variables studied were Tc and NO_3^- concentrations and simulated LAW feed rate. The "Actual" Tc and NO_3^- concentrations for cycles 5, 10, 15, 20 and 25 were determined by ICP-MS and IC analysis respectively, as discussed in Sec. 2.1. The "Actual" values indicated for the remaining cycles were calculated based on the simulant preparation details. The logic behind the values of the composition variables is described in Section 2.1. The baseline LAW feed rate of 3 BV/h was selected since it is the WTP design value for processing LAW of Envelopes A and C provided by Olson (2001). The value of 1.5 BV/h was selected as the lower rate since it is the WTP design value for processing LAW from Envelope B. The maximum value of 6 BV/h was selected with WTP personnel to provide a reasonable range of flow rates expected in the WTP.

3.3.2 Overview

A cycle test commenced with conditioning the resin by pumping the equivalent of nominally two BVs of 0.25 M NaOH through the bed. The simulated LAW was then processed, followed by column rinses of nominally the equivalent of two and one apparatus volumes (AVs) each of 0.1 M NaOH solution and DI water, respectively. Note that 250 BVs of simulated LAW were processed in each cycle compared to the design specification of 112 BVs provided by Olson (2001) such that a greater quantity of ^{99}Tc broke through into the effluent than would be expected in the WTP. Overall ^{99}Tc removal in each cycle was thereby lower than the 98% expected by Olson (2001). The water heater was then switched on, and hot water was recirculated through the column jacket. Flow through the bed was terminated while the hot

water temperature increased to its set point of 65°C over typically 1 h. DI water flow through the bed was initiated once the hot-water-temperature set point had been achieved, and the resin was eluted with up to 55 BVs of DI water.

Cycles 5, 10, 15, 20, 25, and 26 were performed with simulated LAW of baseline composition and baseline flow rates (3 BV/h in all operations) to be able to monitor resin performance at consistent conditions. Cycles 1 through 4 were used to determine an appropriate baseline feed ^{99}Tc concentration. Other cycles were used for the parametric study. The contact time of resin with each reagent was maintained constant for all cycles since exposure time was considered an important variable on chemical degradation characteristics.

Table 3-1. Nominal SL-639 Chemical Degradation Test Schedule

		Concentrations				LAW Feed Rate (BV/h)	
		Tc (mM)		NO_3^- (M)			
Cycle	Operation Dates	Target	Actual	Target	Actual	Target	Actual
1	9/24/01 – 9/28/01	0.047	0.067	1.23	1.34	3.0	3.3
2	10/1/01 – 10/5/01	0.076	0.104	1.23	1.34	3.0	3.2
3	10/8/01 – 10/13/01	0.149	0.205	1.23	1.34	3.0	3.3
4	10/15/01 – 10/19/01	0.300	0.429	1.23	1.34	3.0	3.1
5	10/29/01 – 11/2/01	0.300	0.427	1.23	1.33	3.0	3.2
6	11/5/01 – 11/9/01	0.300	0.414	1.23	1.34	3.0	3.2
7	11/12/01 – 11/16/01	0.300	0.414	1.23	1.23	3.0	0.9
8	11/26/01 – 11/30/01	0.300	0.414	1.23	1.23	3.0	3.4
9	12/3/01 – 12/7/01	0.300	0.414	1.23	1.23	3.0	3.4
10	12/10/01 – 12/14/01	0.300	0.413	1.23	1.32	3.0	3.3
11	1/7/02 – 1/11/02	0.300	0.400	0.10	0.10	6.0	7.3
12	1/14/02 – 1/18/02	0.300	0.400	0.10	0.10	1.5	1.7
13	1/21/02 – 1/25/02	0.300	0.400	0.10	0.10	3.0	3.3
14	1/28/02 – 1/2/02	0.300	0.400	0.50	0.50	1.5	1.7
15	2/4/02 – 2/8/02	0.300	0.281	1.23	1.35	3.0	3.3
16	2/11/02 – 2/15/02	0.300	0.444	0.50	0.50	6.0	7.1
17	2/18/02 – 2/22/02	0.047	0.064	2.16	2.16	1.5	1.6
18	2/25/02 – 2/29/02	0.300	0.400	0.50	0.50	1.5	1.6
19	3/4/02 – 3/8/02	0.047	0.047	2.16	2.16	6.0	6.6
20	3/11/02 – 3/15/02	0.300	0.297(1)	1.23	1.35	3.0	3.0
21	3/18/02 – 3/22/02	0.047	0.063	2.16	2.16	1.5	1.6
22	3/25/02 – 3/29/02	0.300	0.289	2.16	2.16	6.0	6.6
23	4/1/02 – 4/5/02	0.047	0.064	2.16	2.16	1.5	1.6
24	4/8/02 – 4/12/02	0.047	0.062	2.16	2.16	3.0	3.1
25	4/15/02 – 4/19/02	0.300	0.284(1)	1.23	1.34	3.0	3.1
26	4/22/02 – 4/27/02	0.300	0.284	1.23	1.23	3.0	3.2

1. Error may be as high as +/- 30%. See footnote (14) for Table 2-3.

Simulated LAW effluent samples were periodically collected by directing the flow into 20-mL collection vials to collect nominally 5 mL or 2.5 mL of sample, depending on the flow rate. These samples were then analyzed by GEA for their ^{95m}Tc content. The bed height and effluent bottle mass were measured during sampling events. Samples of the simulated LAW feed and effluent of ~20-mL volume were also collected for potential semi-volatile and volatile organic analysis (SVOA/VOA) in

Cycles 1, 5, 10, 15, 20, and 25. Note that BNI determined during the course of this work that SVOA and VOA were to be performed on samples collected in another task

For most cycles, eluate was collected in a single bottle, and then the final 5 mL was collected separately for GEA to determine the ^{95m}Tc content. In order to ascertain the elution profile, samples of eluate were periodically collected during Cycles 1, 2, 5, 10, 15, 20, 25, and 26 into 20-mL vials. Eluate and eluant samples of ~20-mL volume were also collected for potential SVOA/VOA in Cycles 1, 5, 10, 15, 20, and 25.

Activity balance integrity was assessed on Cycles 1, 2, 5, 10, 15, 20, 25, and 26 by performing GEA on 5-mL samples of all effluent composites except from the conditioning operation.

Significant accumulation of gas in the headspace above the resin bed was observed during elution throughout this test. The phenomenon required that the quartz wool be removed and the bed and column re-flooded sometimes during elution, but usually once elution was complete. The gas accumulation was considered to be due to some feature of the test setup during testing, and various methods and modifications were unsuccessfully employed. The gas accumulation was then hypothesized, but only after testing was complete, to be from air coming out of solution as the water was heated in the column. Calculations based on comparing the air solubility in water at 25°C and 65°C indicate that up to ~1.6 mL of air may have accumulated in the column during elution. Incomplete re-flooding, leading to feed channeling, is considered to be the most likely cause for the high early feed breakthroughs (~10%) periodically reported in the following sections. Further testing would be required to determine if preheating the water to remove dissolved air would eliminate the gas accumulation problem.

The quartz wool was replaced after Cycle 4 when re-flooding the bed, with some loss of resin trapped in the discarded wool. The resin was removed from the column after Cycle 26 and weighing showed that approximately 0.8 mL of resin had become trapped in the quartz wool recovered after Cycles 4 and 26. The BV is therefore assumed to have decreased from 5 mL to 4.6 mL after Cycle 4. Note that accurately measuring the bed height to determine BV proved impractical due to the distortion of the bed top surface arising from the quartz wool.

Appendix A contains the operational data for each cycle.

3.3.3 Operational Details for Cycle 1

Details regarding the operation of the first cycle are provided in Table 3-2. Note that this cycle used fresh simulated LAW from Batch 2 that had not been previously processed through the SL-644 column. A total AV of 15 mL was measured in the conditioning operation by monitoring the pH of the effluent and the volume of collected effluent.

Table 3-2. Cycle 1 Process Operation Details

		Total Volume of Reagent		Flow Rate of Reagent	
Operation	**Reagent**	**mL**	**BV**	**mL/h**	**BV/h**
Conditioning	0.25 M NaOH	37	7.4	18	3.6
Waste processing	Batch 2 simulated AN-105 LAW	1344	270	16	3.2
Feed displacement	0.1 M NaOH	31	6.2	15	3.1
Rinse	DI water	16	3.2	16	3.2
Elution	Hot DI water	270	54	15	3.0

Figure 3-1 presents the Tc breakthrough profile for Cycle 1. Tc breakthrough is defined as the Tc concentration in the effluent as a fraction of the Tc concentration in the feed. Probability and normal scales are used for Tc breakthrough and effluent volume, respectively, to facilitate analysis since the profile on such a plot is linear for ideal ion exchange performance. The breakthrough profile is approximately linear past 80 BV with ~3% and then ~15% breakthrough after ~80 BVs and ~240 BVs, respectively. The column distribution coefficient was estimated by extrapolating the breakthrough curve to 50% breakthrough to yield a value of ~420.

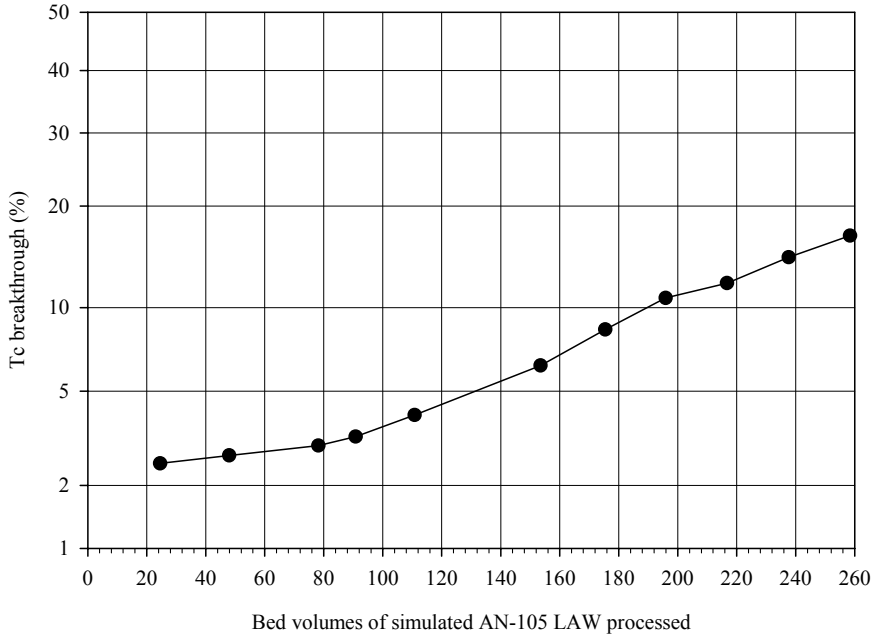

Figure 3-1. Cycle 1 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.2 BV/h, 4.91 M Na, 0.067 mM Tc, 0.079 M K, 1.72 M OH^-, 1.34 M NO_3^-, 1.24 M NO_2^-, ambient conditions, BV = 5.0 mL)

The elution profile on logarithmic and linear axes is presented in Figure 3-2. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and was 1% of that in the simulated LAW feed after ~13 BVs of eluate had been generated.

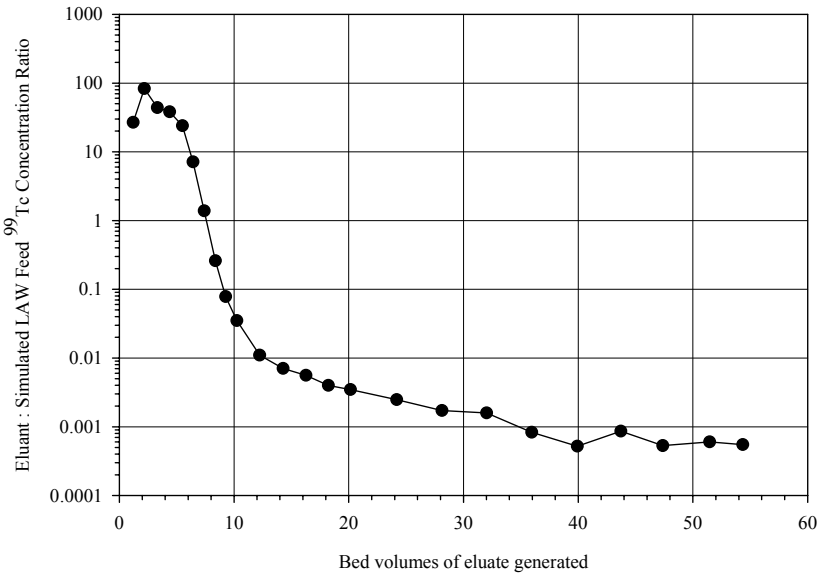

Figure 3-2. Cycle 1 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.2 BV/h, ambient pressure, 65°C, BV = 5.0 mL)

The activity balance for Cycle 1 is presented in Table 3-3 and shows that approximately 89% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered good with 96% of the activity fed to the system accounted for in the effluents.

Table 3-3. Cycle 1 ^{95m}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of feed (%)
Simulated LAW Feed	4.19E6	100
Simulated LAW effluent	2.49E5	5.9
Feed displacement effluent	1.70E4	0.4
Rinse effluent	1.26E4	0.3
Elution effluent	3.73E6	89
Total recovery of feed ^{95m}Tc in effluents	4.01E6	96

3.3.4 Operational Details for Cycles 2, 3 and 4

The operational details presented in Table 3-4 for Cycles 2 through 4 indicate that the system was operated without deviating from the plan summarized in Sections 3.3.1 and 3.3.2. These cycles processed simulated LAW from Batch 2 previously processed through the SL-644 column.

Cycles 2 through 4 investigated the effect on breakthrough of increasing Tc concentration from 0.104 mM to 0.429 mM, and the respective breakthrough profiles are provided in Figure 3-3 through Figure 3-5. Breakthroughs of ~2% were observed in the first sample taken after processing ~20 BVs of simulated LAW for Cycles 2 and 3. An initial breakthrough of 9% was observed after ~30 BVs in Cycle 4, and this relatively high value is considered to be due to feed channeling. The profiles are generally linear after 3% breakthrough on the probability scale. The column distribution coefficients (the number of BVs processed at 50% breakthrough) were estimated by extrapolating the breakthrough curves in cycles 2 and 3 and identified directly from the breakthrough curve of cycle 4. They are recorded in Table 3-5 and are between 410 and 210, decreasing with increasing Tc concentration.

Table 3-4. Operational Details for Cycles 2 Through 4

Cycle	Measurement	Unit	Conditioning (0.25 M NaOH)	Simulated AN-105 Processing	Feed Displacement (0.1 M NaOH)	Rinse (DI water)	Elution (hot DI water)
2	Reagent volume	mL	8.8	1330	31	14	290
		BV	1.8	270	6.2	2.8	58
	Reagent flow rate	mL/h	4.4	16	16	14	16
		BV/h	0.88	3.2	3.2	2.8	3.2
3	Reagent volume	mL	33	1370	30	16	300
		BV	6.6	270	6.0	3.2	60
	Reagent flow rate	mL/h	16	17	14	16	16
		BV/h	3.2	3.4	2.8	3.2	3.2
4	Reagent volume	mL	Not measured	1290	27	15	270
		BV	Not measured	260	5.4	3.0	54
	Reagent flow rate	mL/h	Not measured	16	14	15	14
		BV/h	Not measured	3.2	2.8	3.0	2.8

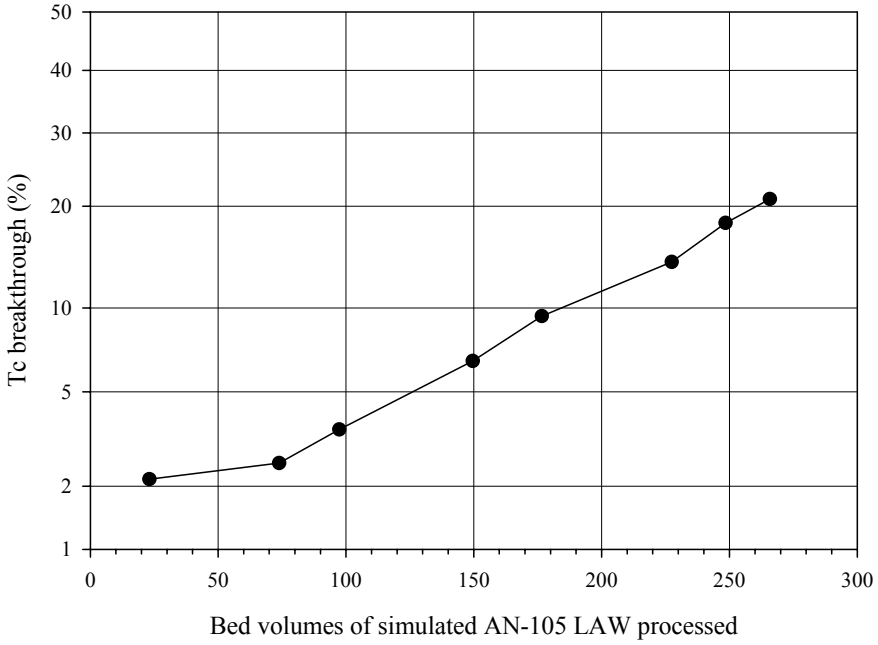

Figure 3-3. Cycle 2 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.2 BV/h, 4.91 M Na, 0.104 mM Tc, 0.079 M K, 1.72 M OH^-, 1.34 M NO_3^-, 1.24 M NO_2^-, ambient conditions, BV = 5.0 mL)

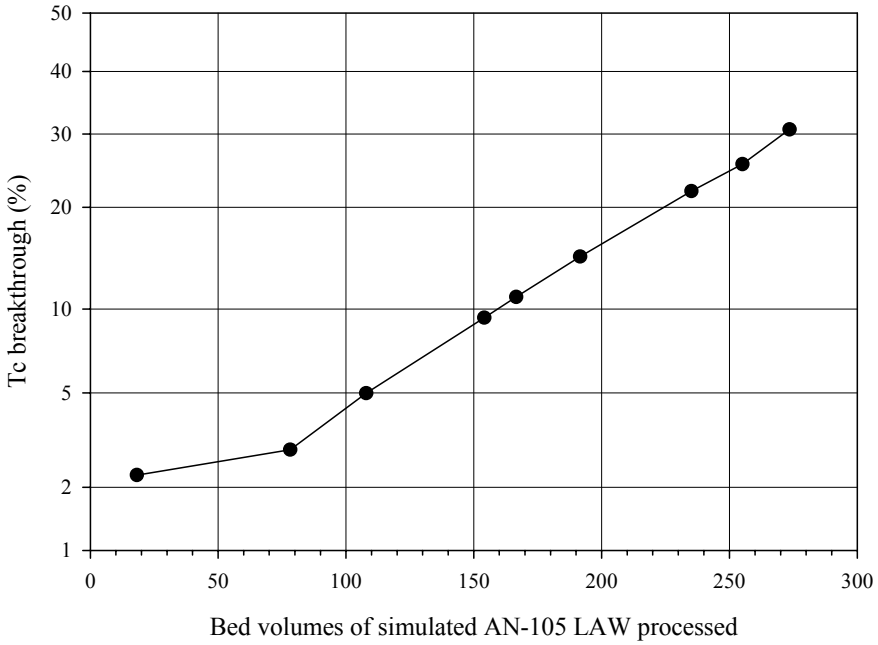

Figure 3-4. Cycle 3 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.4 BV/h, 4.91 M Na, 0.205 mM Tc, 0.079 M K, 1.72 M OH^-, 1.34 M NO_3^-, 1.24 M NO_2^-, ambient conditions, BV = 5.0 mL)

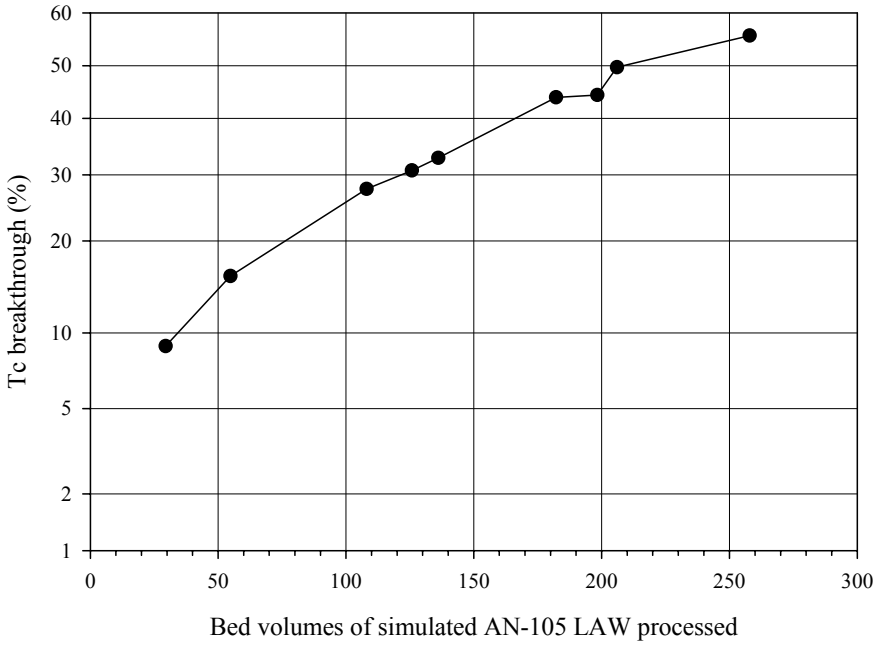

Figure 3-5. Cycle 4 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.2 BV/h, 4.91 M Na, 0.429 mM Tc, 0.079 M K, 1.72 M OH^-, 1.34 M NO_3^-, 1.24 M NO_2^-, ambient conditions, BV = 5.0 mL)

Table 3-5. Column Distribution Coefficients for Cycles 2 Through 4

Cycle	Tc Concentration (mM)	Column-Distribution Coefficient
2	0.111	410
3	0.218	350
4	0.456	220

Table 3-6 shows that the target eluate to simulated LAW feed Cs concentration of 0.01 in the last 5 mL of eluate was achieved in the two cycles in which it was measured.

Table 3-6. Elution Performance Data for Cycles 2 Through 4

Cycle	Eluate to Simulated LAW feed Tc Concentration Ratio in last 5 mL of Eluate
2	Not measured (sample inadvertently discarded)
3	0.003
4	<0.001

3.3.5 Operational Details for Cycle 5

The operational details are presented in Table 3-7 for Cycle 5 and indicate that the system was operated without deviating from the plan summarized in Sections 3.3.1and 3.3.2. The system processed simulated LAW from Batch 1 previously processed in the SL-644 column.

Table 3-7. Cycle 5 Operational Details

		Total Volume of Reagent		Flow Rate of Reagent	
Operation	**Reagent**	**mL**	**BV**	**mL/h**	**BV/h**
Conditioning	0.25 M NaOH	30	6.5	15	3.3
Waste processing	Batch 1 simulated AN-105 LAW	1200	260	15	3.3
Feed displacement	0.1 M NaOH	30	6.5	15	3.2
Rinse	DI water	16	3.5	16	3.5
Elution	Hot DI water	270	58	15	3.3

The simulated AN-105 LAW feed contained Tc at a concentration nominally similar to that used in Cycle 4 at 0.427 mM. The breakthrough profile presented in Figure 3-6 shows that resin breakthrough performance had apparently improved over that observed in Cycle 4 by re-flooding the bed and column. For example, 10% breakthrough was not observed until nearly ~150 BVs of feed had been processed in Cycle 5 whereas breakthrough was already 10% after ~30 BVs in Cycle 4. The breakthrough profile is essentially linear on the probability scale after 100 BVs and extrapolates to a column distribution coefficient of 280. This value contrasts to that of 220 observed in Cycle 4. The feed and first two effluent samples were also analyzed by liquid scintillation counting (LSC) to determine the concentrations of ^{99}Tc and compare with the breakthroughs obtained by ^{95m}Tc GEA. Figure 3-6 shows that initial ^{99}Tc breakthrough was much better than that of ^{95m}Tc. For example, initial ^{95m}Tc breakthrough was ~2% compared to less than 0.01% for ^{99}Tc. Comparison of these results appears to indicate that a fraction of the ^{95m}Tc spike existed in a non-pertechnetate form that would not have been separated by the resin.

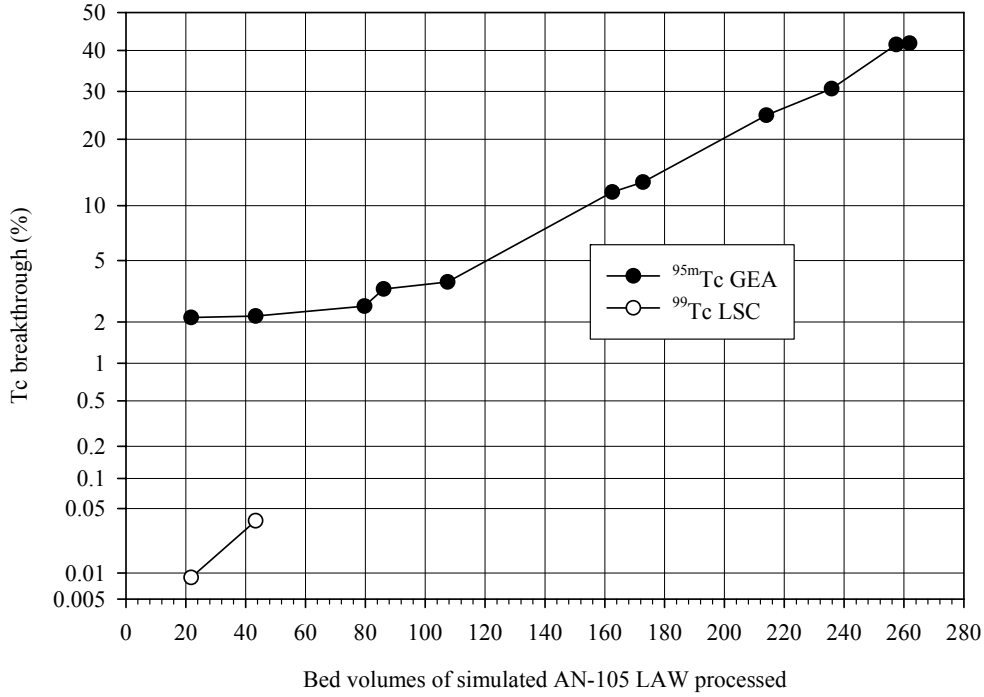

Figure 3-6. Cycle 5 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, 4.83 M Na, 0.427 mM Tc, 0.078 M K, 1.72 M OH^-, 1.33 M NO_3^-, 1.22 M NO_2^-, ambient conditions, BV = 4.6 mL)

The elution profile is presented in Figure 3-7. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and was 1% of that in the simulated LAW feed after ~14 BVs of eluate had been generated as observed in Cycle 1.

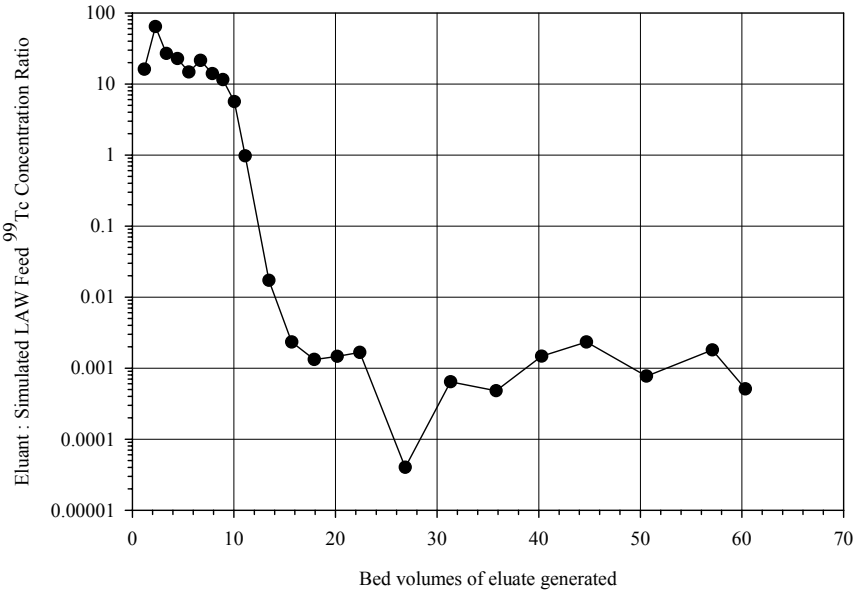

Figure 3-7. Cycle 5 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

The activity balance for Cycle 5 is presented in Table 3-8 and shows that approximately 84% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered good with 90% of the activity fed to the system accounted for in the effluents.

Table 3-8. Cycle 5 ^{95m}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of Feed (%)
Simulated LAW Feed	4.35E5	100
Simulated LAW effluent	1.86E4	4.3
Feed displacement effluent	5.20E3	1.2
Rinse effluent	4.56E3	1.0
Elution effluent	3.65E5	84
Total recovery of feed ^{95m}Tc in effluents	3.93E5	90

Table 3-9 presents the results of the composite simulated LAW effluent and eluate chemical analyses. The eluate analysis shows the presence of Na and K with smaller quantities of other metals, although none of the feed constituents were significantly separated. The increase in the ratio of Na to K in the eluate compared to the simulated LAW appears to suggest preferential separation of K salts, including $KTcO_4$. The high concentrations of Si and B are considered to be due to contamination from glassware.

Table 3-9. Chemical Analysis of Composite Simulated LAW Feed, Effluent and Eluate from Cycle 5

Analyte	Analysis Method	Concentration (mg/L)[1]			Total mass (mg)			Percentage separated[3]
		LAW Feed	LAW Effluent	Eluate	LAW feed	LAW Effluent	Eluate	
Ag	ICP-AES	<0.625	<0.625	<0.025	<0.753	<0.753	<0.007	Indeterminate
Al	ICP-AES	15,600	15,500	1.26	18,800	18,700	0.338	<0.01
As	ICP-AES	*60*	*61*	<0.250	72	73	<0.067	0.09
B	ICP-AES	39.8[4]	29.2[4]	52.1[4]	47.9	35.2	14.0	29
Ba	ICP-AES	*0.43*	*0.45*	<0.010	0.52	0.54	<0.003	<0.58
Ca	ICP-AES	<6.25	<6.25	<0.250	<7.53	<7.53	<0.067	Indeterminate
Cd	ICP-AES	*0.97*	*1.1*	*0.015*	1.2	1.3	0.004	0.33
Cl	IC	5,700	5,400	0.91	6,900	6,500	0.24	<0.01
Cr	ICP-AES	1,430	1,410	0.262	1,720	1,700	0.07	<0.01
F^{-}[7,8]	IC	1,000	1,100	<0.13	1,200	1,300	<0.03	<0.01
K	ICP-AES	3,030	2,990	41.0	3,650	3,600	11.0	0.30
Mg	ICP-AES	<2.5	<2.5	*0.25*	<3.01	<3.01	*0.067*	>2.2[9]
Mo	ICP-AES	39.0	38.4	<0.050	47.0	46.2	<0.013	<0.03
Na	ICP-AES	111,000[5]	109,000[5]	53.6[5]	134,000	131,000	14.4	0.01
P	ICP-AES	122	119	*0.18*	147	143	*0.048*	0.03
Pb	ICP-AES	41.4	46.6	*0.14*	49.8	56.1	*0.038*	0.08
Se	ICP-AES	*49*	*48*	<0.250	59	58	<0.067	<0.11
Si	ICP-AES	138[4]	136[4]	9.13[4]	166	164	2.45	1.5
U	ICP-AES	<50	<50	<2.000	<60	<60	<0.536	Indeterminate
Zn	ICP-AES	*4.7*	*4.8*	<0.050	5.7	5.8	<0.013	<0.23
$C_2O_4^{-}$[8]	IC	<500	<500	<0.25	<600	<600	<0.06	<0.01
NO_2^{-}	IC	56,200	55,300	6.9	67,800	66,800	1.9	<0.01
NO_3^{-}	IC	82,300	80,300	11.6	99,400	96,900	3.1	<0.01
PO_4^{-}[8]	IC	1,400	<500	<0.25	1,700	<600	<0.06	<0.01
SO_4^{-}[8]	IC	2,400	1,500	1.8	2,900	1,800	0.48	0.02
TIC	HP	1,610	1,590	<10	1,940	1,920	<3	<0.15
Total Carbon	Furnace	2,710	2,700	<22	3,270	3,260	<5.9	Indeterminate
TOC	HP	1,140	1,110	<40	1,380	1,340	<11	<0.80
	Furnace	175[6]	49[6]	30	210	60	8.1	3.9
	Furnace Total Carbon – HP TIC[2]	1,100	1,110	<22	1,330	1,340	<5.9	<0.44

1. ICP-AES results in normal type have errors likely <15%, but those in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.
2. The furnace method typically produces the best total-carbon results while the best TIC results are obtained from the HP method. Thus, the best TOC result may be the difference between these measurements.
3. Percentage of feed constituent recovered in the eluate.
4. Si and B analysis compromised by error in sample preparation manifesting in poor recoveries from spike samples.
5. Relative % difference of 7.3% between duplicates did not satisfy the QC acceptance criterion of 3.5%. No significant impact on results expected.
6. TOC recoveries from the caustic matrix spike lower than the QC acceptance criterion makes this result doubtful. See also note 2.
7. F^{-} results from IC should be considered upper bounds due to significant analytical interference from organic compounds such as acetate.
8. F^{-}, PO_4^{-}, SO_4^{-} and $C_2O_4^{-}$ results should be considered qualitative since the high concentrations of NO_3^{-} and NO_2^{-} required the samples to be diluted by up to 10,000 times so that the anions were measured within their IC calibration range and to avoid the IC column becoming overloaded during analysis. The result for P obtained from ICP-AES is considered more accurate.
9. Lower bound value because the feed concentration was below the detection limit of the analytical method.

3.3.6 Operational Details for Cycles 6 Through 9

Table 3-10 presents the operational details for Cycles 6 through 9. The system was generally operated without deviations from the plan summarized in Sections 3.3.1and 3.3.2 except for the LAW processing and feed displacement operations of Cycle 7. Large pressure drops across the column during those operations required the flow rate to be reduced as indicated and the feed displacement operation was temporarily suspended for a weekend. No significant pressure drop was observed when feed displacement was resumed, and the remaining operations of the cycle were completed as planned. It was assumed that a precipitate partially blocked the membrane covering the bottom plunger and that it dissolved over the weekend. The membrane was later removed and replaced with one of coarser mesh. The flow rate of simulated LAW in Cycle 6 inexplicably dropped to 11 mL/h (2 BV/h) during the last 18 h.

Cycle 6 processed simulated LAW from Batch 2 while the remaining cycles processed that from Batch 3. The simulated LAW of Cycles 6 through 9 all contained Tc at a concentration of 0.414 mM, and the breakthrough profiles for Cycles 6, 8, and 9 are presented in Figure 3-8. Breakthrough was limited to ~5% in Cycle 7 and is not illustrated. Figure 3-8 shows that initial breakthrough varied between 2% and 4% in Cycles 6, 8, and 9, and the breakthrough profiles are essentially linear on the probability scale. Breakthrough performance in Cycles 6 and 8 was consistent with that observed in Cycle 5, giving column distribution coefficients of ~280 in both cases. Breakthrough performance in Cycle 9, however, was apparently better, giving a column distribution coefficient of ~390.

Table 3-10. Operational Details for Cycles 6 Through 9

Cycle	Measurement	Unit	Conditioning (0.25 M NaOH)	Simulated AN-105 Processing	Feed Displacement (0.1 M NaOH)	Rinse (DI water)	Elution (hot DI water)
6	Reagent volume	mL	15	1100	22	13	280
		BV	3.3	250	4.8	2.8	62
	Reagent flow rate	mL/h	14	14	12	13	15
		BV/h	3.0	3.0	2.5	2.8	3.3
7	Reagent volume	mL	29	170	24	24	280
		BV	6.3	37	5.2	5.2	61
	Reagent flow rate	mL/h	15	4.2	3.3	16	15
		BV/h	3.3	0.91	0.71	3.5	3.3
8	Reagent volume	mL	31	1300	36	17	280
		BV	6.7	280	7.8	3.7	60
	Reagent flow rate	mL/h	16	16	16	17	15
		BV/h	3.5	3.5	3.5	3.7	3.3
9	Reagent volume	mL	31	1300	32	16	270
		BV	6.7	280	7.0	3.5	60
	Reagent flow rate	mL/h	16	16	16	16	15
		BV/h	3.5	3.5	3.5	3.5	3.3

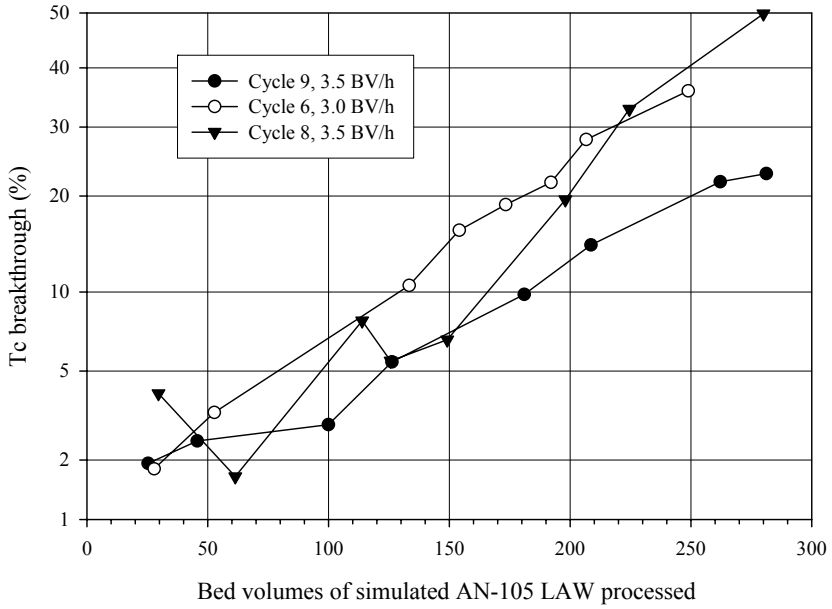

Figure 3-8. Cycle 6, 8 and 9 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 5.34 M Na, 0.414 mM Tc, 0.095 M K, 1.72 M OH^-, 1.23 M NO_3^-, 1.21 M NO_2^-, ambient conditions, BV = 4.6 mL)

Table 3-11 shows that the target eluate to simulated LAW feed Tc concentration of 0.01 in the last 5 mL of eluate was achieved for every cycle.

Table 3-11. Elution Performance Data for Cycles 6 Through 9

Cycle	Eluate to Simulated LAW feed Tc Concentration Ratio in Last 5 mL of Eluate
6	0.002
7	<0.001
8	0.001
9	<0.001

3.3.7 Operational Details for Cycle 10

Table 3-12 presents the operational details for Cycle 10. The system was essentially operated without deviating from the plan summarized in Sections 3.3.1and 3.3.2 except that the cycle had to be temporarily suspended due to a temporary closure of the room after having processed 155 BVs of simulated waste. The column was left idle for approximately 118 h in simulated LAW before operations were resumed.

Table 3-12. Cycle 10 Operational Details

Operation	Reagent	Total Volume of Reagent		Flow Rate of Reagent	
		mL	BV	mL/h	BV/h
Conditioning	0.25M NaOH	31	6.7	15	3.3
Waste processing	Batch 4 simulated AN-105 LAW	1250	270	15	3.3
Feed displacement	0.1M NaOH	31	6.7	15	3.3
Rinse	DI water	15	3.3	15	3.3
Elution	Hot DI water	280	61	15	3.3

The simulated AN-105 LAW feed contained Tc at a concentration of 0.413 mM, and the breakthrough profile is presented in Figure 3-9. The resin-breakthrough performance was initially similar to that observed in Cycle 5. For example, an initial breakthrough of 2% was observed and increased to 5% after ~100 BVs when the profile became linear on the probability scale. The first sample after the suspension in flow showed a reduction in breakthrough. Subsequent samples then showed that the breakthrough profile resumed consistent with that observed before suspending the flow. These phenomena may indicate that the ion exchange process is controlled by film diffusion, although experimental scatter cannot be discounted. The column distribution coefficient is ~280 and identical to that observed in Cycle 5 if the entire breakthrough profile is assumed continuous, i.e., the reduction in breakthrough following resumption of flow is experimental scatter. If the profile is assumed discontinuous, then extrapolating the initial part of the profile to 50% breakthrough yields a column distribution coefficient of ~250. The difference of <10% may not be sufficiently significant to draw conclusions regarding the rate-controlling step.

As in cycle 5, the feed and first two effluent samples were also analyzed by LSC to determine the concentrations of ^{99}Tc and compare with the breakthroughs obtained by ^{95m}Tc GEA. Figure 3-9 shows again that initial ^{99}Tc breakthrough was much better than that of ^{95m}Tc. For example, initial ^{95m}Tc breakthrough was ~2% compared to ~0.02% for ^{99}Tc. Comparison of these results appears to again indicate that a fraction of the ^{95m}Tc spike existed in a non-pertechnetate form that would not have been separated by the resin.

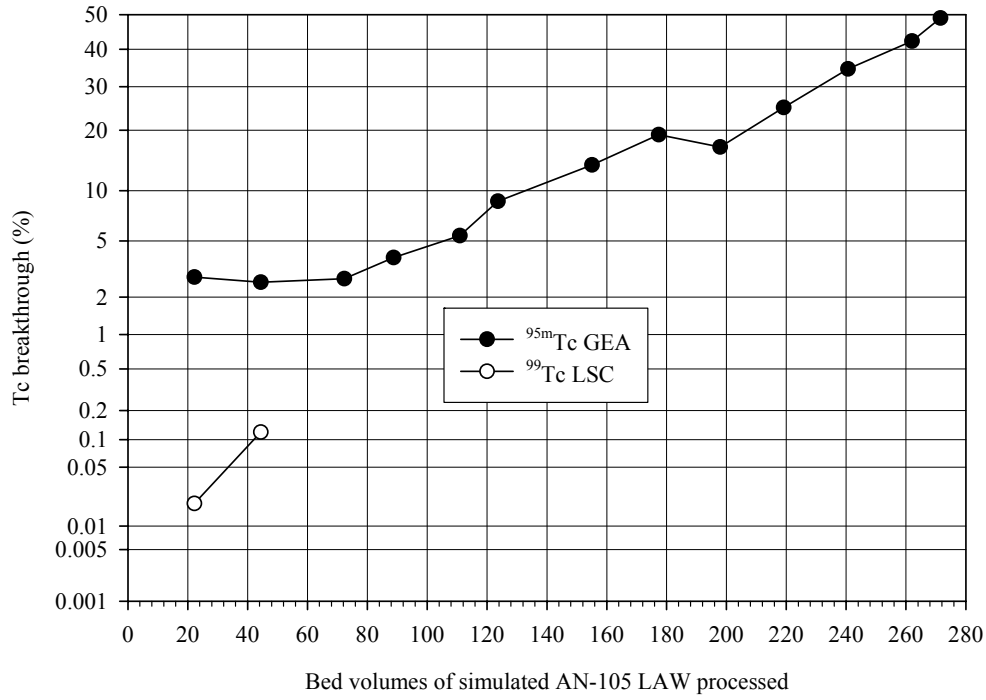

Figure 3-9. Cycle 10 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, 4.78 M Na, 0.413 mM Tc, 0.077 M K, 1.72 M OH^-, 1.32 M NO_3^-, 1.24 M NO_2^-, ambient conditions, BV = 4.6 mL)

Figure 3-10 presents the elution profile. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and was 1% of that in the simulated LAW feed after ~36 BVs of eluate had been generated. The elution performance appears to be worse than observed in Cycles 1 and 5 in which a Tc concentration of 1% of that in the simulated LAW feed was achieved after ~14 BVs of eluate had been generated. The apparent deterioration in performance is considered to be due to eluate channeling arising from gas accumulation in the bed and is probably the cause of the jumps in the profile.

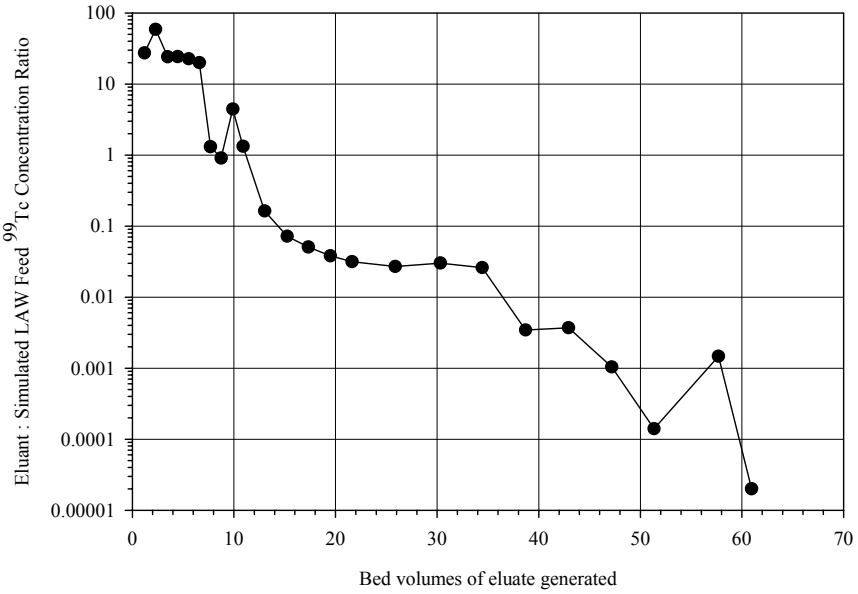

Figure 3-10. Cycle 10 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.2 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

The activity balance for Cycle 10 is presented in Table 3-13 and shows that approximately 76% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered good with 93% of the activity fed to the system accounted for in the effluents.

Table 3-13. Cycle 10 ^{95m}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of feed (%)
Simulated LAW Feed	4.67E5	100
Simulated LAW effluent	6.55E4	14
Feed displacement effluent	6.85E3	1.5
Rinse effluent	4.63E3	1.1
Elution effluent	3.55E5	76
Total recovery of feed ^{95m}Tc in effluents	4.33E5	93

The results of the composite simulated LAW effluent and eluate chemical analyses are presented in Table 3-14. As in cycle 5, the eluate analysis shows the presence of Na and K with smaller quantities of other metals, although none of the feed constituents were significantly separated. The increase in the ratio of Na to K in the eluate compared to the simulated LAW again appears to suggest preferential separation of K salts, including $KTcO_4$. The high concentrations of Si and B are again considered to be due to contamination from glassware.

Table 3-14. Chemical Analysis of Simulated LAW Feed, Effluent and Eluate from Cycle 10

Analyte	Analysis Method	Concentration (mg/L)[1]			Total mass (mg)			Percentage Separated[3]
		LAW Feed	LAW Effluent	Eluate	LAW Feed	LAW Effluent	Eluate	
Ag	ICP-AES	<0.625	<0.625	<0.025	<0.781	<0.781	<0.007	Indeterminate
Al	ICP-AES	15,400	15,300	9.06	19,200	19,100	2.54	0.01
As	ICP-AES	*60*	*59*	<0.250	*75*	*74*	<0.070	<0.09
B	ICP-AES	39.7	29.1	64.8	49.6	36.3	18.1	36
Ba	ICP-AES	<0.25	<0.25	<0.010	<0.312	<0.312	<0.003	Indeterminate
Ca	ICP-AES	<6.25	<6.25	<0.25	<7.81	<7.81	<0.070	Indeterminate
Cd	ICP-AES	*1.1*	*1.1*	*0.016*	*1.37*	*1.37*	0.004	0.29
Cl	IC	5,500	5,100	3.4	6,900	6,400	0.95	0.01
Cr	ICP-AES	1,420	1,400	1.36	1,770	1,750	0.381	0.02
$F^{(6,7)}$	IC	1,000	1,000	<0.13	1,200	1,200	<0.036	<0.01
K	ICP-AES	3,000	2,960	52.3	3,750	3,700	14.6	0.39
Mg	ICP-AES	<2.5	<2.5	*0.29*	<3.12	<3.12	*0.081*	>2.6[8]
Mo	ICP-AES	38.6	38.0	*0.050*	48.2	47.5	*0.014*	0.03
Na	ICP-AES	110,000[4]	109,000[4]	138[4]	137,000	136,000	38.6	0.03
P	ICP-AES	127	123	*0.30*	159	154	*0.084*	0.05
Pb	ICP-AES	51.6	49.9	*0.14*	64.4	62.3	*0.039*	0.06
Se	ICP-AES	*49*	*48*	<0.25	*61*	*60*	<0.07	<0.11
Si	ICP-AES	*120*	127	5.57	*150*	159	1.56	1.0
U	ICP-AES	<50	<50	<2.000	<62	<62	<0.56	Indeterminate
Zn	ICP-AES	*4.7*	*4.6*	<0.050	*5.9*	*5.7*	<0.014	<0.24
$C_2O_4^{-(7)}$	IC	<500	<500	0.5	<600	<600	0.1	>0.02[8]
NO_2^-	IC	56,900	56,000	42.9	70,900	69,700	12.0	0.02
NO_3^-	IC	81,900	80,300	63.7	102,000	100,000	17.8	0.02
$PO_4^{-(7)}$	IC	1,400	1,400	0.7	1,700	1,700	0.2	0.01
$SO_4^{-(7)}$	IC	2,300	<500	1.8	2,900	<600	0.5	0.02
TIC	HP	1,640	1,560	<10	2,040	1,940	<3	<0.15
Total Carbon	Furnace	2,680	2,950	94	3,340	3,670	26	0.78
TOC	HP	1,070	1,080	<40	1,330	1,350	<11	<0.83
	Furnace	<94[5]	49[5]	<47	<120	61	<13	Indeterminate
	Furnace Total Carbon – HP TIC[2]	1,040	1,390	<94	1,300	1,730	<26	<2.0

1. ICP-AES results in normal type have errors likely <15% but those in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.
2. The furnace method typically produces the best total-carbon results while the best TIC results are obtained from the HP method. Thus the best TOC result may be the difference between these measurements.
3. Percentage of feed constituent recovered in the eluate.
4. Relative % difference of 4.0% between duplicates did not satisfy the QC acceptance criterion of 3.5%. No significant impact on results expected.
5. TOC recoveries from the caustic matrix spike lower than the QC acceptance criterion makes this result doubtful. See also note 2.
6. F^- results from IC should be considered upper bounds due to significant analytical interference from organic compounds such as acetate.
7. F^-, PO_4^-, SO_4^- and $C_2O_4^-$ results should be considered qualitative since the high concentrations of NO_3^- and NO_2^- required the samples to be diluted by up to 10,000 times so that the anions were measured within their IC calibration range and to avoid the IC column becoming overloaded during analysis. The result for P obtained from ICP-AES is considered more accurate.
8. Lower bound value because the feed concentration was below the detection limit of the analytical method.

3.3.8 Operational Details for Cycles 11 Through 14

Table 3-15 presents the operational details for Cycles 11 through 14. The cycles were largely performed according to the plan summarized in Sections 3.3.1 and 3.3.2 except for the elution operation of Cycle 11, which was terminated early for schedule reasons. Cycles 11, 12, and 13 processed simulated LAW from Batch 5 while Cycle 14 processed that from Batch 6.

Table 3-15. Operational Details for Cycles 11 Through 14

Cycle	Measurement	Unit	Conditioning (0.25 M NaOH)	Simulated AN-105 Processing	Feed Displacement (0.1 M NaOH)	Rinse (DI water)	Elution (hot DI water)
11	Reagent volume	mL	30	1500	28	15	160
		BV	6.5	330	6.2	3.3	35
	Reagent flow rate	mL/h	15	33	14	15	14
		BV/h	3.3	7.2	3.1	3.3	3.0
12	Reagent volume	mL	30	630	29	15	270
		BV	6.5	140	6.4	3.3	59
	Reagent flow rate	mL/h	15	7.6	15	15	15
		BV/h	3.3	1.7	3.3	3.3	3.3
13	Reagent volume	mL	30	1200	31	13	280
		BV	6.5	270	6.8	2.8	60
	Reagent flow rate	mL/h	15	15	15	13	15
		BV/h	3.3	3.3	3.3	2.8	3.3
14	Reagent volume	mL	31	660	30	15	270
		BV	6.7	140	6.6	3.3	60
	Reagent flow rate	mL/h	15	7.9	15	15	15
		BV/h	3.3	1.7	3.3	3.3	3.3

The simulated LAW feed for Cycles 11 through 14 contained Tc at a concentration of 0.400 mM, but only in Cycle 11 was significant breakthrough observed. This trend in performance was expected since the NO_3^- concentrations of 0.1 M in Cycles 11 through 13 and 0.5 M in Cycle 14 were significantly lower than the baseline of 1.23 M. The breakthrough curve for Cycle 11 is presented in Figure 3-11, and extrapolating to 50% breakthrough gives a column distribution coefficient of ~360.

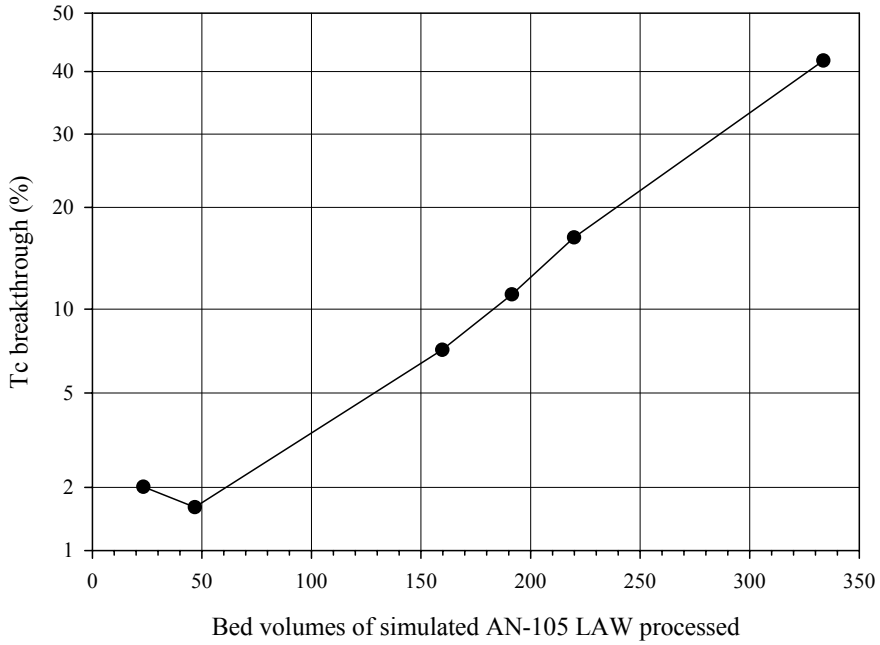

Figure 3-11. Cycle 11 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 7.2 BV/h, 5.34 M Na, 0.400 mM Tc, 0.008 mM K, 2.2 M OH^-, 0.1 M NO_3^-, 1.46 M NO_2^-, ambient conditions, BV = 4.6 mL)

Table 3-16 shows that the target Tc concentration in the eluate of 1% of that in the simulated LAW feed was achieved in every cycle.

Table 3-16. Elution Performance Data for Cycles 11 Through 14

Cycle	Eluate to Simulated LAW feed Tc Concentration Ratio in Last 5 mL of Eluate
11	0.002
12	0.003
13	0.005
14	0.003

3.3.9 Operational Details for Cycle 15

The operational details are presented in Table 3-17 for Cycle 15. The system was essentially operated without deviating from the plan summarized in Sections 3.3.1 and 3.3.2.

Table 3-17. Cycle 15 Operational Details

Operation	Reagent	Total Volume of Reagent		Flow Rate of Reagent	
		mL	BV	mL/h	BV/h
Conditioning	0.25M NaOH	33	7.2	15	3.3
Waste processing	Batch 4 simulated AN-105 LAW	1241	270	15	3.3
Feed displacement	0.1M NaOH	30	6.5	15	3.3
Rinse	DI water	16	3.5	16	3.4
Elution	Hot DI water	274	60	15	3.3

The simulated AN-105 LAW feed contained Tc at a concentration ~30% lower than used in Cycle 10 at 0.281 mM. The difference was likely due to the Tc stock solution composition used in Cycles 1 through 14 being incorrect, as described in Section 2.1. Despite the lower Tc concentration, the breakthrough profile presented in Figure 3-12 shows that resin breakthrough performance had apparently deteriorated over that observed in Cycle 10. For example, 10% breakthrough was observed after ~20 BVs, and ~130 BVs of feed had been processed in Cycles 10 and 15, respectively. The deterioration in performance is again considered due to feed channeling. The breakthrough profile is approximately linear on the probability scale and provides a column distribution coefficient of 230, in contrast to ~280 observed in Cycles 5 and 10.

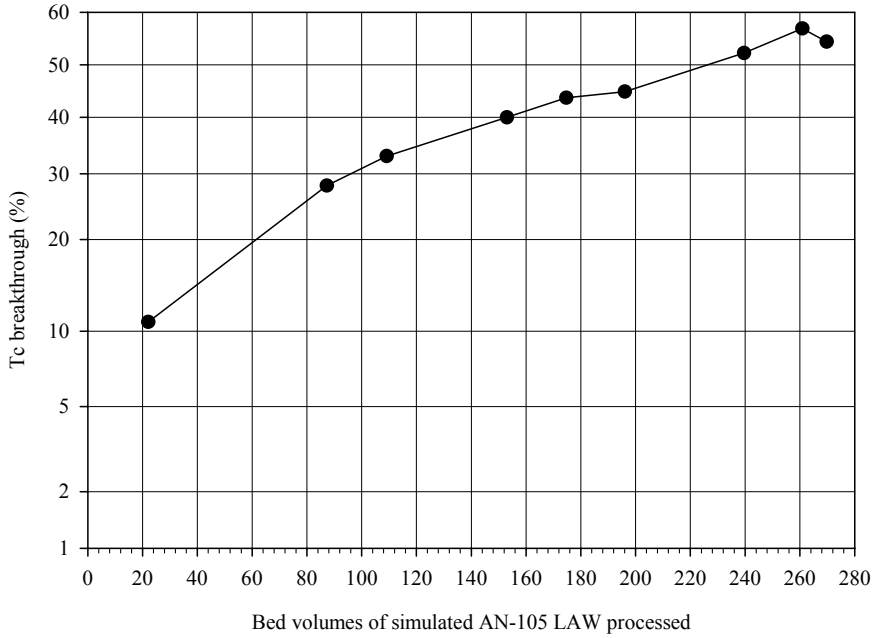

Figure 3-12. Cycle 15 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, 4.91 M Na, 0.281 M Tc, 0.079 M K, 1.72 M OH^-, 1.35 M NO_3^-, 1.26 M NO_2^-, ambient conditions, BV = 4.6 mL)

Figure 3-13 presents the elution profile. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and was 1% of that in the simulated LAW feed after ~26 BVs of eluate had been generated. The performance was somewhat better than in Cycle 10 when the Tc eluate concentration was 1% of that in the LAW feed after 36 BVs.

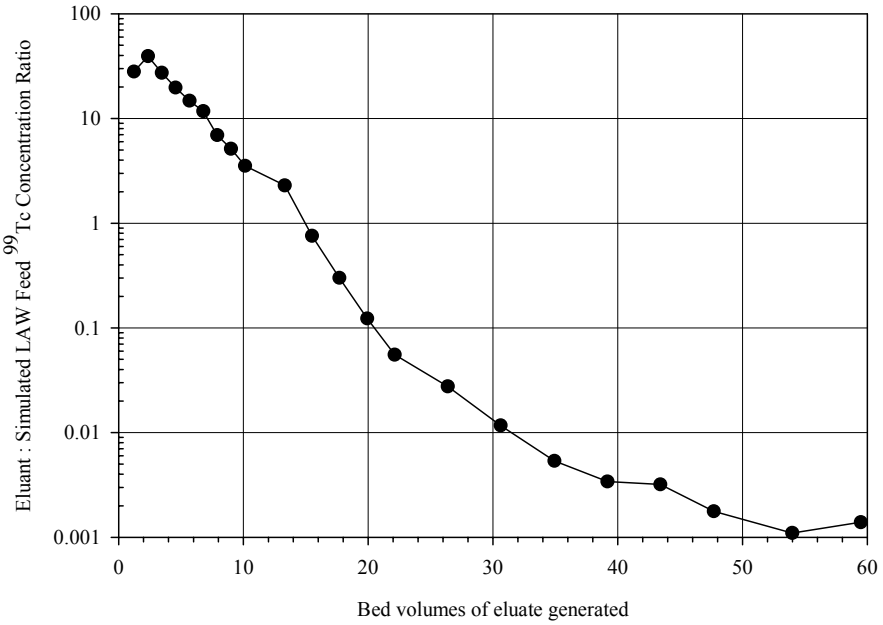

Figure 3-13. Cycle 15 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

The activity balance for Cycle 15 is presented in Table 3-18 and shows that approximately 68% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered reasonable with ~10% more activity in the effluents than in the LAW feed.

Table 3-18. Cycle 15 ^{95m}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of Feed (%)
Simulated LAW Feed	8.90E5	100
Simulated LAW effluent	3.54E5	40
Feed displacement effluent	1.36E4	1.5
Rinse effluent	1.02E4	1.1
Elution effluent	6.03E5	68
Total recovery of feed ^{95m}Tc in effluents	9.81E5	110

Table 3-19 presents the results of the composite simulated LAW effluent and eluate chemical analyses. As in previous cycles, the eluate analysis shows the presence of Na and K with smaller quantities of other metals, although none of the feed constituents were significantly separated. The increase in the ratio of Na to K in the eluate compared to the simulated LAW again appears to suggest preferential separation of K salts, including $KTcO_4$. The high concentrations of Si and B are considered to be due to contamination from glassware.

Table 3-19. Chemical Analysis of Simulated LAW Feed, Effluent and Eluate from Cycle 15

Analyte	Analysis Method	Concentration (mg/L)[1]			Total mass (mg)			Percentage separated [3]
		LAW feed	LAW Effluent	Eluate	LAW feed	LAW Effluent	Eluate	
Ag	ICP-AES	<0.625	<0.625	*0.031*	<0.776	<0.776	*0.008*	Indeterminate
Al	ICP-AES	16,000	16,200	*0.32*	19,900	20,100	*0.09*	<0.01
As	ICP-AES	*62*	*65*	<0.25	*77*	*81*	<0.069	<0.09
B	ICP-AES	36.6	*32*	32.5	45.4	*40*	8.91	0.20
Ba	ICP-AES	*0.49*	<0.25	<0.01	*0.61*	<0.31	<0.003	<0.49
Ca	ICP-AES	<6.25	<6.25	<0.25	<7.76	<7.76	<0.069	Indeterminate
Cd	ICP-AES	*0.82*	<0.375	<0.015	*1.0*	<0.465	<0.004	<0.4
Cl	IC	5,800	6,900	0.73	7,200	8,500	0.20	<0.01
Cr	ICP-AES	1,460	1,540	*0.20*	1,810	1,910	*0.05*	<0.01
$F^{(6,7)}$	IC	1,000	1,000	<0.13	1,200	1,200	<0.04	<0.01
K	ICP-AES	3,080	3,230	26.8	3,820	4,010	7.34	0.19
Mg	ICP-AES	<2.5	<2.5	*0.16*	<3.1	<3.1	*0.04*	>1.3[8]
Mo	ICP-AES	40.0	*42*	<0.05	49.6	*52*	<0.014	<0.03
Na	ICP-AES	113,000[4]	107,000[4]	30[4]	140,000	133,000	8.22	<0.01
P	ICP-AES	125	*120*	*0.13*	155	*149*	*0.04*	0.03
Pb	ICP-AES	55.4	*58*	<0.100	68.8	*72*	<0.03	<0.04
Se	ICP-AES	*50*	*51*	<0.250	*62*	*63*	<0.07	<0.11
Si	ICP-AES	*110*	*130*	*4.2*	*140*	*160*	*1.2*	0.86
U	ICP-AES	<50	<50	<2.000	<62	<62	<0.5	Indeterminate
Zn	ICP-AES	*4.7*	<1.25	<0.050	*5.8*	<1.55	<0.014	<0.24
$C_2O_4^{-(7)}$	IC	<500	<500	<0.25	<600	<600	<0.07	Indeterminate
NO_2^-	IC	57,800	56,200	5.7	71,600	69,600	1.6	<0.01
NO_3^-	IC	83,800	84,600	12.5	104,000	105,000	3.4	<0.01
$PO_4^{-(7)}$	IC	1,300	1,300	<0.25	1,600	1,600	<0.07	<0.01
$SO_4^{-(7)}$	IC	2,600	<500	2.7	3,200	<600	0.74	0.02
TIC	HP	1,680	1,640	<10	2,080	2,030	<2.7	<0.13
Total Carbon	Furnace	2,640	2,630	31	3,270	3,260	8.5	0.26
TOC	HP	1,120	1,140	<40	1,390	1,410	<11	<0.79
	Furnace	43[5]	54[5]	<47	53	67	<13	<25
	Furnace Total Carbon – HP TIC[2]	960	990	<31	1,190	1,230	<8.5	<0.71

1. ICP-AES results in normal type have errors likely <15%, but those in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.
2. The furnace method typically produces the best total-carbon results while the best TIC results are obtained from the HP method. Thus the best TOC result may be the difference between these measurements.
3. Percentage of feed constituent recovered in the eluate.
4. Relative % difference of 4.0% between duplicates did not satisfy the QC acceptance criterion of 3.5%. No significant impact on results expected.
5. TOC recoveries from the caustic matrix spike lower than the QC acceptance criterion makes this result doubtful. See also note 2.
6. F^- results from IC should be considered upper bounds due to significant analytical interference from organic compounds such as acetate.
7. F^-, PO_4^-, SO_4^- and $C_2O_4^-$ results should be considered qualitative since the high concentrations of NO_3^- and NO_2^- required the samples to be diluted by up to 10,000 times so that the anions were measured within their IC calibration range and to avoid the IC column becoming overloaded during analysis. The result for P obtained from ICP-AES is considered more accurate.
8. Lower bound value because the feed concentration was below the detection limit of the analytical method.

3.3.10 Operational Details for Cycles 16 Through 19

Table 3-20 presents the operational details for Cycles 16 through 19. Cycles 16 and 18 processed simulated LAW from Batch 6 while Batch 7 simulated LAW was processed in Cycles 17 and 19. Deviations from the plan summarized in Sections 3.3.1and 3.3.2 are as follows:

- The first LAW feed bottle of Cycle 16 had run dry overnight when between 200 BVs and 300 BVs had been processed. This is accounted for in the breakthrough profile since the initial feed bottle weight was known.
- Cycle 16 elution was temporarily suspended after ~16.6 h for 15 min to add water to the column headspace.
- DI water feed bottle had run dry during Cycle-19 elution at an unknown time. Elution resumed after flooding the column.

The breakthrough profiles are illustrated in Figure 3-14 through Figure 3-16 for Cycles 16, 18, and 19; breakthrough for Cycle 17 was less than 4%. Breakthrough profiles are generally linear on the probability scale, and breakthroughs of between ~2% and ~90% were measured. The column distribution coefficients were estimated, giving values between 280 and 160 for all cycles except 17 and are tabulated in Table 3-21. A lower bound value for cycle 17 is provided corresponding to the volume of simulated LAW processed. The high initial breakthrough of greater than 20% in Cycle 19 is considered most likely due to feed channeling and is probably responsible for the irregular profile. Comparison of the column distribution coefficients from Cycles 16 and 18 suggest that increasing the flow rate improves column performance. However, inappropriate extrapolation of the comparatively low Cycle 18 data is assumed to be responsible for this observation since 10% breakthrough was observed after the same volume had been processed in both cycles.

Table 3-22 describes the elution performance of Cycles 16 through 19. The final eluate concentration was below the detection limit of the method in cycle 17. The target eluate Tc concentration of 1% of that in the LAW feed was achieved in all but Cycle 19 in which the final concentration was 1.3% of that in the LAW feed. The poor performance was most likely due to channeling as a result of the eluate running dry and air remaining in the bed after resuming the elution.

Table 3-20. Operational Details for Cycles 16 Through 19

Cycle	Measurement	Unit	Conditioning (0.25 M NaOH)	Simulated AN-105 Processing	Feed displacement (0.1 M NaOH)	Rinse (DI water)	Elution (hot DI water)
16	Reagent volume	mL	28	2700	29	15	270
		BV	6.1	590	6.4	3.3	58
	Reagent flow rate	mL/h	14	33	15	15	14
		BV/h	3.0	7.2	3.3	3.3	3.0
17	Reagent volume	mL	30	610	30	15	~260
		BV	6.5	130	6.6	3.3	~57
	Reagent flow rate	mL/h	15	7.3	15	15	~14
		BV/h	3.3	1.6	3.3	3.3	~3.0
18	Reagent volume	mL	27	600	28	15	250
		BV	5.9	130	6.0	3.3	53
	Reagent flow rate	mL/h	14	7.2	14	15	13
		BV/h	3.0	1.6	3.1	3.3	2.8
19	Reagent volume	mL	27	2500	28	14	220
		BV	5.9	550	6.2	3.0	47
	Reagent flow rate	mL/h	14	30	14	14	12
		BV/h	3.0	6.5	3.1	3.0	2.6

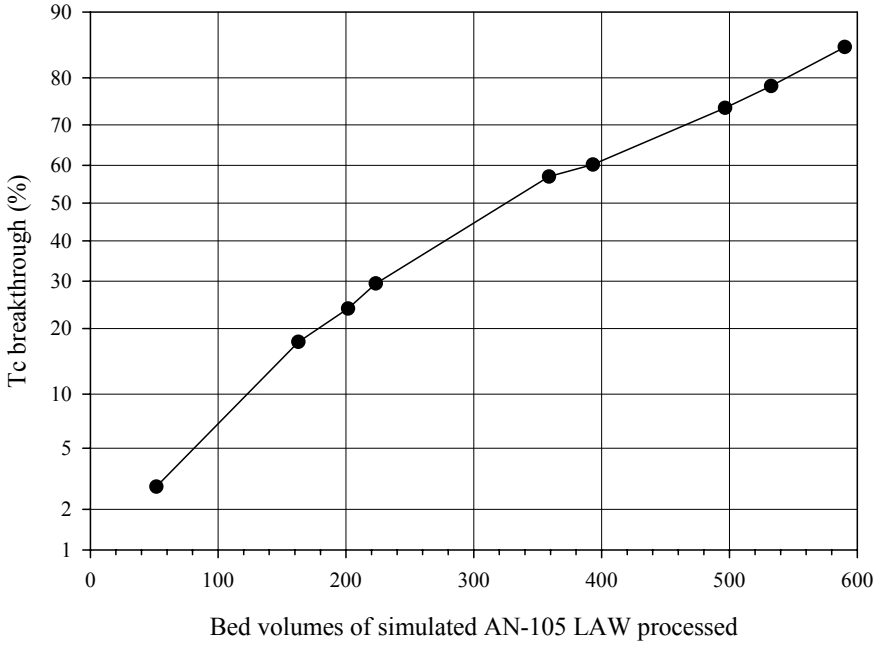

Figure 3-14. Cycle 16 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 7.2 BV/h, 5.34 M Na, 0.444 mM Tc, 0.008 M K, 1.20 M OH^-, 0.50 M NO_3^-, 2.46 M NO_2^-, ambient conditions, BV = 4.6 mL)

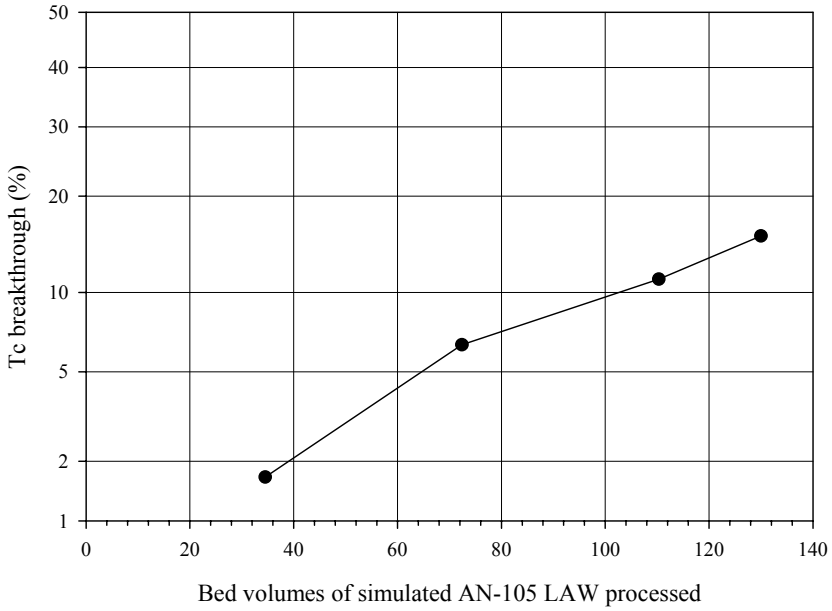

Figure 3-15. Cycle 18 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 1.6 BV/h, 5.34 M Na, 0.400 mM Tc, 0.008 M K, 1.20 M OH^-, 0.50 M NO_3^-, 2.46 M NO_2^-, ambient conditions, BV = 4.6 mL)

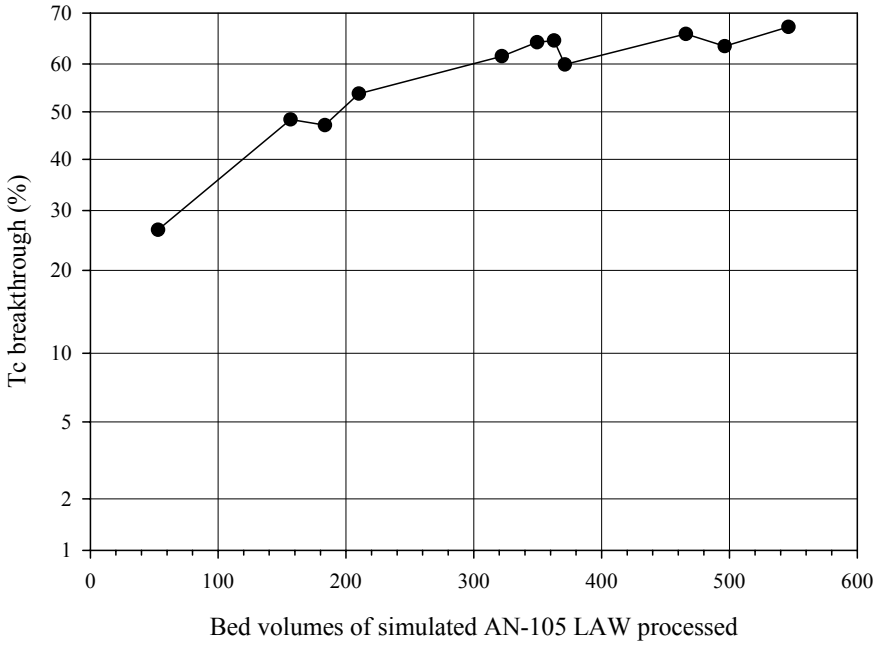

Figure 3-16. Cycle 19 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 6.5 BV/h, 5.34 M Na, 0.047 mM Tc, 0.80 M K, 2.20 M OH^-, 1.36 M NO_3^-, 0.58 M NO_2^-, ambient conditions, BV = 4.6 mL)

Table 3-21. Estimated Column-Distribution Coefficients for Cycles 16 Through 19

Cycle	Simulated LAW Batch #	Tc Concentration (M)	Flow Rate (BV/h)	Column-Distribution Coefficient
16	6	2.91E-4	7.2	320
17	7	4.65E-5	1.6	>130
18	6	2.91E-4	1.6	230
19	7	4.64E-5	6.5	200

Table 3-22. Elution Performance Data for Cycles 16 Through 19

Cycle	Eluate to Simulated LAW feed Tc Concentration Ratio in Last 5 mL of Eluate
16	0.004
17	<0.001
18	0.004
19	0.013

3.3.11 Operational Details for Cycle 20

The operational details are presented in Table 3-23 for Cycle 20. The system was operated without deviating from the plan summarized in Sections 3.3.1 and 3.3.2.

Table 3-23. Cycle 20 Operational Details

		Total Volume of Reagent		Flow Rate of Reagent	
Operation	**Reagent**	**mL**	**BV**	**mL/h**	**BV/h**
Conditioning	0.25 M NaOH	28	6.1	14	3.0
Waste processing	Batch 4 simulated AN-105 LAW	1160	252	14	3.0
Feed displacement	0.1 M NaOH	30	6.5	15	3.2
Rinse	DI water	15	3.3	15	3.2
Elution	Hot DI water	254	55	14	3.0

The simulated AN-105 LAW feed contained Tc at a concentration similar to that used in Cycle 15 at 0.297 mM[1]. The breakthrough profile presented in Figure 3-17 extrapolates to a column distribution coefficient of ~300. As in cycle 10, the feed and first two effluent samples were also analyzed by LSC to determine the concentrations of ^{99}Tc and compare with the breakthroughs obtained by ^{95m}Tc GEA. Figure 3-17 shows again that initial ^{99}Tc breakthrough was much better than that of ^{95m}Tc. For example, initial ^{95m}Tc breakthrough was ~2% compared to ~0.03% for ^{99}Tc. Comparison of these results appears to again indicate that a fraction of the ^{95m}Tc spike existed in a non-pertechnetate form that would not have been separated by the resin.

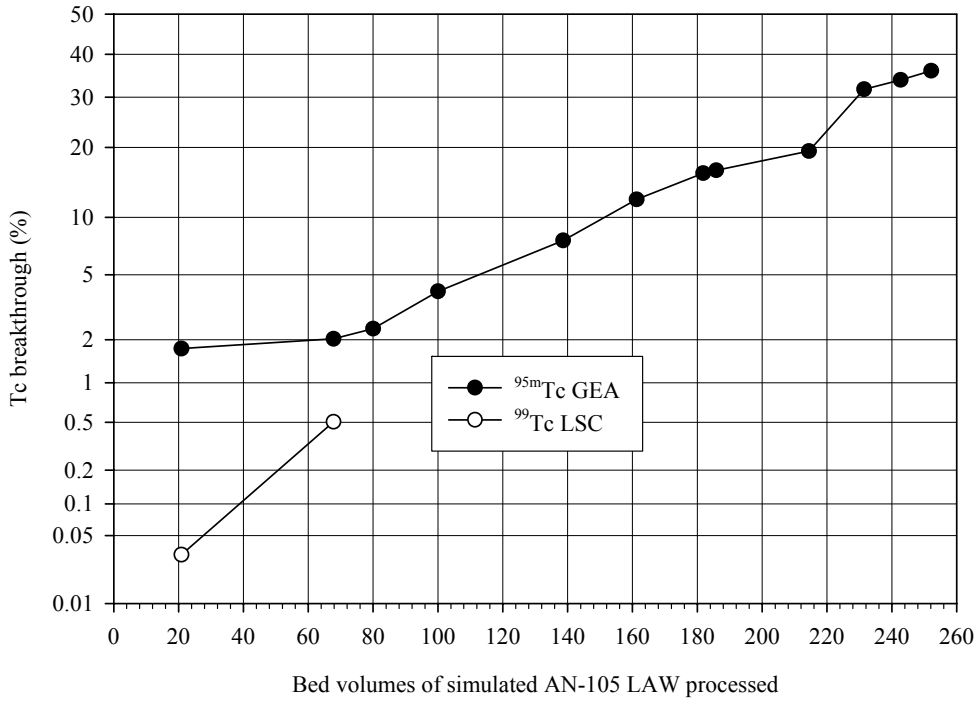

Figure 3-17. Cycle 20 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.0 BV/h, 5.00 M Na, 0.297 mM Tc, 0.084 M K, 1.72 M OH^-, 1.35 M NO_3^-, 1.25 M NO_2^-, ambient conditions, BV = 4.6 mL)

[1] Error may be as high as +/- 30%. See footnote (14) for Table 2-3.

The elution profile is presented in Figure 3-18 and is similar to that observed in Cycle 5. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and was 1% of that in the simulated LAW feed after ~16 BVs of eluate had been generated. The slight maximum observed when approximately 36 BVs of eluate had been collected is considered probably due to measurement error inherent to the test and not significant.

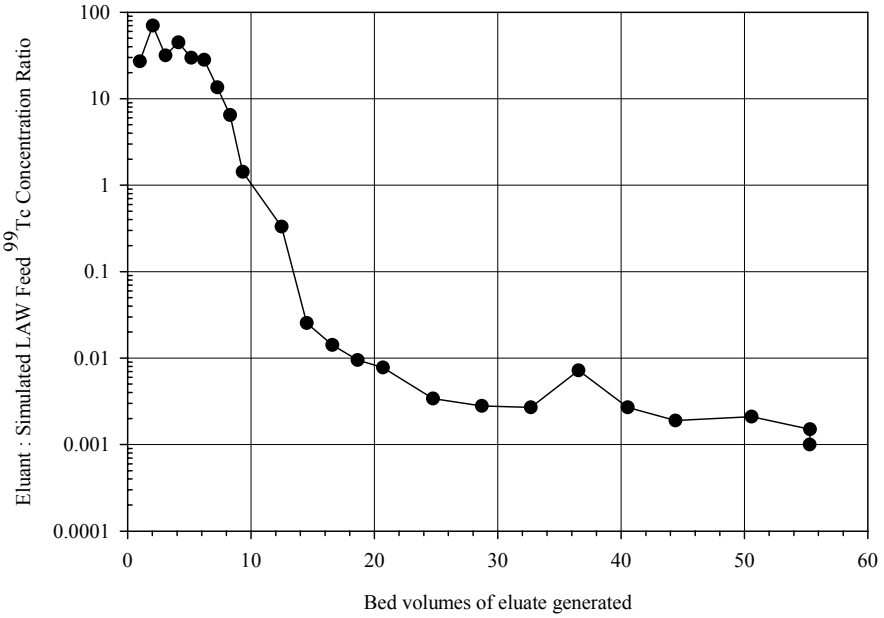

Figure 3-18. Cycle 20 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.0 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

The activity balance for Cycle 20 is presented in Table 3-24 and shows that approximately 95% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered good with 8% more of the activity fed to the system accounted for in the effluents.

Table 3-24. Cycle 20 ^{95m}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of Feed (%)
Simulated LAW Feed	5.48E5	100
Simulated LAW effluent	5.81E4	11
Feed displacement effluent	5.02E3	0.9
Rinse effluent	3.82E3	0.7
Elution effluent	5.22E5	95
Total recovery of feed ^{95m}Tc in effluents	7.74E5	108

Table 3-25 presents the results of the composite simulated LAW effluent and eluate chemical analyses. As in previous cycles, the eluate analysis shows the presence of Na and K with smaller quantities of other metals, although none of the feed constituents were significantly separated. The increase in the ratio of Na to K in the eluate compared to the simulated LAW again appears to suggest preferential separation of K salts, including $KTcO_4$. The high concentrations of Si and B are considered to be again due to contamination from glassware.

Table 3-25. Chemical Analysis of Simulated LAW Feed and Effluent and Eluate from Cycle 20

Analyte	Analysis Method	Concentration (mg/L)[1]			Total mass (mg)			Percentage separated[3]
		LAW Feed	LAW Effluent	Eluate	LAW Feed	LAW Effluent	Eluate	
Ag	ICP-AES	<0.625	<0.625	*0.027*	<0.725	<0.725	*0.007*	>1.0[9]
Al	ICP-AES	16,400	16,500	7.06	19,000	19,100	1.79	<0.01
As	ICP-AES	*62*	*58*	<0.250	*72*	*67*	<0.064	<0.09
B	ICP-AES	37.2[5]	31.5[5]	50.9[5]	43.2	36.5	12.9	30
Ba	ICP-AES	*0.53*	*0.52*	<0.010	*0.61*	*0.60*	<0.003	<0.49
Ca	ICP-AES	<6.25	<6.25	<0.250	<7.25	<7.25	<0.064	Indeterminate
Cd	ICP-AES	*1.0*	*0.99*	<0.015	*1.2*	*1.1*	<0.004	<0.33
Cl	IC	4,600	4,700	2.0	5,300	5,400	0.51	<0.01
Cr	ICP-AES	1,480	1,470	0.894	1,720	1,710	0.227	0.01
F[7,8]	IC	700	800	0.25	800	900	0.06	<0.01
K	ICP-AES	3,260	3,330	47.4	3,780	3,860	12.0	0.32
Mg	ICP-AES	*3.6*	*3.2*	*0.22*	*4.2*	*3.7*	*0.056*	1.3
Mo	ICP-AES	40.1[5]	39.3[5]	<0.050[5]	46.5	45.6	<0.013	<0.03
Na	ICP-AES	115,000	115,000	89.2	133,000	133,000	22.7	0.02
P	ICP-AES	131	129	*0.19*	152	150	*0.048*	0.03
Pb	ICP-AES	54.8	52.3	<0.100	63.6	60.7	<0.025	<0.04
Se	ICP-AES	*49*	*47*	<0.250	*57*	*55*	<0.064	<0.11
Si	ICP-AES	127[5]	131[5]	*6.51*[5]	147	152	*1.65*	1.1
U	ICP-AES	<50	<50	<2.000	<58	<58	<0.51	Indeterminate
Zn	ICP-AES	17.7[4]	17.7[4]	<0.050	20.5	20.5	<0.013	<0.06
$C_2O_4^{-}$[8]	IC	300	300	<0.28	300	300	<0.07	<0.02
NO_2^-	IC	57,500	56,300	24.9	66,500	65,100	6.34	<0.01
NO_3^-	IC	83,400	82,500	44.3	96,500	95,400	11.3	0.01
PO_4^{-}[8]	IC	1,400	500	<0.28	1,600	600	<0.07	<0.01
SO_4^{-}[8]	IC	1,100	700	0.94	1,300	800	0.24	0.02
TIC	HP	1,670	1,720	13	1,930	1,990	3.3	0.17
Total Carbon	Furnace	2,640	2,640	<130	3,050	3,050	<33	<1.1
TOC	HP	1,120	1,040	<4	1,300	1,200	<1	<0.08
	Furnace	200[6]	<170[6]	<85	230	<200	<2.2	<1.0
	Furnace Total Carbon – HP TIC[2]	970	920	<117	1,120	1,060	<30	<2.7

1. ICP-AES results in normal type have errors likely <15%, but those in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.
2. The furnace method typically produces the best total-carbon results while the best TIC results are obtained from the HP method. Thus the best TOC result may be the difference between these measurements.
3. Percentage of feed constituent recovered in the eluate.
4. Observed Zn concentration in the blank did not satisfy QC acceptance criteria and this Zn concentration consequently likely up to 75% over-estimated.
5. B, Mo and Si achieved recoveries of 72%, 73% and 59%, respectively, from the matrix spike sample and so did not satisfy the QC acceptance criterion of >75%. No significant impact on results expected.
6. TOC recoveries from the caustic matrix spike lower than the QC acceptance criterion makes this result doubtful. See also note 2.
7. F^- results from IC should be considered upper bounds due to significant analytical interference from organic compounds such as acetate.
8. F^-, PO_4^-, SO_4^- and $C_2O_4^-$ results should be considered qualitative since the high concentrations of NO_3^- and NO_2^- required the samples to be diluted by up to 10,000 times so that the anions were measured within their IC calibration range and to avoid the IC column becoming overloaded during analysis. The result for P obtained from ICP-AES is considered more accurate.
9. Lower bound value because the feed concentration was below the detection limit of the analytical method.

3.3.12 Operational Details for Cycles 21 Through 24

Table 3-26 provides the operational details for Cycles 21 through 24. Batch 7 simulated LAW was processed in Cycle 21 while the remaining cycles processed simulated LAW from Batch 8.

Figure 3-19, Figure 3-20, and Figure 3-21, respectively, provide the breakthrough profiles for Cycles 21, 22, and 24. The profile for Cycle 23 is not shown since breakthrough was <10% throughout the operation. The profiles are approximately linear on the probability scale for Cycles 21 and 22, and column distribution coefficients of ~122 and 200 were estimated. Breakthrough for Cycle 24 appears to plateau at ~30% after ~170 BVs, and a column distribution coefficient was not estimated. The high initial breakthroughs of greater than 10% for Cycles 21, 22, and 24 are considered due to feed channeling and is probably responsible for the irregular profile.

Table 3-26. Operational Details for Cycles 21 Through 24

Cycle	Measurement	Unit	Conditioning (0.25 M NaOH)	Simulated AN-105 Processing	Feed displacement (0.1 M NaOH)	Rinse (DI water)	Elution (Hot DI water)
21	Reagent volume	mL	26	620	28	14	250
		BV	5.7	130	6.0	3.0	55
	Reagent flow rate	mL/h	13	7.2	14	14	14
		BV/h	2.8	1.6	3.1	3.0	3.0
22	Reagent volume	mL	28	2500	~29[1]	14	~250[1]
		BV	6.1	550	~6.4[1]	3.0	~55[1]
	Reagent flow rate	mL/h	14	30	~15[1]	14	14
		BV/h	3.0	6.5	~3.3[1]	3.0	3.0
23	Reagent volume	mL	~30[1]	610	29	14	250
		BV	~6.5[1]	130	6.4	3.0	55
	Reagent flow rate	mL/h	~15[1]	7.3	15	14	14
		BV/h	~3.0[1]	1.6	3.3	3.0	3.0
24	Reagent volume	mL	29	1200	Not measured	Not measured	250
		BV	6.3	260	Not measured	Not measured	54
	Reagent flow rate	mL/h	15	14	Not measured	Not measured	14
		BV/h	3.3	3.0	Not measured	Not measured	3.0

1. Values approximate since effluent bottle inadvertently not weighed before starting operation. Used the weight previously recorded for the same bottle.

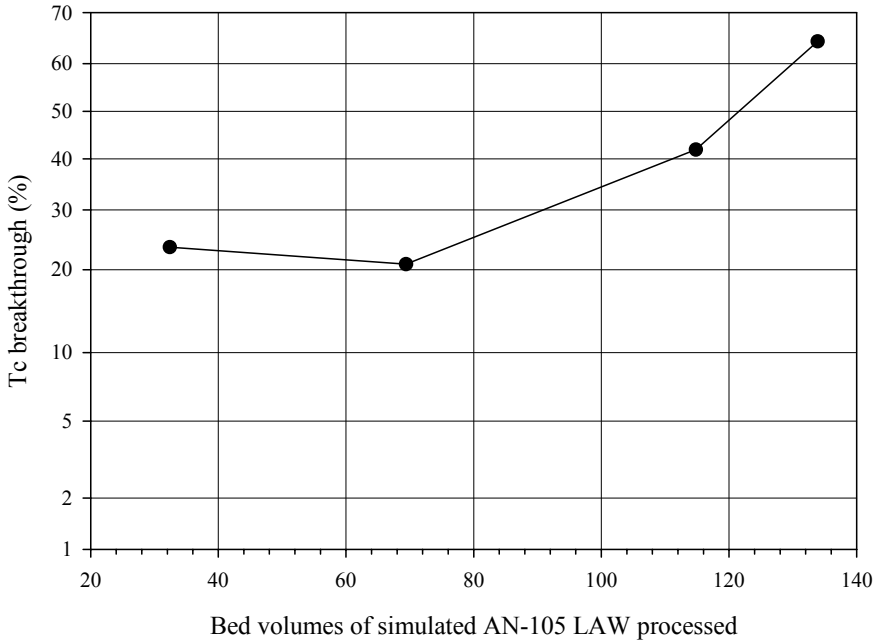

Figure 3-19. Cycle 21 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 1.6 BV/h, 5.34 M Na, 0.063 mM Tc, 0.80 M K, 2.20 M OH^-, 1.36 M NO_3^-, 0.58 M NO_2^-, ambient conditions, BV = 4.6 mL)

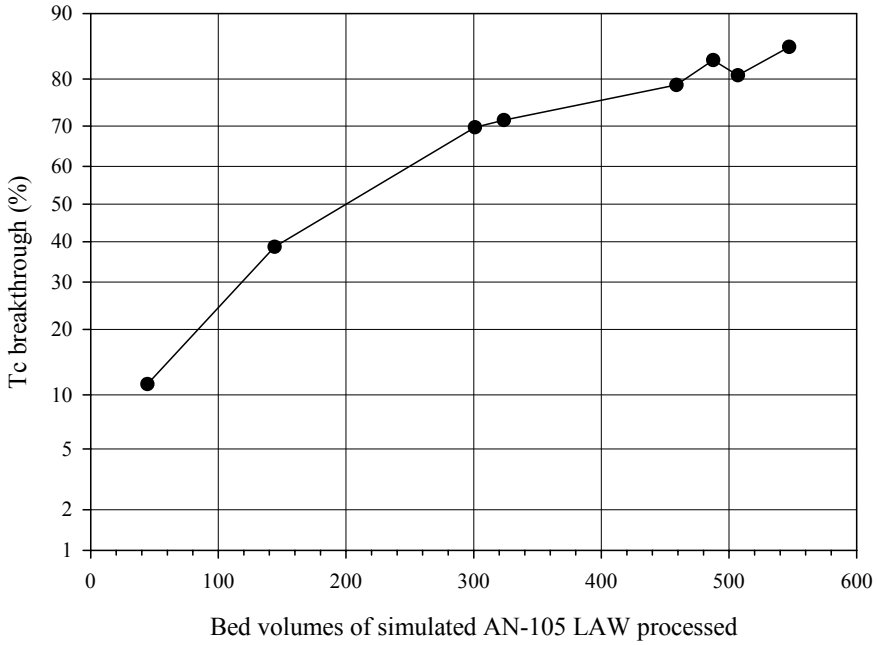

Figure 3-20. Cycle 22 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 6.5 BV/h, 5.34 M Na, 0.289 mM Tc, 0.80 M K, 1.20 M OH^-, 1.36 M NO_3^-, 1.60 M NO_2^-, ambient conditions, BV = 4.6 mL)

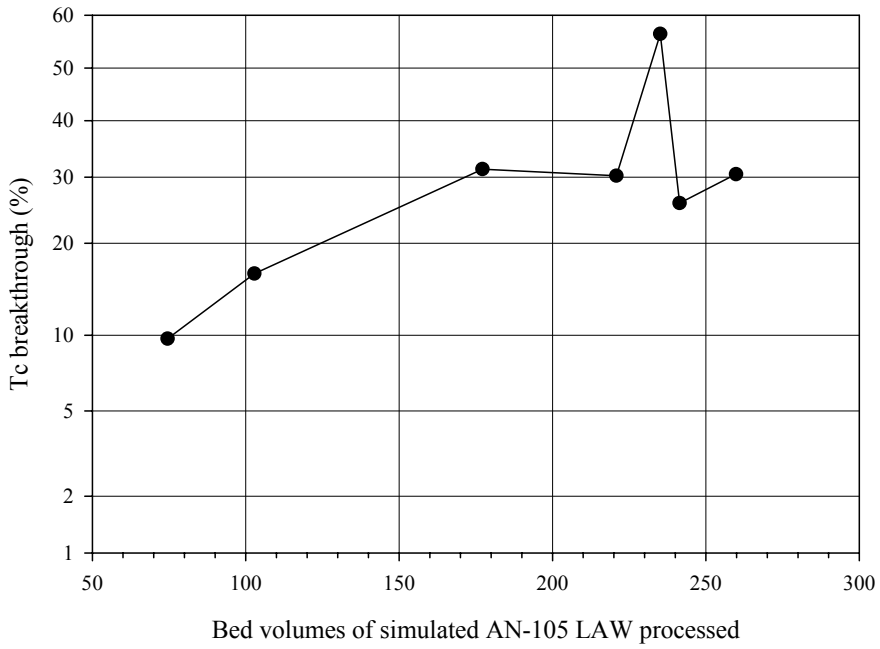

Figure 3-21. Cycle 24 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.0 BV/h, 5.34M Na, 0.062 mM Tc, 0.80M K, 1.20M OH^-, 1.36M NO_3^-, 1.60M NO_2^-, ambient conditions, BV = 4.6 mL)

Table 3-27 shows that the target eluate to simulated LAW feed Cs concentration ratio of 0.01 was achieved in Cycles 21 through 24.

Table 3-27. Elution Performance in Cycles 21 Through 24

Cycle	Eluate to Simulated LAW Feed Tc Concentration Ratio in Last 5 mL of Eluate
21	0.004
22	0.005
23	0.004
24	0.003

3.3.13 Operational Details for Cycle 25

Table 3-28 presents the operational details for Cycle 25.

Table 3-28. Cycle 25 Operational Details

Operation	Reagent	Total Volume of Reagent		Flow Rate of Reagent	
		mL	BV	mL/h	BV/h
Conditioning	0.25M NaOH	29	6.3	14	3.0
Waste processing	Batch 9 simulated AN-105 LAW	1185	258	14	3.0
Feed displacement	0.1M NaOH	28	6.1	14	3.1
Rinse	DI water	14	3.0	14	3.0
Elution	Hot DI water	260	57	14	3.0

The simulated AN-105 LAW feed contained Tc at a concentration similar to that used in Cycle 20 at 0.284 mM[2]. The breakthrough profile presented in Figure 3-22 shows that resin breakthrough performance had apparently deteriorated over that observed in Cycle 20. For example, the column distribution coefficient (50% breakthrough) was 300 and 210 in Cycles 20 and 25, respectively. Initial breakthrough was ~2% and did not increase to 5% until 100 BVs of LAW had been processed in Cycle 20. However, 5% breakthrough was observed from the first sample after 20 BVs in Cycle 25.

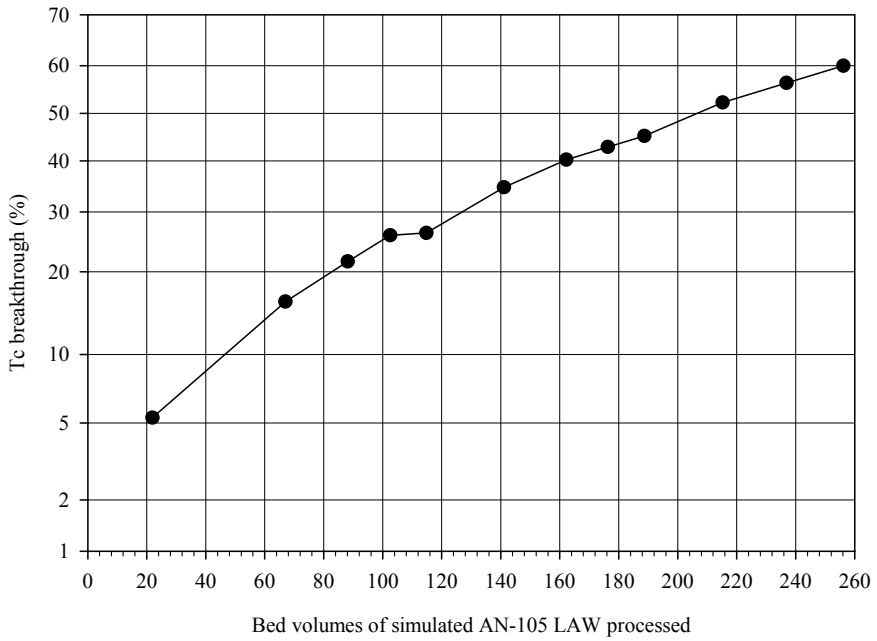

Figure 3-22. Cycle 25 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.0 BV/h, 5.00M Na, 0.284 mM Tc, 0.083M K, 1.72M OH^-, 1.34M NO_3^-, 1.25M NO_2^-, ambient conditions, BV = 4.6 mL)

[2] Error may be as high as +/- 30%. See footnote (14) for Table 2-3.

Figure 3-23 presents the elution profile. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and had reduced to 1% of that in the simulated LAW feed after generating 24 BVs of eluate. Irregularities in the profile are probably due to channeling and inherent uncertainty in the measurement method.

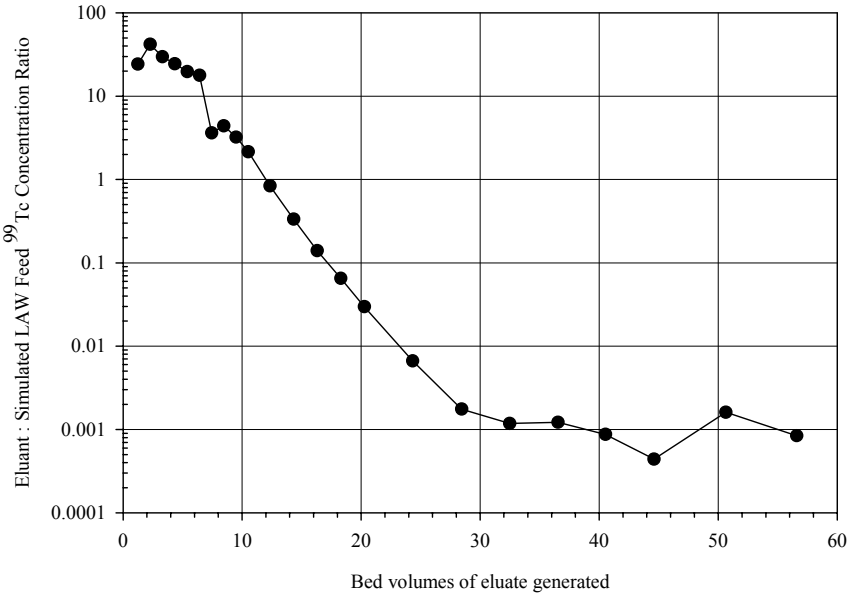

Figure 3-23. Cycle 25 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.0 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

The activity balance for Cycle 25 is presented in Table 3-29 and shows that approximately 73% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered good and shows that 5% more activity was recovered in the effluents than was fed to the system.

Table 3-29. Cycle 25 ^{95m}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of Feed (%)
Simulated LAW Feed	1.91E6	100
Simulated LAW effluent	5.66E5	30
Feed displacement effluent	2.80E4	1.5
Rinse effluent	1.92E4	1.0
Elution effluent	1.39E6	73
Total recovery of feed ^{95m}Tc in effluents	2.00E6	105

Table 3-30 presents the chemical analysis of the simulated LAW feed, effluent, and eluate. As in previous cycles, the eluate analysis shows the presence of Na and K with smaller quantities of other metals, although none of the feed constituents were significantly separated. The increase in the ratio of Na to K in the eluate compared to the simulated LAW again appears to suggest preferential separation of K salts, including $KTcO_4$. The high concentrations of Si and B are considered to be due to contamination from glassware.

Table 3-30. Chemical Analysis of Simulated LAW Feed and Effluent and Eluate from Cycle 25

Analyte	Analysis Method	Concentration (mg/L)[1]			Total mass (mg)			Percentage separated[3]
		LAW Feed	LAW Effluent	Eluate	LAW Feed	LAW Effluent	Eluate	
Ag	ICP-AES	<0.625	<0.625	<0.025	<0.741	<0.741	<0.007	Indeterminate
Al	ICP-AES	15,600	16,300	4.18	18,500	19,300	1.09	<0.01
As	ICP-AES	*59*	*58*	<0.250	*70*	*69*	<0.065	<0.09
B	ICP-AES	25.5[6]	31.5[6]	39.1[6]	30.2	37.3	10.2	34
Ba	ICP-AES	*0.50*	*0.52*	<0.010	*0.59*	*0.62*	<0.003	<0.51
Ca	ICP-AES	<6.25	<6.25	<0.250	<7.41	<7.41	<0.065	Indeterminate
Cd	ICP-AES	*1.1*	*0.99*	<0.015	*1.3*	*1.2*	<0.004	<0.31
Cl	IC	4,500	4,500	1.4	6,400	6,400	0.36	<0.01
Cr	ICP-AES	1,400	1,470	0.604	1,660	1,740	0.157	0.01
F[8,9]	IC	800	700	0.31	1,000	900	0.08	<0.01
K	ICP-AES	3,250	3,330	44.3	3,850	3,950	11.5	0.30
Mg	ICP-AES	*3.4*	*3.2*	*0.16*	*4.0*	*3.8*	*0.042*	1.1
Mo	ICP-AES	37.9[6]	39.3[6]	<0.050[6]	44.9	46.6	<0.013	<0.03
Na	ICP-AES	111,000	115,000	63.9	132,000	136,000	16.6	0.01
P	ICP-AES	90.0	129	*0.16*	107	153	*0.042*	0.04
Pb	ICP-AES	49.1	52.3	<0.100	58.2	62.0	<0.026	<0.04
Se	ICP-AES	*46*	*47*	<0.250	*55*	*56*	<0.065	<0.12
Si	ICP-AES	*110*[6]	131[6]	*5.97*[6]	*130*	155	*1.6*	1.2
U	ICP-AES	<50	<50	<2.000	<59	<59	<0.52	Indeterminate
Zn	ICP-AES	17.1[4]	18.0[4]	<0.050	20.3	21.3	<0.013	<0.06
$C_2O_4^{-}$[9]	IC	200	200	<0.28	300	300	<0.07	<0.02
NO_2^-	IC	57,300	55,800	17.4	81,000	78,900	4.52	<0.01
NO_3^-	IC	83,000	80,900	32.8	117,000	114,000	8.52	<0.01
PO_4^{-}[9]	IC	1,400	1,600	<0.28	2,000	2,300	<0.07	<0.01
SO_4^{-}[9]	IC	1,100	1,100	1.4	1,600	1,600	0.36	0.02
TIC	HP	1,580	1,730	8	1,880	2,060	2	0.11
Total Carbon	Furnace	2,720	2,820	<130	3,230	3,350	<34	<1.1
TOC	HP	1,220	1,140	<4	1,450	1,360	<1	<0.07
	Furnace	<170[7]	<170[7]	[5]	<200	<200	[5]	Indeterminate
	Furnace Total Carbon – HP TIC[2]	1,140	1,090	<120	1,360	1,300	<31	<2.3

1. ICP-AES results in normal type have errors likely <15%, but those in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.
2. The furnace method typically produces the best total-carbon results while the best TIC results are obtained from the HP method. Thus, the best TOC result may be the difference between these measurements.
3. Percentage of feed constituent recovered in the eluate.
4. Observed Zn concentration in the blank did not satisfy QC acceptance criteria and this Zn concentration consequently likely up to 75% over-estimated.
5. Not measured due to insufficient sample.
6. B, Mo and Si achieved recoveries of 72%, 73% and 59%, respectively, from the matrix spike sample and so did not satisfy the QC acceptance criterion of >75%. No significant impact on results expected.
7. TOC recoveries from the caustic matrix spike lower than the QC acceptance criterion makes this result doubtful. See also note 2.
8. F^- results from IC should be considered upper bounds due to significant analytical interference from organic compounds such as acetate.
9. F^-, PO_4^-, SO_4^- and $C_2O_4^-$ results should be considered qualitative since the high concentrations of NO_3^- and NO_2^- required the samples to be diluted by up to 10,000 times so that the anions were measured within their IC calibration range and to avoid the IC column becoming overloaded during analysis. The result for P obtained from ICP-AES is considered more accurate.

The poor performance of the resin in Cycle 25 relative to that observed in Cycle 20 was considered most likely due to channeling arising from air accumulation in the bed and, therefore, not due to chemical degradation. An additional cycle was executed in an attempt to repeat the Cycle 20 performance.

3.3.14 Operational Details for Cycle 26

Table 3-31 presents the operational for Cycle 26.

Table 3-31. Cycle 26 Operational Details

Operation	Reagent	Total Volume of Reagent		Flow Rate of Reagent	
		mL	BV	mL/h	BV/h
Conditioning	0.25 M NaOH	32	7.0	14	3.0
Waste processing	Batch 10 simulated AN-105 LAW	1225	266	15	3.3
Feed displacement	0.1 M NaOH	31	6.7	16	3.4
Rinse	DI water	15	3.3	15	3.3
Elution	Hot DI water	274	60	15	3.3

The simulated AN-105 LAW feed contained Tc at a concentration similar to that used in Cycle 25 at 0.284 mM. Fresh simulated LAW was processed in this cycle and was not spiked with ^{95m}Tc. Instead, PNWD staff determined the ^{99}Tc concentrations by liquid scintillation counting (LSC) to monitor resin performance. The breakthrough profile presented in Figure 3-24 shows that resin breakthrough performance was consistent with that observed in Cycle 20 after ~2% breakthrough. For example, the column distribution coefficients (50% breakthrough) were ~300. Initial breakthroughs were ~0.06% and ~2% in Cycles 26 and 20, respectively. The difference is hypothesized to be due to a fraction of the ^{95m}Tc being in a non-pertechnetate form that SL-639 would not have separated. Indeed, ^{99}Tc LSC analysis of the first two samples from processing simulated LAW in cycles 5, 10 and 15 indicated breakthroughs of ~0.1% compared to ~2% based on ^{95m}Tc GEA. Breakthrough did not increase to 5% until 115 BVs of LAW had been processed in Cycle 26, although 5% breakthrough was observed from the first sample after 20 BVs in Cycle 25.

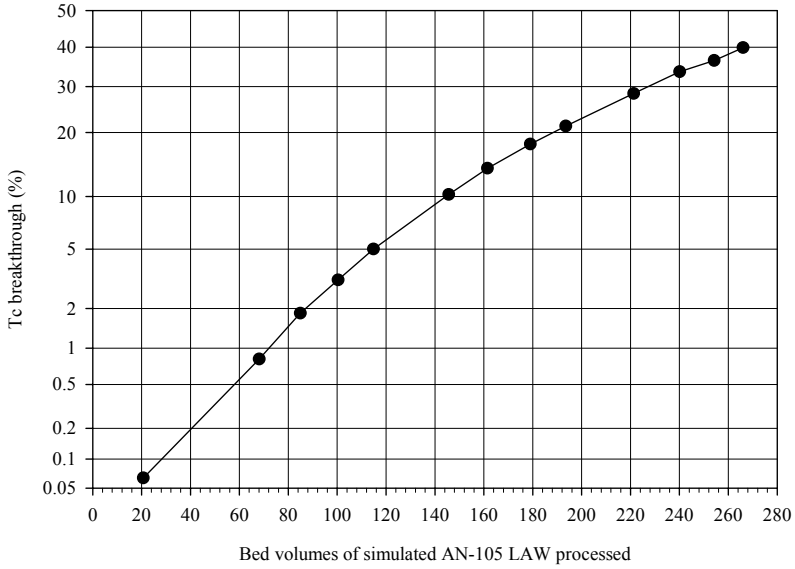

Figure 3-24. Cycle 26 Technetium-Breakthrough Performance (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, 5.34 M Na, 0.284 mM Tc, 9.51E-2 M K, 1.72 M OH^-, 1.23 M NO_3^-, 1.21 M NO_2^-, ambient conditions, BV = 4.6 mL)

Figure 3-25 presents the elution profile. The Tc concentration in the eluate peaked when ~2 BVs of eluate had been generated and reduced to 1% of that in the simulated LAW feed after 20 BVs.

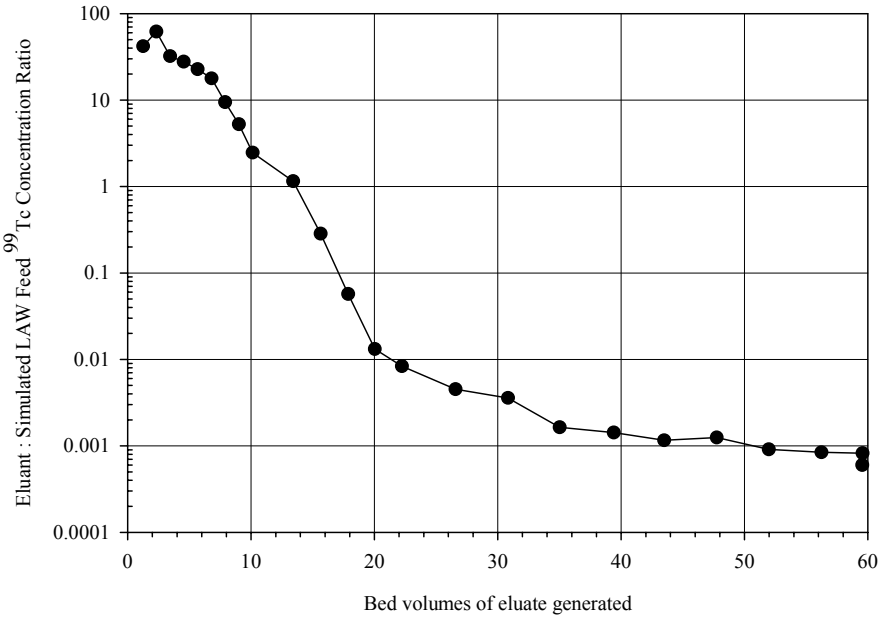

Figure 3-25. Cycle 26 Elution Profile (SL639 resin batch 010227CTC-9-23, 3.3 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

The activity balance for Cycle 26 is presented in Table 3-32 and shows that approximately 94% of the influent Tc was separated onto the resin and recovered by elution. The balance is considered good and shows that 9% more activity was recovered in the effluents than was fed to the system.

Table 3-32. Cycle 26 ^{95}Tc Activity Balance

Process Stream	Total Count Rate (CPM)	Fraction of Feed (%)
Simulated LAW Feed	1.24E9	100
Simulated LAW effluent	1.52E8	12.2
Feed displacement effluent	1.54E7	1.2
Rinse effluent	1.96E7	1.6
Elution effluent	1.17E9	94
Total recovery of feed ^{99}Tc in effluents	1.36E9	109

3.3.15 Spent Resin Analysis

The resin was removed from the column after completion of this cycle for further analysis by weighing, scanning electron microscopy (SEM), modified TCLP and digestion followed by ICP-MS to determine the concentration of residual Tc.

The concentrations of the TC metals in the leachates from the spent-resin leach are compared with their regulatory levels in Table 3-33. The results indicate that the spent resin would not exhibit any toxicity characteristics if a formal TCLP were performed since all of the leachate concentrations are below the regulatory levels. Further testing using TCLP methods approved by the Washington State Department of Ecology would need to be completed with both actual and simulated wastes to develop a disposal pathway and identify disposal methods. Ag, Hg and Ba were the only TC metals detected at concentration factors of >10, >100 and >100, respectively, below their regulatory levels.

Table 3-33. Results of Modified TCLP on Spent SL-639 Resin

Metal	Regulatory Level (mg/L)	Concentration in Leachate (mg/L)
Ag	5.0	*0.37*
As	5.0	<0.575
Ba	100.0	0.240
Cd	1.0	<0.035
Cr	5.0	<0.046
Hg	0.2	0.000673
Pb	5.0	<0.230
Se	1.0	<0.575
Note: Results in italics are within ten times their detection limit with errors likely exceeding 15%. Results preceded by < are below the detection limits of the method.		

The leached resin was digested in 16M HNO_3 at 200°C and the ICP-MS analysis of the digestate returned a ^{99}Tc concentration of 0.66 μg/g (0.33 μg/mL) of resin[3]. The TCLP leachate was also analyzed by ICP-MS and returned an equivalent Tc concentration of 0.03 μg/g of resin[3]. Therefore, the total concentration of Tc on the spent resin was 0.69 μg/g or 5.86 mCi/m^3. All WTP project QC criteria were satisfied for these analyses.

[3] Error may be as high as +/- 30%. The resin and leachate ICP-MS analyses were completed in early August, 2002 and early December 2002, respectively. Subsequent independent verification analyses by LSC in late May, 2003, of the calibration and calibration verification standard materials gave concentrations 16% and 24% higher, respectively, than the assigned values for the standards. The resin analysis was performed at the same time as the Cycle 20 and 25 feed analyses, and so based on the discussion in footnote 14 of Table 2-3, the error bar may not be this large.

4.0 Results Analysis

This section describes the physical changes in the resin, the impact of chemical degradation on process performance, the analysis of results from parametric study, and the toxicity characteristics of spent resin.

4.1 Physical Changes in Resin

No physical changes in the resin were indicated by the constancy of the resin bed height and color. Resin mass losses were considered most likely due to resin becoming caught in the quartz wool when it was discarded in Cycle 4 and upon completion of Cycle 26.

The fresh and used resins were examined with a Scanning Electron Microscope equipped with an Oxford ISIS X-ray energy dispersive spectrometer. A few resin particles (3-5) were placed on sticky carbon mount and were examined uncoated. As shown in Figure 4-1, at low magnification (x140), the used and unused resins appear similar.

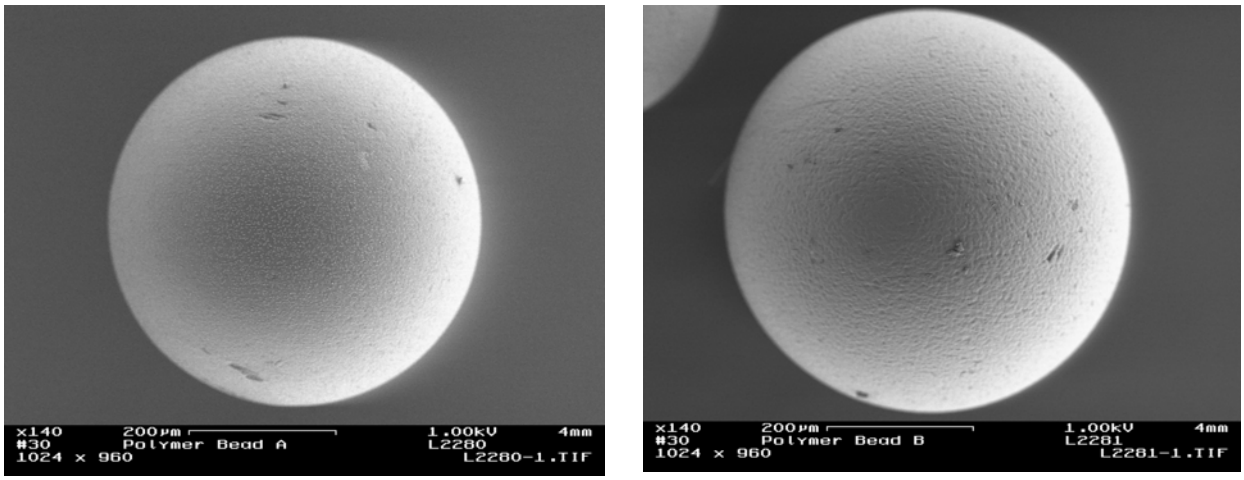

Figure 4-1. Low Magnification (x140) SEM Images of Unused (left) and Used (right) SL-639 from Batch 010227CTC-9-23

At higher magnification (x3000), the surface of the fresh resin appears covered in small crystals identified as sodium chloride by X-ray energy dispersive spectroscopy, as shown in Figure 4-2. The crystals are absent from the used resin. Comparison of the fresh and used resin surfaces appears to show the latter more rough and pitted.

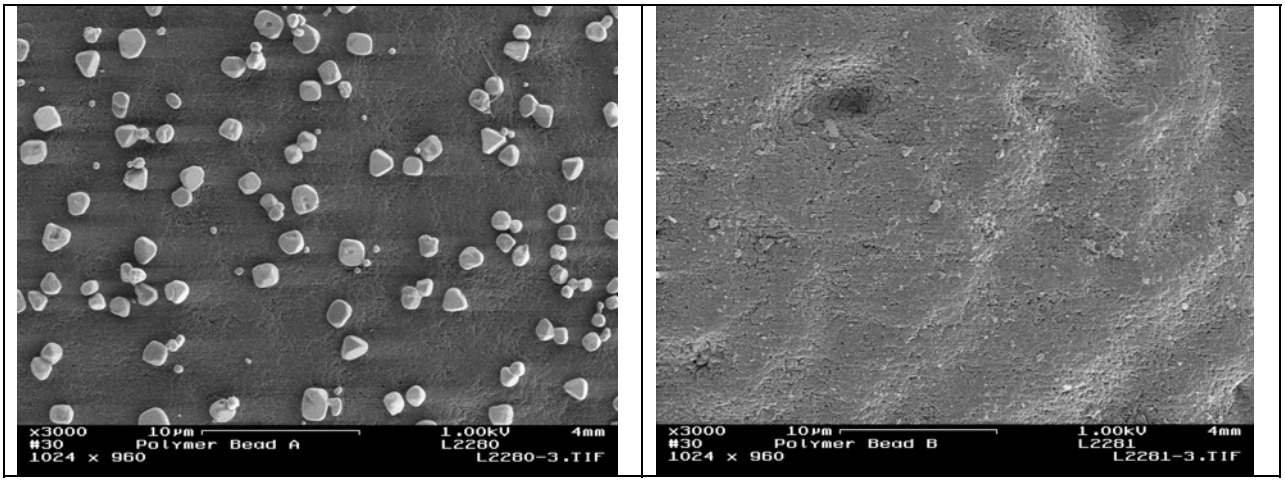

Figure 4-2. Medium Magnification (x3000) SEM Images of Unused (left) and Used (right) SL-639 from Batch 010227CTC-9-23

4.2 Impact of Chemical Degradation on Process Performance

4.2.1 Breakthrough Performance

Chemical degradation would be expected to impact the breakthrough performance of the resin. Figure 4-3 compares the breakthrough profiles from Cycles 5, 10, 15, 20, 25, and 26. Note that the Tc concentration in the feed to cycle 1 was significantly lower than in the cycles compared in Figure 4-3 and is not considered here. The breakthrough profiles from Cycles 15 and 25 are clearly anomalous, and the poor performance is considered due to feed channeling from air bubbles in the bed remaining from the elution operation of the previous cycle. The breakthrough profiles of the remaining cycles are approximately coincident above 2% breakthrough, indicating that the resin did not chemically degrade. The breakthrough profiles from Cycles 20 and 26 and from Cycles 5 and 10 are approximately coincident, although the extrapolated profiles provide column distribution coefficients of ~300 and ~280 for Cycles 20 and 26 and 5 and 10, respectively. Section 4.3 shows that these results are consistent with the difference in Tc concentration. As described before in Section 0, the initial 2% breakthrough in Cycles 5, 10, and 20 was probably due to a fraction of the ^{95m}Tc tracer being in a non-pertechnetate form that would not have been separated by the resin.

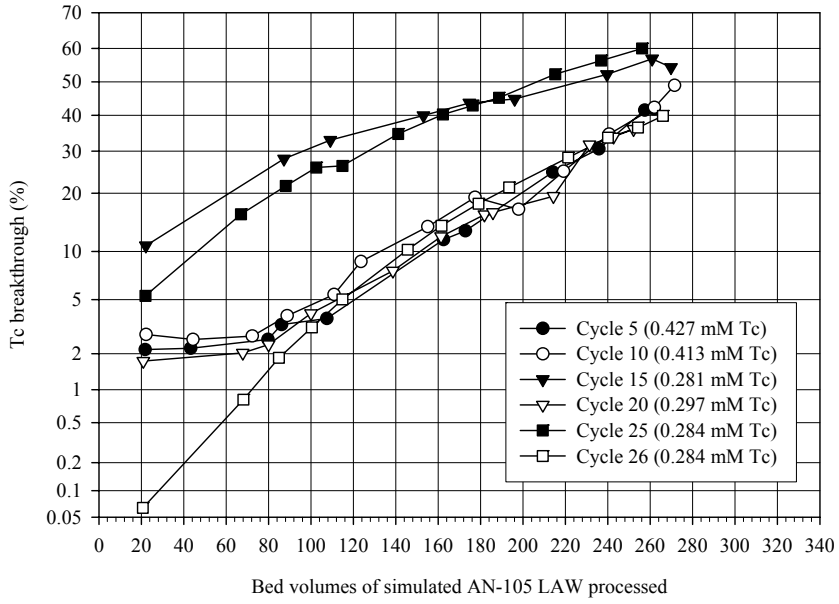

Figure 4-3. Comparison of Breakthrough Profiles from Cycles 5, 10, 15, 20, 25, and 26 (SL639 resin batch 010227CTC-9-23, nominal 3 BV/h, 5.34 M Na, 0.095 M K, 1.72 M OH^-, 1.23 M NO_3, 1.21 M NO_2^-, ambient conditions, BV = 4.6 mL)

4.2.2 Elution Performance

Figure 4-4 shows significant scatter in the elution profiles from Cycles 1, 5, 10, 15, 20, 25, and 26. Cycles 10 and 15 exhibited only gradual reductions in the eluate Tc concentration, reducing to 1% of that in the simulated LAW feed after generating more than 30 BVs of eluate. In contrast, Cycles 5, 20, 25, and 26 exhibited relatively sharp elution profiles in which the Tc eluate concentration attained 1% of that in the simulated LAW feed after approximately 14, 16, 24 and 20 BVs, respectively. The inconsistent elution performance is hypothesized to be due to channeling of eluate caused by air bubbles in the bed generated from air coming out of solution as the eluate is heated from room temperature to 65°C.

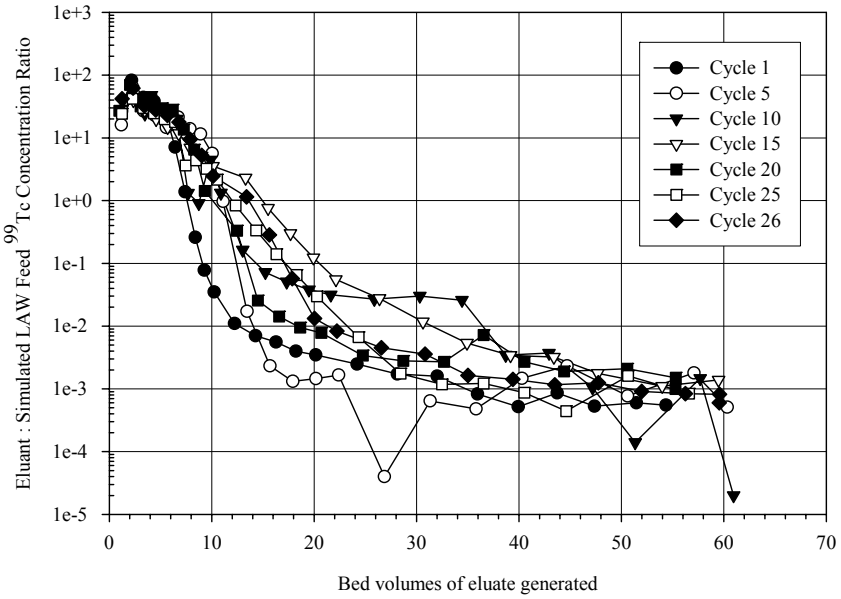

Figure 4-4. Comparison of Elution Profiles from Cycles 1, 5, 10, 15, 20, 25, and 26 (SL639 resin batch 010227CTC-9-23, nominal 3 BV/h, ambient pressure, 65°C, BV = 4.6 mL)

4.3 Analysis of Results from Parametric Study

Throughout the test, cycles were performed at various simulated LAW flow rates and Tc and NO_3^- concentrations to investigate the impact of these parameters on breakthrough performance. A complete statistical analysis proved unreasonable due to the frequent early breakthrough probably arising from feed channeling. However, Cycles 1, 2, 3, and 5 processed simulated LAW with successively higher Tc concentrations and exhibited no early breakthrough. The breakthrough profiles from these cycles are presented in Figure 4-5 and show that breakthrough performance deteriorated with increasing Tc concentration, as expected. Figure 4-6 correlates the column distribution coefficient with the $[NO_3^-]$: [Tc] ratio and also plots the result from Cycle 20. The column-distribution coefficient increases according to the logarithm of the $[NO_3^-]$: [Tc] ratio, as expected, and the data were correlated by linear regression to the expression,

$$\lambda = 80\mathrm{Ln}\left(\frac{[NO_3^-]}{[TcO_4^-]}\right) - 360 \qquad (4.1)$$

The impact of nitrite concentration was also evaluated. Nearly all of the cycles operated at nitrite concentrations other than baseline either did not attain significant breakthrough or manifested early breakthrough attributed to feed channeling. However, Cycle 16 processed simulated LAW with nitrate and nitrite concentrations of nominally 0.5 M and 2.46 M, respectively, albeit at a higher flow rate. Note that a chemical analysis was not performed on this feed, and the concentrations are based on the batch-preparation procedure. Figure 4-7 plots the data of Figure 4-6 with the result from Cycle 16 and clearly shows the anomalous nature of the latter result when considered in terms of the NO_3^- to Tc concentration ratio. However, the Cycle 16 result becomes consistent with those from other cycles when the results are considered in terms of the ratio of the sum of the NO_3^- and NO_2^- concentrations to Tc concentration, as also shown in Figure 4-7. Therefore, there appears to be some evidence that NO_2^-, as well as NO_3^-, is also a major competitor to TcO_4^-. The column distribution coefficient is then correlated according to

$$\lambda = 80\mathrm{Ln}\left\{\frac{[NO_3^-] + [NO_2^-]}{[TcO_4^-]}\right\} - 420 \qquad (4.2)$$

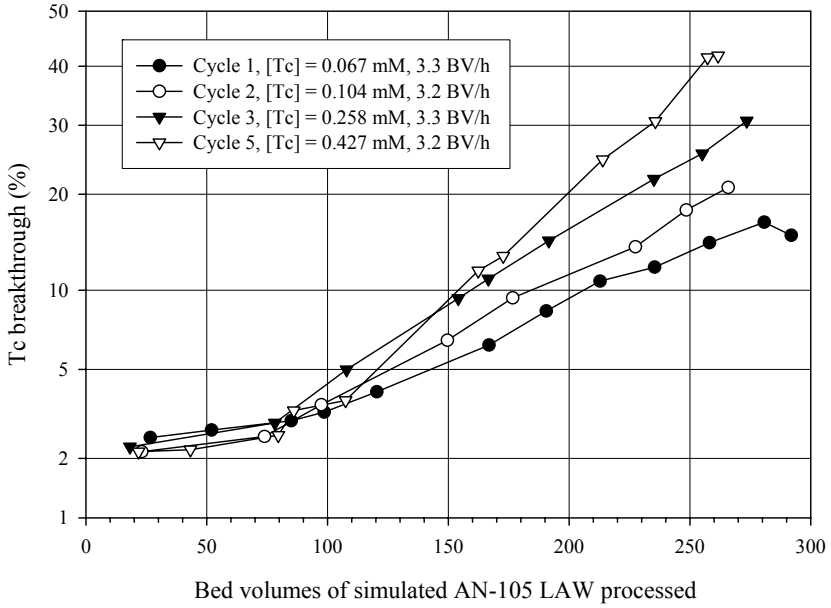

Figure 4-5. Breakthrough Comparison as a Function of Tc Concentration (SL639 resin batch 010227CTC-9-23, 5.34 M Na, 0.095 M K, 1.72 M OH^-, 1.23 M NO_3^-, 1.21 M NO_2^-, ambient conditions, BV = 4.6 mL)

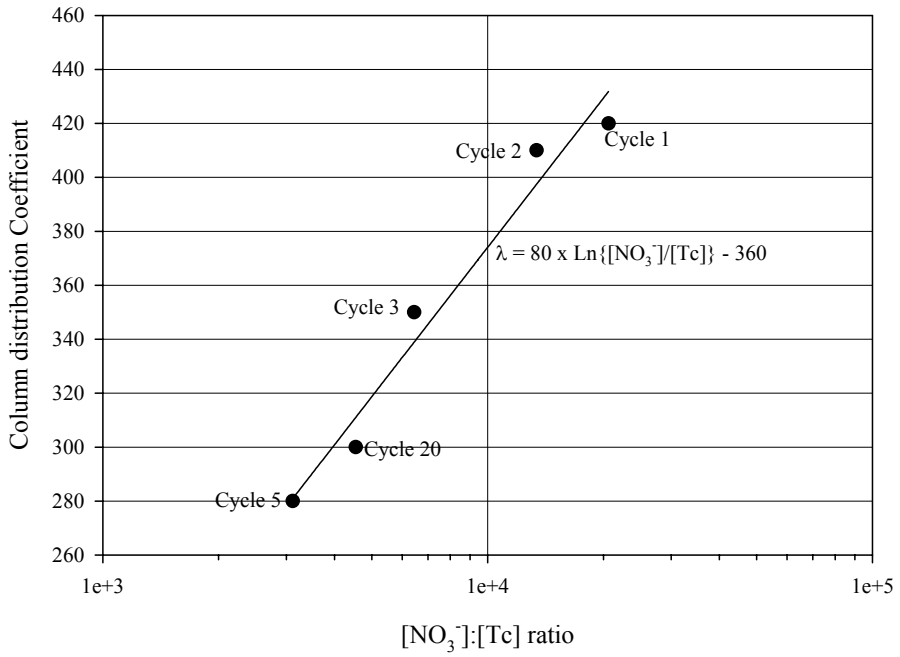

Figure 4-6. Correlation of Column-Distribution Coefficient with $[NO_3^-]$: [Tc] Ratio (SL639 resin batch 010227CTC-9-23, nominal 3 BV/h, 5.34 M Na, 0.095 M K, 1.72 M OH^-, 1.23 M NO_3^-, 1.21 M NO_2^-, ambient conditions, BV = 4.6 mL)

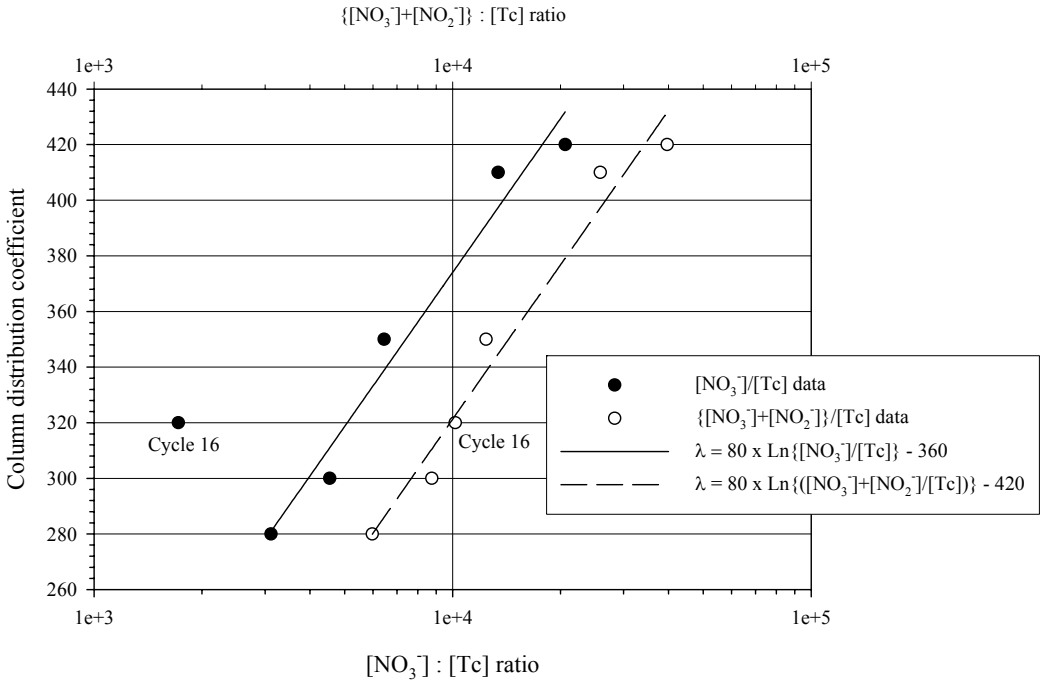

Figure 4-7. Correlation of Column-Distribution Coefficient with $[NO_3^-]$: [Tc] and $\{[NO_2^-]+[NO_3^-]\}$: [Tc] Ratios (SL639 resin batch 010227CTC-9-23, 5.34 M Na, 0.095 M K, 1.72 M OH^-, ambient conditions, BV = 4.6 mL)

5.0 Design and Operating Implications for WTP

This section discusses the implications for the WTP design and operations of test observations and results.

No deterioration in the breakthrough or elution performance of the SL-639 resin observed after 26 cycles.

An interpretation of this result to derive a resin service life for a 3-column system is difficult because a bed processes LAW in the lag, second, and then lead positions before it is eluted and regenerated. Olson (2001) defines a cycle (a design-cycle for the purposes of this discussion) for the bed in the polishing, lag, and lead positions normally processing 112 BVs of LAW in each position and undergoing elution and regeneration after processing LAW in the lead position. Olson (2001) assumes that the bed is replaced every 10 design-cycles.

The worse case is that any chemical degradation occurring in the elution operations is insignificant compared to that when processing LAW. In this case, the ion exchange bed would require replacement no more frequently than after every nine design-cycles according to these test results. The design assumption, therefore, appears likely consistent with the test result.

Facility for venting of air coming out of solution as the eluant is heated is required.

The significant deterioration in breakthrough and elution performance experienced in some cycles was considered to be due to channeling arising from bubbles generated in the bed as air came out of solution when the eluant was heated in the column. For example, two elution cycles required over 30 BVs of eluant before the concentration of Tc in the eluate reduced to less than 1% of that in the simulated LAW feed compared to the WTP design assumption of 22 BVs provided by Olson (2001). This may have been avoided if the eluant were pre-heated in a ventilated and stirred vessel before it was fed to the column. Further testing would be required to determine if preheating the water to remove dissolved air would eliminate the gas accumulation problem. Occasional backwashing of the WTP ion exchange columns may be required if such a phenomenon occurs in the WTP.

Notwithstanding the channeling noted above, 22 BVs of eluant at a flow rate of 3 BV/h was effective in reducing the Tc concentration in the eluate to less than 1% of that in the simulated LAW feed.

This result suggests that elution could be performed at a flow rate of 3 BV/h to achieve the same result as the 1 BV/h currently specified by Olson (2001) for the WTP.

The modified TCLP on the spent resin indicates that it may not exhibit toxicity characteristics.

This result suggests that the spent resin could be planned for disposal as a non-toxic waste. However, this result may not be appropriate for regulatory purposes or submissions since the TCLP had to be modified from the standard EPA SW-846 method due to the small sample size. Further testing using TCLP methods approved by the Washington State Department of Ecology would need to be completed with both actual and simulated wastes to develop a disposal pathway and identify disposal methods.

Residual 0.69 μg/g ^{99}Tc found on the spent resin.

Chemical analysis of the leached resin and TCLP leachate showed that the spent resin contained Tc at a concentration of 0.69 μg/g or 5.86 mCi/m^3. This value is below the Hanford Site Solid Waste Acceptance Criteria (McDowell (2002)) category 1 limit (23 mCi/m^3) and is a factor of >10 lower than that of the 60 mCi/m^3 found by Kurath and Wagner (2000) on resin previously used to process actual AW-101 and AN-107 LAW samples.

6.0 Conclusions

The following conclusions from this work are categorized for clarity.

Physical Characteristics of Resin

- No physical changes in the resin were inferred from the constancy of the resin bed height and color. SEM analysis of the resin surface showed that it had become more rough and pitted. There was no significant loss of resin through dissolution.

Process Performance of Resin

- There was no significant deterioration in the breakthrough and elution performance of the SL-639 resin after 26 cycles of simulated LAW processing and elution.
- Poor elution and breakthrough performance in some cycles was attributed to channeling caused by the presence of bubbles in the bed that were generated as air came out of solution when the eluant was heated inside the column. This may have been avoided if the eluant were pre-heated in a ventilated and stirred vessel before it was fed to the column and should be noted for WTP design purposes. Further testing would be required to determine if preheating the water to remove dissolved air would eliminate the gas accumulation problem.

Design and Operation Implications for the WTP

- On the basis of these results, a bed in the 3-column WTP system would require replacement no more frequently than after every 9th elution, assuming the worse case in that any degradation occurs only when processing LAW. Olson (2001) describes the WTP Tc removal system, consisting of three columns operating in a carousel fashion with elution being performed after a column processes LAW in the lead position. The current design assumption documented by Olson (2001) that replacement occurs every 10 cycles appears, therefore, likely consistent.
- This task required that a preliminary assessment of the toxicity characteristics of the resin be undertaken. The modified TCLP indicates that the spent resin would not exhibit toxicity characteristics if a formal TCLP were performed. However, this result may not be appropriate for regulatory purposes or submissions since the TCLP had to be modified from the standard EPA SW-846 method due to the small sample size. Further testing using TCLP methods approved by the Washington State Department of Ecology would need to be completed with both actual and simulated wastes to develop a disposal pathway and identify disposal methods.
- Chemical analysis of the leached resin and TCLP leachate showed the spent resin to contain Tc at a concentration of 0.69 μg/g or 5.86 mCi/m^3. This value is below the Hanford Site Solid Waste Acceptance Criteria (McDowell (2002)) category 1 limit (23 mCi/m^3).

7.0 References

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Appendix A

Cycle Process Data Sheets

CYCLE 1 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	311.5	g		
Feed SG	1.250	g/mL		
Bed volume in 0.25M NaOH	5.0	mL		
Technetium concentration	6.67E-05	M		
Potassium concentration	7.90E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.34	M		
Nitrite concentration	1.24	M		
Flow rate	16.3	mL/h, or	3.3	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	27693	100	6.385	2602
Feed 2	15909	60	6.385	2492
Feed 3	27263	100	6.434	2542
Feed 4	15513	60	6.385	2430
Feed 5	15583	60	6.434	2422
Average				2498

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
456.7	145.2	9/24/01 9:30	9/24/01 15:10	20.5	122.4	24.5	9735	1200	7.748	6.198	62.823	2.515
596.0	284.5	9/24/01 15:30	9/24/01 21:50	17.6	239.4	47.9	14378	1800	7.049	5.639	67.991	2.722
779.1	467.6	9/24/01 22:10	9/25/01 7:00	16.6	391.0	78.2	14283	1800	6.354	5.083	74.929	3.000
851.3	539.8	9/25/01 7:20	9/25/01 11:10	15.1	453.8	90.8	15351	1800	6.254	5.003	81.820	3.276
969.7	658.2	9/25/01 11:30	9/25/01 17:55	14.8	554.1	110.8	23549	2000	7.024	5.619	100.579	4.027
1229.4	917.9	9/25/01 18:15	9/26/01 7:10	16.1	767.5	153.5	36582	2000	7.015	5.612	156.445	6.264
1359.2	1047.7	9/26/01 7:30	9/26/01 13:50	16.4	876.9	175.4	48753	2000	6.945	5.556	210.596	8.432
1480.9	1169.4	9/26/01 14:10	9/26/01 20:30	15.4	979.5	195.9	58506	2000	6.535	5.228	268.581	10.754
1604.0	1292.5	9/26/01 20:50	9/27/01 3:10	15.5	1083.3	216.7	60576	1800	6.743	5.394	299.451	11.990
1727.8	1416.3	9/27/01 3:30	9/27/01 9:50	15.6	1187.9	237.6	12390	300	6.901	5.521	359.078	14.377
1851.1	1539.6	9/27/01 10:10	9/27/01 16:30	15.6	1291.9	258.4	13855	300	6.680	5.344	414.820	16.609
1909.3	1597.8	9/27/01 16:50	9/27/01 19:48	15.7	1343.5	268.7	12044	300	6.358	5.086	378.861	15.169

Cycle 1 Elution

Effluent bottle tare 59.9 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
6.022	6.022	6.022	18.066	1.204	40840	300	0.098	0.098	83347	501915	501915	13.462	26.697
4.893	10.915	10.915	14.679	2.183	50665	120	0.098	0.098	258495	1264816	1766731	47.384	82.798
5.691	16.606	16.606	17.073	3.321	27167	120	0.099	0.099	137207	780845	2547576	68.327	43.949
5.298	21.904	21.904	15.894	4.381	23365	120	0.098	0.098	119209	631570	3179146	85.266	38.184
5.610	27.514	27.514	16.83	5.503	14632	120	0.098	0.098	74653	418804	3597950	96.498	23.912
4.608	32.122	32.122	13.824	6.424	12926	360	0.097	0.097	22210	102342	3700292	99.243	7.114
4.880	37.002	37.002	14.64	7.400	126254	360	4.880	4.880	4312	21042	3721334	99.808	1.381
4.926	41.928	41.928	14.778	8.386	11990	180	4.926	4.926	811	3997	3725331	99.915	0.260
4.435	46.363	46.363	13.305	9.273	32575	1800	4.435	4.435	245	1086	3726417	99.944	0.078
4.836	51.199	51.199	14.508	10.240	15947	1800	4.836	4.836	110	532	3726949	99.958	0.035

Effluent bottle mass (g)	Mass of eluate in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	CPM/mL	C/C0
65.1	5.2	9/27/01 3:44	9/27/01 4:04	15.60	61.2	12.234	4919	1800	4.772	4.772	34.360	0.01101
70.3	10.4	9/27/01 4:24	9/27/01 4:44	15.60	71.4	14.277	3301	1800	5.015	5.015	21.941	0.00703
75.2	15.3	9/27/01 5:04	9/27/01 5:24	14.70	81.3	16.269	2644	1800	5.061	5.061	17.414	0.00558
80.1	20.2	9/27/01 5:44	9/27/01 6:04	14.70	91.1	18.217	1809	1800	4.837	4.837	12.466	0.00399
85.0	25.1	9/27/01 6:24	9/27/01 6:44	14.70	100.8	20.154	1555	1800	4.787	4.787	10.828	0.00347
100.3	40.4	9/27/01 7:04	9/27/01 8:04	15.30	120.9	24.178	1119	1800	4.821	4.821	7.737	0.00248
115.1	55.2	9/27/01 8:24	9/27/01 9:24	14.80	140.6	28.116	788	1800	4.887	4.887	5.375	0.00172
130.0	70.1	9/27/01 9:44	9/27/01 10:44	14.90	160.1	32.017	684	1800	4.605	4.605	4.951	0.00159
144.6	84.7	9/27/01 11:04	9/27/01 12:04	14.60	179.7	35.947	394	1800	5.053	5.053	2.599	0.00083
159.8	99.9	9/27/01 12:24	9/27/01 13:24	15.20	199.6	39.926	227	1800	4.691	4.691	1.613	0.00052
174.0	114.1	9/27/01 13:44	9/27/01 14:44	14.20	218.6	43.727	387	1800	4.808	4.808	2.683	0.00086
187.4	127.5	9/27/01 15:04	9/27/01 16:00	14.36	236.9	47.370	241	1800	4.815	4.815	1.668	0.00053
203.2	143.3	9/27/01 16:20	9/27/01 17:25	14.58	257.3	51.463	263	1800	4.664	4.664	1.880	0.00060
212.7	152.8	9/27/01 17:45	9/27/01 18:24	14.62	271.7	54.345	252	1800	4.910	4.910	1.711	0.00055

Cycle 1 Operational Details and Activity Balance

Data							
Density of 0.25M NaOH	1.0095	g/mL					
Density of 0.1M NaOH	1.0039	g/mL					
Conditioning							
Tare mass of effluent bottle	99.5	g					
Final mass of effluent bottle	136.6	g					
Mass of feed processed	37.1	g, or	36.8	mL			
Start date and time	9/24/01 6:30						
Finish date and time	9/24/01 8:30						
Average flow rate	18.4	mL/h or	3.7	BV/h			
Bed volume	5.0	mL					
Feed							
Starting mass of effluent bottle	311.5	g					
Final mass of effluent bottle	1909.3	g					
Mass of all samples	81.606						
Mass of feed processed	1679	g or	1344	mL			
Average flow rate	16.3	mL/h or	3.3	BV/h			
Acivity concentration in feed	2497.6	CPM/g					
Total activity processed	4.19E+06	CPM					
Simulated LAW Effluent							
Total acitvity in samples	16652.5	CPM					
Activity in bulk composite sample	13706	counts in	900	seconds of mass	6.271	g	
Composite bulk activity concentration	145.7	CPM/g					
Total mass of effluent	1597.8	g					
Total activity in bulk effluent	232811.9	CPM					
Total activity in simulated LAW effluent	2.49E+05	CPM, or	5.9%	of feed			
Feed Displacement							
Tare mass of effluent bottle	14.5	g					
Final mass of effluent bottle	50.8	g					
Mass of feed processed	36.3	g or	30.6	mL			
Start date and time	9/27/01 20:09						
Finish date and time	9/27/01 22:09						
Average flow rate	15.3	mL/h or	3.1	BV/h			
Activity in bulk composite sample	27798	counts in	600	seconds of mass	5.93	g	
Composite bulk activity concentration	468.8	CPM/g					
Total activity in effluent	1.70E+04	CPM, or	0.4%	of feed			
Water Rinse							
Tare mass of effluent bottle	14.3	g					
Final mass of effluent bottle	30.5	g					
Mass of feed processed	16.2	g, or	15.9	mL			
Start date and time	9/27/01 22:11						
Finish date and time	9/27/01 23:11						
Average flow rate	15.9	mL/h or	3.2	BV/h			
Activity in bulk composite sample	19795	counts in	300	seconds of mass	5.098	g	
Composite bulk activity concentration	776.6	CPM/g					
Total activity in effluent	1.26E+04	CPM, or	0.3%	of feed			
Elution							
Total mass of eluant processed	272	g					
Start date and time	9/27/01 0:24						
Finish date and time	9/27/01 18:44						
Average flow rate	14.82	mL/h, or	3.0	BV/h			
Total acitvity in samples	3727567.9	CPM					
Activity in bulk composite sample	940	counts in	1800	seconds of mass	5.098	g	
Composite bulk activity concentration	6.1	CPM/g					
Total mass of effluent	152.8	g					
Total activity in bulk effluent	939.1	CPM					
Total activity in effluent	3.73E+06	CPM, or	88.9%	of feed			
Total							
Total activity in all effluents	4007568.3	CPM					
Total activity in feed	4194456.3	CPM					
Activity recovery, as fraction of feed	95.5%						

CYCLE 2 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	320.8	g		
Feed density	1.25	g/mL		
Bed volume in 0.25M NaOH	5.0	mL		
Technetium concentration	1.04E-04	M		
Potassium concentration	7.90E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.34	M		
Nitrite concentration	1.24	M		
Flow rate	16.0	mL/h, or	3.2	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	10111	240	6.304	401
Feed 2				
Feed 3				
Feed 4				
Feed 5				
Average				401

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
458.3	137.5	10/2/01 9:00	10/2/01 16:02	15.6	115.3	23.1	1708	1800	6.594	5.275	8.634	2.153
769.3	448.5	10/2/01 16:22	10/3/01 7:54	16.0	369.5	73.9	2067	1800	6.764	5.411	10.186	2.540
909.4	588.6	10/3/01 8:14	10/3/01 15:09	16.2	487.1	97.4	2929	1800	6.888	5.510	14.174	3.535
1228.6	907.8	10/3/01 15:29	10/4/01 7:32	15.9	747.8	149.6	5286	1800	6.723	5.378	26.209	6.536
1391.2	1070.4	10/4/01 7:52	10/4/01 16:01	16.0	883.2	176.6	7467	1800	6.609	5.287	37.661	9.392
1701.5	1380.7	10/4/01 16:21	10/5/01 8:00	15.9	1136.8	227.4	11301	1800	6.732	5.386	55.957	13.955
1827.0	1506.2	10/5/01 8:20	10/5/01 14:37	16.0	1242.6	248.5	14665	1800	6.760	5.408	72.313	18.034
1928.4	1607.6	10/5/01 14:57	10/5/01 20:00	16.1	1329.2	265.8	17045	1800	6.783	5.426	83.763	20.890

CYCLE 3 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	319.8	g		
Feed density	1.25	g/mL		
Bed volume in 0.25M NaOH	5.0	mL		
Technetium concentration	2.05E-04	M		
Potassium concentration	7.90E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.34	M		
Nitrite concentration	1.24	M		
Flow rate	16.5	mL/h or	3.3	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	10195	240	6.321	403.219
Feed 2	9585	240	6.321	379.093
Feed 3				
Feed 4				
Feed 5				
Average				391.156

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
426.5	106.7	10/8/01 7:37	10/8/01 13:07	15.5	90.8	18.2	1824	1800	6.841	5.473	8.888	2.272
794.9	475.1	10/8/01 13:27	10/9/01 7:35	16.3	391.0	78.2	2327	1800	6.764	5.411	11.468	2.932
973.7	653.9	10/9/01 7:55	10/9/01 16:33	16.6	539.5	107.9	4034	1800	6.888	5.510	19.522	4.991
1255.7	935.9	10/9/01 16:53	10/10/01 6:25	16.7	770.7	154.1	7644	1800	6.964	5.571	36.588	9.354
1326.8	1007.0	10/10/01 6:45	10/10/01 10:09	16.7	833.0	166.6	8770	1800	6.825	5.460	42.833	10.950
1475.9	1156.1	10/10/01 10:29	10/10/01 17:41	16.6	957.8	191.6	11803	1800	6.896	5.517	57.052	14.586
1741.3	1421.5	10/10/01 18:01	10/11/01 6:57	16.4	1175.7	235.1	17997	1800	6.966	5.573	86.118	22.016
1859.1	1539.3	10/11/01 7:17	10/11/01 13:01	16.4	1275.6	255.1	14102	1200	7.036	5.629	100.213	25.620
1967.2	1647.4	10/11/01 13:21	10/11/01 18:40	16.3	1367.6	273.5	12572	900	6.981	5.585	120.059	30.693

CYCLE 4 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	426.1	g		
Feed density	1.25	g/mL		
Bed volume in 0.25M NaOH	5.0	mL		
Technetium concentration	4.29E-04	M		
Potassium concentration	7.90E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.34	M		
Nitrite concentration	1.24	M		
Flow rate	15.5	mL/h or	3.1	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	11647	300	6.244	373
Feed 2	11902	300	6.244	381
Feed 3				
Feed 4				
Feed 5				
Average				377

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
604.5	178.4	10/22/01 22:36	10/23/01 7:48	15.5	147.4	29.5	5859	1800	5.800	4.640	34	8.928
756.4	330.3	10/23/01 8:08	10/23/01 15:49	15.8	274.2	54.8	11790	1800	6.664	5.331	59	15.637
1082.5	656.4	10/23/01 16:09	10/24/01 8:36	15.9	540.5	108.1	21173	1800	6.754	5.403	104	27.707
1186.5	760.4	10/24/01 8:56	10/24/01 14:09	15.9	629.1	125.8	11788	900	6.777	5.422	116	30.747
1244.0	817.9	10/24/01 14:29	10/24/01 17:23	15.9	680.3	136.1	12094	900	6.499	5.199	124	32.894
1526.0	1099.9	10/24/01 17:43	10/25/01 8:23	15.4	911.0	182.2	15741	900	6.332	5.066	166	43.943
1620.2	1194.1	10/25/01 8:43	10/25/01 13:39	15.3	991.4	198.3	10685	600	6.382	5.106	167	44.392
1662.3	1236.2	10/25/01 13:59	10/25/01 16:15	14.9	1030.1	206.0	11655	600	6.219	4.975	187	49.692
1980.0	1553.9	10/25/01 16:35	10/26/01 9:36	14.9	1289.4	257.9	13566	600	6.452	5.162	210	55.750

CYCLE 5 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	315.3	g	
Feed density	1.250	g/mL	
Bed volume in 0.25M NaOH	4.6	mL	
Technetium concentration	4.27E-04	M	
Potassium concentration	7.80E-02	M	
Hydroxide concentration	1.72	M	
Nitrate concentration	1.33	M	
Nitrite concentration	1.22	M	
Flow rate	14.7	mL/h or	3.2 BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	9041	300	6.295	287
Feed 2	9401	300	6.295	299
Feed 3	8812	300	6.270	281
Feed 4				
Feed 5				
Average				289

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)	Total CPM in sample
434.8	119.5	10/29/01 7:07	10/29/01 14:08	13.6	100.5	21.8	1133	1800	6.067	4.854	6.225	2.154	37.77
551.9	236.6	10/29/01 14:28	10/29/01 20:48	14.8	199.0	43.3	1163	1800	6.087	4.870	6.369	2.204	38.77
754.8	439.5	10/29/01 21:08	10/30/01 8:05	14.8	366.4	79.7	1426	1800	6.386	5.109	7.443	2.576	47.53
786.1	470.8	10/30/01 8:25	10/30/01 10:05	15.0	396.0	86.1	1622	1800	5.616	4.493	9.627	3.331	54.07
903.3	588.0	10/30/01 10:25	10/30/01 16:48	14.7	494.7	107.5	1976	1800	6.170	4.936	10.675	3.694	65.87
1213.7	898.4	10/30/01 17:08	10/31/01 9:50	14.9	747.4	162.5	5612	1800	5.554	4.443	33.681	11.654	187.07
1266.8	951.5	10/31/01 10:10	10/31/01 12:45	16.4	794.8	172.8	6924	1800	6.130	4.904	37.651	13.028	230.80
1497.8	1182.5	10/31/01 13:05	11/1/01 2:08	14.2	984.5	214.0	13154	1800	6.128	4.902	71.551	24.758	438.47
1616.9	1301.6	11/1/01 2:28	11/1/01 8:48	15.0	1084.8	235.8	16616	1800	6.260	5.008	88.477	30.615	553.87
1734.5	1419.2	11/1/01 9:08	11/1/01 15:28	14.9	1184.2	257.4	23878	1800	6.627	5.302	120.105	41.558	795.93
1753.4	1438.1	11/1/01 15:48	11/1/01 16:50	14.6	1204.4	261.8	7701	600	6.366	5.093	120.971	41.858	770.10

Cycle 5 Elution

Effluent bottle tare 60.8 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
5.447	5.447	5.447	16.341	1.184	2740	300	0.094	0.094	5829.787	3.18E+04	31755	8.696	16.138
5.000	10.447	10.447	15	2.271	22231	600	0.096	0.096	23157.292	1.16E+05	147541	40.405	64.102
4.986	15.433	15.433	14.958	3.355	9415	600	0.097	0.097	9706.186	4.84E+04	195936	53.658	26.868
5.036	20.469	20.469	15.108	4.450	11963	900	0.097	0.097	8221.993	4.14E+04	237342	64.997	22.760
5.105	25.574	25.574	15.315	5.560	11761	900	0.148	0.148	5297.748	2.70E+04	264387	72.403	14.665
5.272	30.846	30.846	15.816	6.706	14999	1200	0.097	0.097	7731.443	4.08E+04	305147	83.566	21.402
5.353	36.199	36.199	16.059	7.869	135268	300	5.353	5.353	5053.914	2.71E+04	332201	90.974	13.990
4.791	40.990	40.990	14.373	8.911	99633	300	4.791	4.791	4159.173	1.99E+04	352128	96.431	11.513
5.212	46.202	46.202	15.636	10.044	53173	300	5.212	5.212	2040.407	1.06E+04	362762	99.344	5.648
4.878	51.080	51.080	14.634	11.104	8545	300	4.878	4.878	350.349	1.71E+03	364471	99.812	0.970

Effluent bottle mass (g)	Mass of eluant processed (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	CPM/mL	C/C0	Total CPM in sample
66.4	5.6	11/1/01 3:20	11/1/01 3:40	16.80	61.8	13.444	961	1800	5.163	5.163	6.204	0.01717	32
71.5	10.7	11/1/01 4:00	11/1/01 4:20	15.30	72.1	15.683	219	3000	5.201	5.201	0.842	0.00233	4
76.6	15.8	11/1/01 4:40	11/1/01 5:00	15.30	82.4	17.910	123	3000	5.144	5.144	0.478	0.00132	2
82.0	21.2	11/1/01 5:20	11/1/01 5:41	15.43	92.7	20.161	131	3000	4.954	4.954	0.529	0.00146	3
87.1	26.3	11/1/01 6:01	11/1/01 6:20	16.11	103.0	22.393	93	1800	5.167	5.167	0.600	0.00166	3
102.9	42.1	11/1/01 6:40	11/1/01 7:41	15.54	123.5	26.857	2	1800	4.731	4.731	0.014	0.00004	0
118.3	57.5	11/1/01 8:01	11/1/01 9:00	15.66	144.1	31.331	36	1800	5.183	5.183	0.232	0.00064	1
133.7	72.9	11/1/01 9:20	11/1/01 10:20	15.40	164.7	35.799	27	1800	5.151	5.151	0.175	0.00048	1
149.2	88.4	11/1/01 10:40	11/1/01 11:40	15.50	185.3	40.285	82	1800	5.138	5.138	0.532	0.00147	3
164.8	104.0	11/1/01 12:00	11/1/01 13:00	15.60	205.6	44.693	118	1800	4.674	4.674	0.842	0.00233	4
164.8	126.1	11/1/01 13:20	11/1/01 14:57	13.64	232.8	50.609	43	1800	5.162	5.162	0.278	0.00077	1
164.8	150.2	11/1/01 15:17	11/1/01 16:41	17.25	262.6	57.082	110	1800	5.626	5.626	0.652	0.00180	4
164.8	150.2	11/1/01 17:01	11/1/01 17:01	15.69	267.8	58.219	0	1800	5.230	5.230	0.000	0.00000	0
174.6	160.0	11/1/01 17:21	11/1/01 18:00	15.08	277.5	60.333	28	1800	5.088	5.088	0.183	0.00051	1

SVOA sample mass 22.053 g, taken from 11/1/01 13:20 to 11/1/01 14:57

VOA sample mass 24.150 g, taken from 11/1/01 15:17 to 11/1/01 16:41

	A	B	C	D	E	F	G
1	**Cycle 5 Operational Details and Activity Balance**						
2	Data						
3	Density of 0.25M NaOH	1.0095	g/mL				
4	Density of 0.1M NaOH	1.0039	g/mL				
5							
6	Regeneration						
7	Tare mass of effluent bottle	26.1	g				
8	Final mass of effluent bottle	55.9	g				
9	Mass of feed processed	29.8	g, or	29.5	mL		
10	Start date and time	10/29/01 5:06					
11	Finish date and time	10/29/01 7:06					
12	Average flow rate	14.8	mL/h or	3.2	BV/h		
13	Bed volume	4.6	mL				
14							
15	Feed						
16	Starting mass of effluent bottle	315.3	g				
17	Final mass of effluent bottle	1753.4	g				
18	Mass of all samples	67.391					
19	Mass of feed processed	1505.491	g or	1204	mL		
20	Average flow rate	14.7	mL/h or	3.2	BV/h		
21	Acivity concentration in feed	289.0	CPM/g				
22	Total activity processed	4.35E+05	CPM				
23							
24	Simulated LAW Effluent						
25	Total acitvity in samples	3220.2	CPM				
26	Activity in bulk composite sample	2007	counts in	1800	seconds of mass	6.269	g
27	Composite bulk activity concentration	10.7	CPM/g				
28	Total mass of effluent	1438.1	g				
29	Total activity in bulk effluent	15346.8	CPM				
30	Total activity in simulated LAW effluent	1.86E+04	CPM, or	4.3%	of feed		
31							
32	Feed Displacement						
33	Tare mass of effluent bottle	14.5	g				
34	Final mass of effluent bottle	50.3	g				
35	Mass of feed processed	35.8	g or	29.7	mL		
36	Start date and time	11/1/01 19:23					
37	Finish date and time	11/1/01 21:23					
38	Average flow rate	14.8	mL/h or	3.2	BV/h		
39	Activity in bulk composite sample	26268	counts in	1800	seconds of mass	6.03	g
40	Composite bulk activity concentration	145.2	CPM/g				
41	Total activity in effluent	5.20E+03	CPM, or	1.2%	of feed		
42							
43	Water Rinse						
44	Tare mass of effluent bottle	14.3	g				
45	Final mass of effluent bottle	30.5	g, estimated				
46	Mass of feed processed	16.2	g, or	16.5	mL		
47	Start date and time	11/1/01 21:23					
48	Finish date and time	11/1/01 22:23					
49	Average flow rate	16.5	mL/h or	3.6	BV/h		
50	Activity in bulk composite sample	41518	counts in	1800	seconds of mass	4.918	g
51	Composite bulk activity concentration	281.4	CPM/g				
52	Total activity in effluent	4.56E+03	CPM, or	1.0%	of feed		
53							
54	Elution						
55	Total mass of eluant processed	278	g				
56	Start date and time	11/2/01 0:00					
57	Finish date and time	11/2/01 18:20					
58	Average flow rate	15.14	mL/h, or	3.3	BV/h		
59	Total acitvity in samples	364530.7	CPM				
60	Activity in bulk composite sample	117	counts in	1800	seconds of mass	0.993	g
61	Composite bulk activity concentration	3.9	CPM/g				
62	Total mass of effluent	160.003	g				
63	Total activity in bulk effluent	628.4	CPM				
64	Total activity in effluent	3.65E+05	CPM, or	83.9%	of feed		
65							
66	Total						
67	Total activity in all effluents	393483.3	CPM				
68	Total activity in feed	435091.9	CPM				
69	Activity recovery, as fraction of feed	90.4%					

CYCLE 6 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	326.4	g		
Feed density	1.26	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.14E-04	M		
Potassium concentration	7.90E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.34	M		
Nitrite concentration	1.24	M		
Flow rate	14.6	mL/h or	3.2	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	8036	300	6.212	259
Feed 2	9922	360	6.212	266
Feed 3				
Feed 4				
Feed 5				
Average				262

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
481.4	155.0	11/5/01 22:36	11/6/01 7:02	14.6	127.9	27.8	887	1800	6.211	4.929	4.760	1.814
619.7	293.3	11/6/01 7:22	11/6/01 14:55	14.5	242.6	52.7	1603	1800	6.121	4.858	8.730	3.326
1081.3	754.9	11/6/01 15:15	11/7/01 16:23	14.6	613.8	133.4	5124	1800	6.181	4.906	27.633	10.528
1195.0	868.6	11/7/01 16:43	11/7/01 22:55	14.6	709.0	154.1	7825	1800	6.247	4.958	41.753	15.908
1299.8	973.4	11/7/01 23:15	11/8/01 5:00	14.5	797.0	173.3	9086	1800	6.103	4.844	49.626	18.908
1403.0	1076.6	11/8/01 5:20	11/8/01 11:10	14.0	883.8	192.1	10539	1800	6.142	4.875	57.196	21.792
1481.0	1154.6	11/8/01 11:30	11/8/01 15:52	14.2	950.3	206.6	12795	1800	5.802	4.605	73.509	28.007
1722.0	1395.6	11/8/01 16:12	11/9/01 9:59	10.8	1144.8	248.9	11414	1800	4.029	3.198	94.432	35.979

CYCLE 7 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	314.7	g		
Feed density	1.26	g/mL		
Bed volume in 0.25M NaOH	4.60	mL		
Technetium concentration	4.14E-04	M		
Potassium concentration	9.51E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.23	M		
Nitrite concentration	1.21	M		
Flow rate	4.2	mL/h or	0.9	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	10661	720	6.253	142
Feed 2				
Feed 3				
Feed 4				
Feed 5				
Average				142

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
394.7	80.0	11/12/01 22:31	11/13/01 6:42	7.8	65.4	14.2	317	3600	2.362	1.875	2.237	1.574
434.8	120.1	11/13/01 7:02	11/13/01 16:08	3.5	99.4	21.6	860	3600	2.727	2.164	5.256	3.699
496.0	181.3	11/13/01 16:28	11/14/01 8:23	3.1	149.9	32.6	625	3600	2.487	1.974	4.188	2.948
517.2	202.5	11/14/01 8:43	11/14/01 14:18	3.0	168.9	36.7	1289	3600	2.735	2.171	7.855	5.529

CYCLE 8 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	312.9	g		
Feed SG	1.26			
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.14E-04	M		
Potassium concentration	9.51E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.23	M		
Nitrite concentration	1.21	M		
Flow rate	15.5	mL/h or	3.4	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	8014	720	6.235	107
Feed 2	10622	1000	6.212	103
Feed 3				
Feed 4				
Feed 5				
Average				105

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
477.7	164.8	11/26/01 22:41	11/27/01 7:30	14.8	136.1	29.6	1699	3600	6.711	5.326	4.219	4.024
655.3	342.4	11/27/01 7:50	11/27/01 16:56	15.5	282.3	61.4	688	3600	6.583	5.225	1.742	1.661
953.3	640.4	11/27/01 17:16	11/28/01 8:29	15.5	523.9	113.9	3193	3600	6.453	5.121	8.247	7.865
1015.2	702.3	11/28/01 8:49	11/28/01 11:59	15.5	578.3	125.7	2289	3600	6.617	5.252	5.765	5.499
1144.2	831.3	11/28/01 12:19	11/28/01 18:55	15.5	685.9	149.1	2752	3600	6.560	5.206	6.992	6.668
1420.6	1107.7	11/28/01 19:15	11/29/01 9:22	15.5	910.9	198.0	8697	3600	7.073	5.613	20.493	19.545
1567.2	1254.3	11/29/01 9:42	11/29/01 17:15	15.4	1032.6	224.5	13939	3600	6.732	5.343	34.509	32.912
1882.4	1569.5	11/29/01 17:35	11/30/01 9:42	15.5	1287.9	280.0	20329	3600	6.486	5.148	52.238	49.821

CYCLE 9 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	314	g		
Feed density	1.250	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.14E-04	M		
Potassium concentration	9.51E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.23	M		
Nitrite concentration	1.21	M		
Flow rate	15.6	mL/h or	3.4	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	24221	1000	6.298	231
Feed 2	13890	600	6.298	221
Feed 3				
Feed 4				
Feed 5				
Average				226

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
452.9	138.9	12/4/01 2:37	12/4/01 10:00	15.1	116.5	25.3	882	1800	6.752	5.402	4.354	1.930
563.0	249.0	12/4/01 10:20	12/4/01 16:00	15.5	209.9	45.6	1100	1800	6.583	5.266	5.570	2.468
868.4	554.4	12/4/01 16:20	12/5/01 8:00	15.6	459.4	99.9	1304	1800	6.564	5.251	6.622	2.935
1013.4	699.4	12/5/01 8:20	12/5/01 15:50	15.5	580.7	126.2	2405	1800	6.521	5.217	12.294	5.448
1321.8	1007.8	12/5/01 16:10	12/6/01 8:00	15.6	832.6	181.0	4345	1800	6.553	5.242	22.102	9.795
1474.3	1160.3	12/6/01 8:20	12/6/01 16:10	15.6	959.6	208.6	6008	1800	6.194	4.955	32.332	14.329
1775.7	1461.7	12/6/01 16:30	12/7/01 8:00	15.6	1205.8	262.1	9524	1800	6.424	5.139	49.419	21.901
1878.5	1564.5	12/7/01 8:20	12/7/01 13:37	15.6	1293.3	281.2	10208	1800	6.552	5.242	51.933	23.015

CYCLE 10 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	324.5	g			
Feed density	1.260	g/mL			
Bed volume in 0.25M NaOH	4.6	mL			
Technetium concentration	4.13E-04	M			
Potassium concentration	7.70E-02	M			
Hydroxide concentration	1.72	M			
Nitrate concentration	1.32	M			
Nitrite concentration	1.24	M			
Flow rate	15.1	mL/h or	3.3	BV/h	

VOA sample mass	29.591	g, taken from	12/18/01 10:25	to	12/18/01 12:01
SVOA sample mass	23.797	g, taken from	12/18/01 9:07	to	12/18/01 10:25

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	10344	300	6.257	331
Feed 2	9298	300	6.257	297
Feed 3	9885	300	6.247	316
Feed 4	11870	360	6.257	316
Feed 5	11315	360	6.247	302
Feed 6	9854	360	6.257	262
Feed 7	9487	360	6.247	253
Average				297

Effluent bottle mass (g)	Mass of effluent in bottle & VOA/SVOA (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)	Total CPM in sample
447.0	122.5	12/10/01 9:50	12/10/01 16:28	14.7	102.3	22.2	1611	1800	6.424	5.098	8.359	2.816	53.70
568.9	244.4	12/10/01 16:48	12/10/01 23:08	15.3	204.3	44.4	1504	1800	6.549	5.198	7.655	2.579	50.13
723.9	399.4	12/10/01 23:28	12/11/01 7:31	15.3	332.5	72.3	1600	1800	6.557	5.204	8.134	2.740	53.33
813.3	488.8	12/11/01 7:51	12/11/01 12:29	15.3	408.7	88.8	2260	1800	6.582	5.224	11.445	3.856	75.33
934.8	610.3	12/11/01 12:49	12/11/01 19:09	15.2	510.2	110.9	3105	1800	6.455	5.123	16.034	5.401	103.50
1001.9	677.4	12/11/01 19:29	12/11/01 23:00	15.1	568.6	123.6	5025	1800	6.468	5.133	25.897	8.724	167.50
1177.7	853.2	12/11/01 23:20	12/12/01 8:28	15.3	713.2	155.1	7860	1800	6.441	5.112	40.677	13.703	262.00
1300.6	976.1	12/12/01 8:48	12/12/01 15:12	15.2	815.9	177.4	10910	1800	6.400	5.079	56.823	19.142	363.67
1309.2	984.7	12/12/01 15:32	12/12/01 16:05	12.4	822.7	178.8							
1413.4	1088.9	12/17/01 13:47	12/17/01 19:29	15.7	910.2	197.9	9023	1800	6.037	4.791	49.821	16.783	300.77
1530.1	1205.6	12/17/01 19:49	12/18/01 2:07	14.7	1007.7	219.1	13799	1800	6.210	4.929	74.069	24.951	459.97
1648.2	1323.7	12/18/01 2:27	12/18/01 8:47	14.8	1106.7	240.6	20279	1800	6.577	5.220	102.777	34.623	675.97
1712.6	1441.5	12/18/01 9:07	12/18/01 15:31	14.6	1205.0	262.0	11563	900	6.135	4.869	125.651	42.328	770.87
1761.4	1490.3	12/18/01 15:51	12/18/01 18:30	14.6	1248.7	271.5	13720	900	6.291	4.993	145.393	48.978	914.67

Cycle 10 Elution

Effluent bottle tare 61.1 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
5.507	5.507	5.507	16.521	1.197	28815	1800	0.094	0.094	10218	5.63E+04	56271	15.851	27.319
5.027	10.534	10.534	15.081	2.290	8424	240	0.096	0.096	21938	1.10E+05	166551	46.916	58.651
5.498	16.032	16.032	16.494	3.485	25176	1800	0.093	0.093	9024	4.96E+04	216163	60.892	24.125
4.480	20.512	20.512	13.44	4.459	22923	1800	0.084	0.084	9096	4.08E+04	256915	72.371	24.320
5.026	25.538	25.538	15.078	5.552	22921	1800	0.090	0.090	8489	4.27E+04	299582	84.390	22.697
4.852	30.390	30.390	14.556	6.607	20212	1800	0.090	0.090	7486	3.63E+04	335904	94.622	20.014
4.974	35.364	35.364	14.922	7.688	73225	1800	4.974	4.974	491	2.44E+03	338344	95.310	1.312
4.866	40.230	40.230	14.598	8.746	49338	1800	4.866	4.866	338	1.64E+03	339989	95.773	0.904
5.262	45.492	45.492	15.786	9.890	262332	1800	5.262	5.262	1662	8.74E+03	348733	98.236	4.443
4.670	50.162	50.162	14.01	10.905	69451	1800	4.670	4.670	496	2.32E+03	351048	98.888	1.325

Effluent bottle mass (g)	Mass of eluate in bottle & VOA/SVOA (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	C/C0	Total CPM in sample
65.9	4.8	12/19/01 2:35	12/19/01 2:55	14.40	59.9	13.026	9098	1800	4.958	4.958	61.167	0.16353	303
70.7	9.6	12/19/01 3:15	12/19/01 3:35	14.40	70.1	15.235	4336	1800	5.360	5.360	26.965	0.07209	145
75.5	14.4	12/19/01 3:55	12/19/01 4:16	13.71	79.7	17.331	2762	1800	4.844	4.844	19.006	0.05081	92
80.5	19.4	12/19/01 4:36	12/19/01 4:55	15.79	89.7	19.497	2123	1800	4.964	4.964	14.256	0.03811	71
85.4	24.3	12/19/01 5:15	12/19/01 5:35	14.70	99.5	21.620	1722	1800	4.865	4.865	11.799	0.03154	57
100.1	39.0	12/19/01 5:55	12/19/01 6:55	14.70	119.1	25.883	1484	1800	4.908	4.908	10.079	0.02695	49
115.0	53.9	12/19/01 7:15	12/19/01 8:15	14.90	139.5	30.316	1861	1800	5.494	5.494	11.291	0.03019	62
129.3	68.2	12/19/01 8:35	12/19/01 9:37	13.84	158.4	34.435	1355	1800	4.647	4.647	9.720	0.02599	45
144.0	82.9	12/19/01 9:57	12/19/01 10:55	15.21	178.0	38.704	191	1800	4.935	4.935	1.290	0.00345	6
158.6	97.5	12/19/01 11:15	12/19/01 12:15	14.60	197.5	42.928	201	1800	4.832	4.832	1.387	0.00371	7
173.2	112.1	12/19/01 12:35	12/19/01 13:35	14.60	217.0	47.183	58	1800	4.975	4.975	0.389	0.00104	2
173.2	126.3	12/19/01 13:55	12/19/01 14:55	14.18	236.2	51.345	8	1800	4.962	4.962	0.054	0.00014	0
173.2	150.4	12/19/01 15:15	12/19/01 16:54	15.09	265.4	57.690	83	1800	5.030	5.030	0.550	0.00147	3
188.1	165.3	12/19/01 17:14	12/19/01 18:14	14.90	280.3	60.943	1	1800	5.024	5.024	0.007	0.00002	0

SVOA sample mass 14.183 g, taken from 12/19/01 13:55 to 12/19/01 14:55

VOA sample mass 24.154 g, taken from 12/19/01 15:15 to 12/19/01 16:54

Operational Details and Activity Balance for Cycle 10

Data							
Density of 0.25M NaOH	1.0095	g/mL					
Density of 0.1M NaOH	1.0039	g/mL					
Regeneration							
Tare mass of effluent bottle	25.7	g					
Final mass of effluent bottle	56.8	g					
Mass of feed processed	31.1	g, or	30.8	mL			
Start date and time	12/10/01 7:48						
Finish date and time	12/10/01 9:48						
Average flow rate	15.4	mL/h or	3.3	BV/h			
Bed volume	4.6	mL					
Feed							
Starting mass of effluent bottle	324.5	g					
Final mass of effluent bottle	1761.4	g					
Mass of all samples	136.514						
Mass of feed processed	1573	g or	1249	mL			
Average flow rate	15.1	mL/h or	3.3	BV/h			
Acivity concentration in feed	296.9	CPM/g					
Total activity processed	4.67E+05	CPM					
Simulated LAW Effluent							
Total acitvity in samples	4251.4	CPM					
Activity in bulk composite sample	7673	counts in	1800	seconds of mass	6.219	g	
Composite bulk activity concentration	41.1	CPM/g					
Total mass of effluent	1490	g					
Total activity in bulk effluent	61290.6	CPM					
Total activity in simulated LAW effluent	6.55E+04	CPM, or	14.0%	of feed			
Feed Displacement							
Tare mass of effluent bottle	14.5	g					
Final mass of effluent bottle	49.8	g					
Mass of feed processed	35.3	g or	30.8	mL			
Start date and time	12/18/01 18:55						
Finish date and time	12/18/01 20:55						
Average flow rate	15.4	mL/h or	3.3	BV/h			
Activity in bulk composite sample	33390	counts in	1800	seconds of mass	5.735	g	
Composite bulk activity concentration	194.1	CPM/g					
Total activity in effluent	6.85E+03	CPM, or	1.5%	of feed			
Water Rinse							
Tare mass of effluent bottle	14.3	g					
Final mass of effluent bottle	29.6	g					
Mass of feed processed	15.3	g, or	15.1	mL			
Start date and time	12/18/01 21:01						
Finish date and time	12/18/01 22:01						
Average flow rate	15.1	mL/h or	3.3	BV/h			
Activity in bulk composite sample	52971	counts in	1800	seconds of mass	5.072	g	
Composite bulk activity concentration	348.1	CPM/g					
Total activity in effluent	5.33E+03	CPM, or	1.1%	of feed			
Elution							
Total mass of eluant processed	280	g					
Start date and time	12/18/01 23:15						
Finish date and time	12/19/01 18:34						
Average flow rate	14.51	mL/h, or	3.2	BV/h			
Total acitvity in samples	351891.2	CPM					
Activity in bulk composite sample	557	counts in	1800	seconds of mass	0.989	g	
Composite bulk activity concentration	18.8	CPM/g					
Total mass of effluent	165.337	g					
Total activity in bulk effluent	3103.9	CPM					
Total activity effluent	3.55E+05	CPM, or	76.0%	of feed			
Total							
Total activity in all effluents	432714.2	CPM					
Total activity in feed	467069.7	CPM					
Activity recovery, as fraction of feed	92.6%						

CYCLE 11 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	312	g		
Feed density	1.22	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.00E-04	M		
Potassium concentration	8.00E-03	M		
Hydroxide concentration	2.2	M		
Nitrate concentration	0.1	M		
Nitrite concentration	1.46	M		
Flow rate	33.4	mL/h or	7.3	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	8252	300	6.196	266
Feed 2				
Feed 3				
Feed 4				
Feed 5				
Average				266

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
436.0	124.0	1/7/02 10:00	1/7/02 13:03	33.3	107.0	23.3	1058	1800	6.578	5.392	5.361	2.013
561.0	249.0	1/7/02 13:13	1/7/02 16:20	32.9	215.1	46.8	881	1800	6.804	5.577	4.316	1.620
1187.8	875.8	1/7/02 16:30	1/8/02 7:57	33.3	734.6	159.7	4103	1800	7.087	5.809	19.298	7.245
1359.1	1047.1	1/8/02 8:07	1/8/02 12:20	33.3	880.7	191.5	6172	1800	6.920	5.672	29.730	11.161
1511.4	1199.4	1/8/02 12:30	1/8/02 16:15	33.3	1011.3	219.8	9241	1800	6.985	5.725	44.099	16.556
2143.3	1831.3	1/8/02 16:25	1/9/02 7:53	33.5	1534.5	333.6	21538	1800	6.443	5.281	111.428	41.833

CYCLE 12 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	312.6	g		
Feed density	1.22	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.00E-04	M		
Potassium concentration	8.00E-03	M		
Hydroxide concentration	2.2	M		
Nitrate concentration	0.1	M		
Nitrite concentration	1.46	M		
Flow rate	7.6	mL/h or	1.7	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	10199	700	2.476	353
Feed 2	9300	700	2.476	322
Feed 3				
Feed 4				
Feed 5				
Average				338

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
348.5	35.9	1/14/02 10:09	1/14/02 16:31	4.6	31.1	6.8	979	1800	2.085	1.709	15.651	4.637
456.4	143.8	1/14/02 16:47	1/15/02 7:38	6.0	121.1	26.3	713	1800	1.880	1.541	12.642	3.746
550.0	237.4	1/15/02 7:54	1/15/02 16:05	9.4	200.1	43.5	1215	1800	2.806	2.300	14.433	4.276
710.6	398.0	1/15/02 16:21	1/16/02 7:26	8.7	333.9	72.6	995	1800	2.599	2.130	12.761	3.781
794.0	481.4	1/16/02 7:42	1/16/02 16:33	7.7	404.4	87.9	1110	1800	2.574	2.110	14.375	4.259
932.0	619.4	1/16/02 16:49	1/17/02 7:16	7.8	519.6	113.0	960	1800	2.626	2.152	12.186	3.611
1000.8	688.2	1/17/02 7:32	1/17/02 14:37	8.0	578.1	125.7	1078	1800	2.568	2.105	13.993	4.146
1062.4	749.8	1/17/02 14:53	1/17/02 21:13	8.0	630.9	137.2	1158	1800	2.784	2.282	13.865	4.108

CYCLE 13 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	313.3	g		
Feed density	1.220	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.00E-04	M		
Potassium concentration	8.00E-03	M		
Hydroxide concentration	2.2	M		
Nitrate concentration	0.1	M		
Nitrite concentration	1.46	M		
Flow rate	15.1	mL/h or	3.3	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	17431	700	6.113	244
Feed 2	14279	600	6.113	234
Feed 3	14919	600	6.113	244
Feed 4				
Feed 5				
Average				241

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
400.7	87.4	1/21/02 10:50	1/21/02 16:20	13.0	76.7	16.7	974	1800	6.146	5.038	5.283	2.195
684.1	370.8	1/21/02 16:40	1/22/02 7:55	15.2	314.0	68.3	2254	3600	6.163	5.052	6.096	2.533
825.7	512.4	1/22/02 8:15	1/22/02 16:00	15.0	434.9	94.5	1464	3600	5.902	4.838	4.134	1.718
1193.2	879.9	1/22/02 16:20	1/23/02 12:11	15.2	741.3	161.1	1861	3600	6.246	5.120	4.966	2.063
1269.9	956.6	1/23/02 12:31	1/23/02 16:42	15.0	809.2	175.9	2061	3600	6.128	5.023	5.605	2.329
1532.4	1219.1	1/23/02 17:02	1/24/02 7:10	15.2	1029.4	223.8	1965	3600	6.235	5.111	5.253	2.182
1635.2	1321.9	1/24/02 7:30	1/24/02 13:01	15.3	1118.8	243.2	2665	3600	6.185	5.070	7.181	2.984
1775.7	1462.4	1/24/02 13:21	1/24/02 20:50	15.4	1239.1	269.4	2617	3600	6.331	5.189	6.889	2.862

CYCLE 14 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	312.5	g		
Feed density	1.240	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.00E-04	M		
Potassium concentration	8.00E-03	M		
Hydroxide concentration	1.2	M		
Nitrate concentration	0.5	M		
Nitrite concentration	2.46	M		
Flow rate	7.9	mL/h or	1.7	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	11052	600	2.463	449
Feed 2	11069	600	2.463	449
Feed 3				
Feed 4				
Feed 5				
Average				449

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
376.9	64.4	1/28/02 9:30	1/28/02 16:25	7.5	54.0	11.7	1254	3600	2.618	2.111	7.983	1.778
527.5	215.0	1/28/02 16:41	1/29/02 8:05	7.9	177.6	38.6	1163	3600	2.584	2.084	7.501	1.670
600.6	288.1	1/29/02 8:21	1/29/02 15:46	7.9	238.6	51.9	1144	3600	2.560	2.065	7.448	1.659
780.8	468.3	1/29/02 16:02	1/30/02 10:32	7.9	386.2	83.9	1307	3600	2.768	2.232	7.870	1.752
833.6	521.1	1/30/02 10:48	1/30/02 16:16	7.8	430.9	93.7	1434	3600	2.656	2.142	8.998	2.004
979.5	667.0	1/30/02 16:32	1/31/02 7:23	7.9	550.7	119.7	1439	3600	2.622	2.115	9.147	2.037
1058.6	746.1	1/31/02 7:39	1/31/02 15:40	8.0	616.5	134.0	1381	3600	2.610	2.105	8.819	1.964
1108.2	795.7	1/31/02 15:56	1/31/02 20:55	8.0	658.8	143.2	1678	3600	2.778	2.240	10.067	2.242

CYCLE 15 - SIMULATED AN-105 PROCESSING

Effluent bottle tare	315.5	g			
Feed density	1.260	g/mL			
Bed volume in 0.25M NaOH	4.6	mL			
Technetium concentration	2.81E-04	M			
Potassium concentration	7.70E-02	M			
Hydroxide concentration	1.72	M			
Nitrate concentration	1.32	M			
Nitrite concentration	1.24	M			
Flow rate	15.0	mL/h or	3.3	BV/h	

VOA sample mass	29.326	g, taken from	2/7/02 11:11	to	2/7/02 12:47
SVOA sample mass	15.966	g, taken from	2/7/02 12:47	to	2/7/02 13:38

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	10931	180	6.361	573
Feed 2	11340	180	6.385	592
Feed 3	10923	180	6.361	572
Feed 4	10747	180	6.385	561
Feed 5	10710	180	6.361	561
Feed 6	10862	180	6.385	567
Feed 7	10728	180	6.361	562
Feed 8	10854	180	6.385	567
Average				569

Effluent bottle mass (g)	Mass of effluent in bottle & VOA/SVOA (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)	Total CPM in sample
437.4	121.9	2/4/02 9:15	2/4/02 15:55	14.51	101.7	22.1	11844	1800	6.277	4.982	62.896	11.046	394.80
808.7	493.2	2/4/02 16:15	2/5/02 11:55	14.98	401.5	87.3	31580	1800	6.449	5.118	163.229	28.666	1052.67
928.7	613.2	2/5/02 12:15	2/5/02 18:35	15.04	501.7	109.1	36058	1800	6.254	4.963	192.186	33.751	1201.93
1177.2	861.7	2/5/02 18:55	2/6/02 8:10	14.88	703.9	153.0	43775	1800	6.265	4.972	232.908	40.902	1459.17
1296.5	981.0	2/6/02 8:30	2/6/02 14:50	14.95	803.6	174.7	15853	600	6.233	4.947	254.340	44.666	1585.30
1414.2	1098.7	2/6/02 15:10	2/6/02 21:30	14.75	901.9	196.1	16258	600	6.226	4.941	261.131	45.859	1625.80
1660.5	1345.0	2/6/02 21:50	2/7/02 10:50	15.04	1102.3	239.6	18909	600	6.211	4.929	304.444	53.465	1890.90
1732.1	1461.9	2/7/02 11:10	2/7/02 17:30	14.65	1200.0	260.9	20707	600	6.244	4.956	331.630	58.240	2070.70
1777.1	1506.9	2/7/02 17:50	2/7/02 20:15	14.78	1241.0	269.8	10545	300	6.654	5.281	316.952	55.662	2109.00

Cycle 15 Elution

Effluent bottle tare 61 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
5.642	5.642	5.642	16.9	1.227	10613	360	0.088	0.088	20100	1.13E+05	113406	18.831	28.016
5.180	10.822	10.822	15.5	2.353	15928	360	0.094	0.094	28241	1.46E+05	259695	43.122	39.362
5.098	15.920	15.920	15.3	3.461	16872	600	0.086	0.086	19619	1.00E+05	359711	59.729	27.344
5.076	20.996	20.996	15.2	4.564	13176	600	0.093	0.093	14168	7.19E+04	431627	71.671	19.747
5.158	26.154	26.154	15.5	5.686	17111	1000	0.097	0.097	10584	5.46E+04	486219	80.736	14.752
5.077	31.231	31.231	15.2	6.789	7991	600	0.095	0.095	8412	4.27E+04	528925	87.827	11.724
5.141	36.372	36.372	15.4	7.907	17054	40	5.141	5.141	4976	2.56E+04	554506	92.074	6.935
5.068	41.440	41.440	15.2	9.009	12446	40	5.068	5.068	3684	1.87E+04	573175	95.174	5.134
5.155	46.595	46.595	15.5	10.129	13056	60	5.155	5.155	2533	1.31E+04	586231	97.342	3.530
5.036	51.631	51.631	15.1	11.224	33115	240	5.036	5.036	1644	8.28E+03	594510	98.717	2.291

Effluent bottle mass (g)	Mass of eluate in bottle & VOA/SVOA (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	C/C0	Total CPM in sample
65.5	4.5	2/8/02 4:10	2/8/02 4:30	13.5	61.2	13.309	27691	600	5.090	5.090	544.028	0.75826	2769
71.3	10.3	2/8/02 4:50	2/8/02 5:14	14.5	71.3	15.501	18466	1200	4.284	4.284	215.523	0.30039	923
76.3	15.3	2/8/02 5:34	2/8/02 5:50	18.8	81.4	17.690	13418	1800	5.070	5.070	88.218	0.12296	447
81.2	20.2	2/8/02 6:10	2/8/02 6:30	14.7	91.6	19.922	6391	1800	5.364	5.364	39.715	0.05535	213
86.2	25.2	2/8/02 6:50	2/8/02 7:10	15.0	101.8	22.120	3036	1800	5.115	5.115	19.785	0.02758	101
100.8	39.8	2/8/02 7:30	2/8/02 8:30	14.6	121.3	26.379	1254	1800	4.990	4.990	8.377	0.01168	42
115.4	54.4	2/8/02 8:50	2/8/02 9:50	14.6	140.8	30.618	566	1800	4.899	4.899	3.851	0.00537	19
130.3	69.3	2/8/02 10:10	2/8/02 11:10	14.9	160.7	34.925	361	1800	4.914	4.914	2.449	0.00341	12
144.9	83.9	2/8/02 11:30	2/8/02 12:30	14.6	180.2	39.176	341	1800	4.952	4.952	2.295	0.00320	11
159.5	98.5	2/8/02 12:50	2/8/02 13:50	14.6	199.7	43.413	186	1800	4.889	4.889	1.268	0.00177	6
174.3	113.3	2/8/02 14:10	2/8/02 15:10	14.8	219.4	47.694	116	1800	4.896	4.896	0.790	0.00110	4
174.3	137.4	2/8/02 15:30	2/8/02 17:07	14.9	248.3	53.982	1	1800	4.821	4.821	0.007	0.00001	0
174.3	157.7	2/8/02 17:27	2/8/02 18:50	14.7	273.6	59.473	147	1800	4.928	4.928	0.994	0.00139	5

SVOA sample mass 20.331 g, taken from 2/8/02 17:27 to 2/8/02 18:50

VOA sample mass 24.104 g, taken from 2/8/02 15:30 to 2/8/02 17:07

Cycle 15 Operational Details and Activity Balance

Data							
Density of 0.25M NaOH	1.0095	g/mL					
Density of 0.1M NaOH	1.0039	g/mL					
Regeneration							
Tare mass of effluent bottle	26.2	g					
Final mass of effluent bottle	59.1	g					
Mass of feed processed	32.9	g, or	32.6	mL			
Start date and time	2/4/02 7:12						
Finish date and time	2/4/02 9:12						
Average flow rate	15.0	mL/h or	3.3	BV/h			
Bed volume	4.6	mL					
Feed							
Mass of feed processed	1564	g or	1241	mL			
Average flow rate	15.0	mL/h or	3.3	BV/h			
Acivity concentration in feed	569.4	CPM/g					
Total activity processed	8.90E+05	CPM					
Simulated LAW Effluent							
Total acitvity in samples	13390.3	CPM					
Estimated activity in VOA/SVOA samples	11657.0	CPM					
Activity in bulk composite sample	11324	counts in	600	seconds of mass	5.024	g	
Composite bulk activity concentration	225.4	CPM/g					
Total mass of effluent	1462	g					
Total activity in bulk effluent	329441.8	CPM					
Total activity in simulated LAW effluent	3.54E+05	CPM, or	39.8%	of feed			
Feed Displacement							
Tare mass of effluent bottle	14.6	g					
Final mass of effluent bottle	48.6	g					
Mass of feed processed	34	g or	30.1	mL			
Start date and time	2/7/02 20:40						
Finish date and time	2/7/02 22:40						
Average flow rate	15.1	mL/h or	3.3	BV/h			
Activity in bulk composite sample	22611	counts in	600	seconds of mass	5.644	g	
Composite bulk activity concentration	400.6	CPM/g					
Total activity in effluent	1.36E+04	CPM, or	1.5%	of feed			
Water Rinse							
Tare mass of effluent bottle	14.4	g					
Final mass of effluent bottle	30	g					
Mass of feed processed	15.6	g, or	15.6	mL			
Start date and time	2/7/02 22:43						
Finish date and time	2/7/02 23:43						
Average flow rate	15.6	mL/h or	3.4	BV/h			
Activity in bulk composite sample	16322	counts in	300	seconds of mass	5.008	g	
Composite bulk activity concentration	651.8	CPM/g					
Total activity in effluent	1.02E+04	CPM, or	1.1%	of feed			
Elution							
Total mass of eluant processed	274	g					
Start date and time	2/8/02 0:50						
Finish date and time	2/8/02 19:10						
Average flow rate	14.92	mL/h, or	3.2	BV/h			
Total acitvity in samples	599063	CPM					
Activity in bulk composite sample	557	counts in	18000	seconds of mass	0.088	g	
Composite bulk activity concentration	21.1	CPM/g					
Total mass of effluent	150.437	g					
Total activity in bulk effluent	3174.0	CPM					
Total activity in effluent	6.02E+05	CPM, or	67.6%	of feed			
Total							
Total activity in all effluents	980515.6	CPM					
Total activity in feed	890409.2	CPM					
Activity recovery, as fraction of feed	110.1%						

CYCLE 16 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	316.6	g		
Effluent bottle B tare	295.2	g		
Feed density	1.240	mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.44E-04	M		
Potassium concentration	8.00E-03	M		
Hydroxide concentration	1.2	M		
Nitrate concentration	0.5	M		
Nitrite concentration	2.46	M		
Flow rate	32.8	mL/h or	7.1	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	16336	300	6.073	538
Feed 2	11598	240	6.124	473
Feed 3	12950	240	6.073	533
Feed 4	11675	240	6.124	477
Feed 5				
Average				505

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
604.1	287.5	2/11/02 9:30	2/11/02 16:11	34.7	237.3	51.6	2909	1800	6.722	5.421	14	2.855
1231.4	914.8	2/11/02 16:21	2/12/02 7:31	33.4	748.7	162.8	18361	1800	6.888	5.555	89	17.585
1446.1	1129.5	2/12/02 7:41	2/12/02 12:57	32.9	927.5	201.6	8452	600	6.981	5.630	121	23.961
1563.6	1247.0	2/12/02 13:07	2/12/02 15:59	33.1	1027.7	223.4	15035	900	6.730	5.427	149	29.475
467.7	2012.8	2/12/02 16:09	2/13/02 11:42	31.6	1651.0	358.9	20416	600	7.078	5.708	288	57.085
656.4	2201.5	2/13/02 11:52	2/13/02 16:42	31.5	1808.7	393.2	10574	300	6.950	5.605	304	60.220
1239.4	2784.5	2/13/02 16:52	2/14/02 7:05	33.1	2284.3	496.6	12385	300	6.636	5.352	373	73.872
1438.6	2983.7	2/14/02 7:15	2/14/02 12:09	32.8	2450.1	532.6	12836	300	6.480	5.226	396	78.405
1760.7	3305.8	2/14/02 12:19	2/14/02 20:21	32.3	2714.7	590.2	12930	300	6.003	4.841	431	85.255

CYCLE 17 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	130.6	g		
Feed density	1.290	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	6.40E-05	M		
Potassium concentration	8.00E-01	M		
Hydroxide concentration	2.2	M		
Nitrate concentration	1.36	M		
Nitrite concentration	0.58	M		
Flow rate	7.3	mL/h or	1.6	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	9628	600	2.545	378
Feed 2				
Feed 3				
Feed 4				
Feed 5				
Average				378

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
364.3	233.7	2/18/02 9:00	2/19/02 9:01	7.5	183.0	39.8	897	1800	2.309	1.790	12.949	3.423
602.1	471.5	2/19/02 9:17	2/20/02 9:48	7.5	369.3	80.3	934	1800	2.588	2.006	12.030	3.180
815.9	685.3	2/20/02 10:04	2/21/02 10:00	6.9	536.9	116.7	531	1800	2.348	1.820	7.538	1.993
903.7	773.1	2/21/02 10:16	2/21/02 20:04	6.9	606.8	131.9	628	1800	2.371	1.838	8.829	2.334

CYCLE 18 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	294.2	g		
Feed density	1.240	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.00E-04	M		
Potassium concentration	8.00E-03	M		
Hydroxide concentration	1.2	M		
Nitrate concentration	0.5	M		
Nitrite concentration	2.46	M		
Flow rate	7.2	mL/h or	1.6	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	14047	300	6.241	450
Feed 2	13920	300	6.241	446
Feed 3				
Feed 4				
Feed 5				
Average				448

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
488.5	194.3	2/25/02 9:20	2/26/02 8:15	6.8	158.6	34.5	536	1800	2.381	1.920	7.504	1.675
702.7	408.5	2/26/02 8:31	2/27/02 8:22	7.2	333.3	72.4	2044	1800	2.371	1.912	28.736	6.413
916.4	622.2	2/27/02 8:38	2/28/02 8:03	7.4	507.6	110.3	3705	1800	2.481	2.001	49.778	11.108
1026.3	732.1	2/28/02 8:19	2/28/02 20:24	7.3	598.1	130.0	4811	1800	2.339	1.886	68.562	15.300

CYCLE 19 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	293.2	g		
Effluent bottle B tare	294.8	g		
Feed density	1.290	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	4.70E-05	M		
Potassium concentration	8.00E-01	M		
Hydroxide concentration	2.2	M		
Nitrate concentration	1.36	M		
Nitrite concentration	0.58	M		
Flow rate	30.2	mL/h or	6.6	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	11925	600	6.520	183
Feed 2	12043	600	6.520	185
Feed 3	10381	600	6.614	157
Feed 4	10640	600	6.614	161
Feed 5				
Average				171

Effluent bottle mass (g)	Mass of feed processed (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
602.7	307.9	3/4/02 8:10	3/4/02 16:10	29.84	243.7	53.0	16513	3600	6.529	5.061	42.153	26.526
1211.8	917.0	3/4/02 16:20	3/5/02 7:55	30.30	721.0	156.7	20109	2400	6.540	5.070	76.869	48.372
1363.7	1068.9	3/5/02 8:05	3/5/02 11:55	30.72	843.9	183.5	10033	1200	6.694	5.189	74.940	47.158
1514.4	1219.6	3/5/02 12:05	3/5/02 15:55	30.48	966.0	210.0	11491	1200	6.715	5.205	85.562	53.842
2171.9	1877.1	3/5/02 16:05	3/6/02 9:50	28.71	1480.7	321.9	12889	1200	6.584	5.104	97.881	61.594
2329.3	2034.5	3/6/02 10:00	3/6/02 13:03	40.01	1607.7	349.5	13129	1200	6.415	4.973	102.330	64.394
2401.3	2106.5	3/6/02 13:13	3/6/02 15:03	30.44	1668.7	362.8	13628	1200	6.625	5.136	102.853	64.723
336.4	2149.7	3/6/02 15:13	3/6/02 16:24	28.30	1707.5	371.2	15222	1200	6.912	5.358	110.113	59.908
892.6	2705.9	3/6/02 16:34	3/7/02 7:00	29.87	2143.2	465.9	10516	900	5.776	4.478	121.376	66.036
1066.0	2879.3	3/7/02 7:10	3/7/02 11:40	29.87	2282.6	496.2	11253	900	6.416	4.974	116.926	63.615
1356.2	3169.5	3/7/02 11:50	3/7/02 19:19	30.06	2512.6	546.2	12080	900	6.501	5.040	123.878	67.397

CYCLE 20 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	292.8	g		
Feed density	1.260	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	2.97E-04	M		
Potassium concentration	7.70E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.32	M		
Nitrite concentration	1.24	M		
Flow rate	14.0	mL/h or	3.0	BV/h

VOA sample mass	29.432	g, taken from	3/14/02 8:22	to	3/14/02 10:05
SVOA sample mass	21.490	g, taken from	3/14/02 13:55	to	3/14/02 15:05

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	11338	300	6.261	362
Feed 2	11582	300	6.258	370
Feed 3	12209	300	6.261	390
Feed 4	11504	300	6.258	368
Feed 5	12209	300	6.261	390
Feed 6	12119	300	6.258	387
Feed 7	11172	300	6.261	357
Average				375
Feed 8 (5/9/02)	11665	600	6.261	186

Effluent bottle mass (g)	Mass of effluent in bottle & VOA/SVOA (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)	Total CPM in sample
408.2	115.4	3/11/02 9:20	3/11/02 16:10	13.40	96.0	20.9	1082	1800	5.569	4.420	6.476	1.728	36.07
674.4	381.6	3/11/02 16:30	3/12/02 7:50	13.78	312.1	67.8	1377	1800	6.089	4.833	7.538	2.011	45.90
739.2	446.4	3/12/02 8:10	3/12/02 12:00	13.42	368.0	80.0	1475	1800	5.599	4.444	8.781	2.342	49.17
849.5	556.7	3/12/02 12:20	3/12/02 18:40	13.82	460.0	100.0	2552	1800	5.694	4.519	14.940	3.985	85.07
1067.3	774.5	3/12/02 19:00	3/13/02 7:10	14.21	637.6	138.6	5033	1800	5.877	4.664	28.546	7.615	167.77
1193.1	900.3	3/13/02 7:30	3/13/02 14:40	13.93	742.0	161.3	7870	1800	5.812	4.613	45.136	12.040	262.33
1306.0	1013.2	3/13/02 15:00	3/13/02 21:20	14.15	836.4	181.8	10586	1800	6.006	4.767	58.752	15.672	352.87
1323.7	1030.9	3/13/02 21:40	3/13/02 22:40	14.05	854.7	185.8	9810	1800	5.415	4.298	60.388	16.108	327.00
1483.6	1190.8	3/13/02 23:00	3/14/02 8:02	14.05	986.2	214.4	12568	1800	5.806	4.608	72.155	19.247	418.93
1547.0	1283.6	3/14/02 8:22	3/14/02 13:35	13.87	1064.4	231.4	19878	1800	5.601	4.445	118.300	31.557	662.60
1585.6	1343.7	3/14/02 13:55	3/14/02 17:20	13.92	1116.4	242.7	20647	1800	5.450	4.325	126.281	33.686	688.23
1634.4	1392.5	3/14/02 17:40	3/14/02 20:20	13.93	1159.7	252.1	23387	1800	5.808	4.610	134.223	35.804	779.57

Cycle 20 Elution

Effluent bottle tare 61.4 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
4.560	4.560	4.560	13.68	0.991	8646	600	0.096	0.096	9006	4.11E+04	41069	7.181	19.067
4.792	9.352	9.352	14.376	2.033	30497	600	0.052	0.052	58648	2.81E+05	322110	56.322	124.162
4.737	14.089	14.089	14.211	3.063	13966	600	0.083	0.083	16827	7.97E+04	401817	70.259	35.623
4.812	18.901	18.901	14.436	4.109	12370	600	0.057	0.057	21702	1.04E+05	506246	88.519	45.944
4.814	23.715	23.715	14.442	5.155	13114	600	0.091	0.091	14411	6.94E+04	575621	100.650	30.509
4.785	28.500	28.500	14.355	6.196	12313	600	0.074	0.074	16639	7.96E+04	655239	114.571	35.226
4.938	33.438	33.438	14.814	7.269	316327	600	4.938	4.938	6406	3.16E+04	551555	96.442	13.562
4.723	38.161	38.161	14.169	8.296	144614	600	4.723	4.723	3062	1.45E+04	566017	98.970	6.482
4.754	42.915	42.915	14.262	9.329	32012	600	4.754	4.754	673	3.20E+03	569218	99.530	1.426
4.677	47.592	47.592	14.031	10.346	21953	1800	4.677	4.677	156	7.32E+02	569949	99.658	0.331

Re-analyzed samples 5/9/02

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass	Sample volume	Corrected CPM/mL	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
4.560	4.560	4.560	13.68	0.991	9628	1200	0.076	0.076	12745	5.81E+04	58118	10.162	26.982
4.792	9.352	9.352	14.376	2.033	31165	1200	0.095	0.095	33004	1.58E+05	216274	37.816	69.872
4.737	14.089	14.089	14.211	3.063	14262	1200	0.096	0.096	14946	7.08E+04	287074	50.196	31.642
4.812	18.901	18.901	14.436	4.109	13238	1200	0.063	0.063	21140	1.02E+05	388800	67.983	44.755
4.814	23.715	23.715	14.442	5.155	13393	1200	0.096	0.096	14036	6.76E+04	456367	79.798	29.714
4.785	28.500	28.500	14.355	6.196	12542	1200	0.095	0.095	13282	6.36E+04	519922	90.911	28.119
4.938	33.438	33.438	14.814	7.269									
4.723	38.161	38.161	14.169	8.296									
4.754	42.915	42.915	14.262	9.329									
4.677	47.592	47.592	14.031	10.346									

Effluent bottle mass (g)	Mass of eluant processed (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	C/C0	Total CPM in sample
66.4	5.0	3/15/02 4:05	3/15/02 4:25	15.00	57.4	12.470	1722	1800	4.771	4.771	12.031	0.02547	57
71.0	9.6	3/15/02 4:45	3/15/02 5:05	13.80	66.8	14.511	966	1800	4.787	4.787	6.727	0.01424	32
75.8	14.4	3/15/02 5:25	3/15/02 5:45	14.40	76.3	16.584	635	1800	4.736	4.736	4.469	0.00946	21
80.6	19.2	3/15/02 6:05	3/15/02 6:25	14.40	85.8	18.644	519	1800	4.675	4.675	3.701	0.00783	17
85.4	24.0	3/15/02 6:45	3/15/02 7:05	14.40	95.2	20.699	227	1800	4.655	4.655	1.625	0.00344	8
99.4	38.0	3/15/02 7:25	3/15/02 8:25	14.00	113.9	24.755	187	1800	4.656	4.656	1.339	0.00283	6
113.1	51.7	3/15/02 8:45	3/15/02 9:45	13.70	132.1	28.710	170	1800	4.493	4.493	1.261	0.00267	6
126.8	65.4	3/15/02 10:05	3/15/02 11:05	13.70	150.3	32.676	465	1800	4.543	4.543	3.412	0.00722	16
140.4	79.0	3/15/02 11:25	3/15/02 12:25	13.60	168.1	36.550	161	1800	4.220	4.220	1.272	0.00269	5
154.2	92.8	3/15/02 12:45	3/15/02 13:45	13.80	186.4	40.527	122	1800	4.494	4.494	0.905	0.00192	4
167.6	106.2	3/15/02 14:05	3/15/02 15:05	13.40	204.3	44.404	132	1800	4.437	4.437	0.992	0.00210	4
167.6	130.1	3/15/02 15:25	3/15/02 17:10	13.63	232.6	50.575	95	1800	4.534	4.534	0.698	0.00148	3
167.6	147.2	3/15/02 17:30	3/15/02 18:45	13.88	254.4	55.308	66	1800	4.626	4.626	0.476	0.00101	2

SVOA sample mass 17.143 g, taken from 3/15/02 17:30 to 3/15/02 6:45

VOA sample mass 23.853 g, taken from 3/15/02 15:25 to 3/15/02 17:10

Operational Details and Activity Balance for Cycle 20

Data						
Density of 0.25M NaOH	1.0095	g/mL				
Density of 0.1M NaOH	1.0039	g/mL				
Regeneration						
Tare mass of effluent bottle	26.4	g				
Final mass of effluent bottle	54.4	g				
Mass of feed processed	28	g, or	27.7	mL		
Start date and time	3/11/02 7:20					
Finish date and time	3/11/02 9:20					
Average flow rate	13.9	mL/h or	3.0	BV/h		
Bed volume	4.6	mL				
Feed						
Starting mass of effluent bottle	292.8	g				
Final mass of effluent bottle	1634.4	g				
Mass of all samples	119.648	g				
Mass of feed processed	1461	g or	1160	mL		
Average flow rate	14.0	mL/h or	3.0	BV/h		
Acivity concentration in feed	374.9	CPM/g				
Total activity processed	5.48E+05	CPM				
Simulated LAW Effluent						
Total acitvity in samples	3875.5	CPM				
Estimated activity in VOA/SVOA samples	4310.1	CPM				
Activity in bulk composite sample	6992	counts in	1800	seconds of mass	6.26	g
Composite bulk activity concentration	37.2	CPM/g				
Total mass of effluent	1342	g				
Total activity in bulk effluent	49949.2	CPM				
Total activity in simulated LAW effluent	5.81E+04	CPM, or	10.6%	of feed		
Feed Displacement						
Tare mass of effluent bottle	14.6	g				
Final mass of effluent bottle	48.7	g				
Mass of feed processed	34.1	g or	29.7	mL		
Start date and time	3/14/02 20:42					
Finish date and time	3/14/02 22:42					
Average flow rate	14.9	mL/h or	3.2	BV/h		
Activity in bulk composite sample	25344	counts in	1800	seconds of mass	5.737	g
Composite bulk activity concentration	147.3	CPM/g				
Total activity in effluent	5.02E+03	CPM, or	0.9%	of feed		
Water Rinse						
Tare mass of effluent bottle	14.4	g				
Final mass of effluent bottle	29.2	g				
Mass of feed processed	14.8	g, or	14.6	mL		
Start date and time	3/14/02 22:43					
Finish date and time	3/14/02 23:43					
Average flow rate	14.6	mL/h or	3.2	BV/h		
Activity in bulk composite sample	39253	counts in	1800	seconds of mass	5.074	g
Composite bulk activity concentration	257.9	CPM/g				
Total activity in effluent	3.82E+03	CPM, or	0.7%	of feed		
Elution						
Total mass of eluant processed	254.415	g				
Start date and time	3/15/02 0:45					
Finish date and time	3/15/02 19:05					
Average flow rate	13.88	mL/h, or	3.0	BV/h		
Total activity in samples	5.70E+05	CPM				
Activity in bulk composite sample	1814	counts in	1800	seconds of mass	5.02	g
Composite bulk activity concentration	12.0	CPM/g				
Total mass of effluent	147.196	g				
Total activity in bulk effluent	1773.0	CPM				
Total activity in effluent	5.72E+05	CPM, or	104.4%	of feed		
Total						
Total activity in all effluents	638877.5	CPM				
Total activity in feed	547796.3	CPM				
Activity recovery, as fraction of feed	116.6%					

CYCLE 21 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	128.3	g		
Feed density	1.290	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	6.25E-05	M		
Potassium concentration	8.00E-01	M		
Hydroxide concentration	2.2	M		
Nitrate concentration	1.36	M		
Nitrite concentration	0.58	M		
Flow rate	7.2	mL/h or	1.6	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	12658	10000	2.053	37
Feed 2				
Feed 3				
Feed 4				
Feed 5				
Average				37

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
317.9	189.6	3/18/02 9:30	3/19/02 8:04	6.51	148.9	32.4	3605	10000	2.487	1.928	8.697	23.510
535.1	406.8	3/19/02 8:20	3/20/02 7:12	7.36	319.3	69.4	3294	10000	2.564	1.988	7.708	20.837
802.0	673.7	3/20/02 7:28	3/21/02 10:40	7.61	528.2	114.8	6641	10000	2.569	1.991	15.510	41.927
912.8	784.5	3/21/02 10:56	3/21/02 22:40	7.32	616.0	133.9	10203	10000	2.566	1.989	23.857	64.490

CYCLE 22 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	293.7	g		
Effluent bottle B tare	293.8	g		
Feed density	1.290	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	2.89E-04	M		
Potassium concentration	8.00E-01	M		
Hydroxide concentration	1.2	M		
Nitrate concentration	1.36	M		
Nitrite concentration	1.6	M		
Flow rate	30.2	mL/h or	6.6	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	17922	600	6.514	275
Feed 2	17198	600	6.597	261
Feed 3	17175	600	6.514	264
Feed 4	16755	600	6.597	254
Feed 5				
Average				263

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
551.2	257.5	3/25/02 9:13	3/25/02 16:07	28.93	204.7	44.5	8699	2700	6.595	5.112	29	11.325
1135.5	841.8	3/25/02 16:17	3/26/02 7:15	30.26	662.6	144.1	28887	2700	6.411	4.970	100	38.687
2060.8	1767.1	3/26/02 7:25	3/27/02 7:16	30.07	1384.8	301.0	22557	1200	6.250	4.845	180	69.722
2188.8	1895.1	3/27/02 7:26	3/27/02 10:45	29.92	1488.9	323.7	17507	900	6.316	4.896	185	71.397
1089.3	2690.6	3/27/02 10:55	3/28/02 7:10	30.45	2110.6	458.8	13234	600	6.486	5.028	204	78.834
1253.7	2855.0	3/28/02 7:20	3/28/02 11:31	30.46	2243.1	487.6	14121	600	6.547	5.075	216	83.334
1361.3	2962.6	3/28/02 11:41	3/28/02 14:26	30.33	2331.6	506.9	13759	600	6.589	5.108	209	80.680
1593.4	3194.7	3/28/02 14:36	3/28/02 20:30	30.50	2516.6	547.1	15026	600	6.562	5.087	229	85.470

CYCLE 23 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	131.2	g		
Feed density	1.290	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	6.40E-05	M		
Potassium concentration	8.00E-01	M		
Hydroxide concentration	1.2	M		
Nitrate concentration	1.36	M		
Nitrite concentration	1.6	M		
Flow rate	7.3	mL/h or	1.6	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	12025	300	2.508	959
Feed 2	11891	300	2.508	948
Feed 3				
Feed 4				
Feed 5				
Average				954

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
317.6	186.4	4/1/02 12:36	4/2/02 8:34	7.24	146.4	31.8	3369	1800	2.496	1.935	44.992	4.718
533.4	402.2	4/2/02 8:50	4/3/02 7:50	7.27	315.9	68.7	4586	1800	2.799	2.170	54.615	5.727
754.4	623.2	4/3/02 8:06	4/4/02 8:03	7.15	489.4	106.4	7741	1800	2.789	2.162	92.518	9.702
906.9	775.7	4/4/02 8:19	4/5/02 0:28	7.32	610.9	132.8	12053	1800	4.289	3.325	93.674	9.823

CYCLE 24 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle A tare	293.7	g		
Feed density	1.290	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	6.18E-05	M		
Potassium concentration	8.00E-01	M		
Hydroxide concentration	1.2	M		
Nitrate concentration	1.36	M		
Nitrite concentration	1.6	M		
Flow rate	14.4	mL/h or	3.1	BV/h

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	14129	300	6.436	439
Feed 2	14148	300	6.436	440
Feed 3	13916	300	6.436	432
Feed 4	14040	300	6.436	436
Feed 5				
Average				437

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)
729.7	436.0	4/8/02 9:07	4/9/02 7:00	15.44	342.7	74.5	7717	1800	6.068	4.704	42.392	9.704
893.2	599.5	4/9/02 7:20	4/9/02 16:15	14.21	473.0	102.8	9774	1800	4.606	3.571	70.734	16.191
1328.8	1035.1	4/9/02 16:35	4/10/02 16:40	14.02	815.1	177.2	11750	900	5.718	4.433	136.994	31.359
1581.9	1288.2	4/10/02 17:00	4/11/02 7:11	13.83	1015.9	220.8	14765	900	5.927	4.595	166.076	38.016
1660.5	1366.8	4/11/02 7:31	4/11/02 11:52	14.01	1081.5	235.1	10139	600	5.981	4.636	169.520	38.804
1691.8	1398.1	4/11/02 12:12	4/11/02 14:00	13.48	1110.4	241.4	12006	900	5.988	4.642	133.667	30.597
1795.3	1501.6	4/11/02 14:20	4/11/02 20:00	14.16	1195.3	259.8	12654	900	6.008	4.657	140.413	32.141

CYCLE 25 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	326.8	g			
Feed density	1.250	g/mL			
Bed volume in 0.25M NaOH	4.6	mL			
Technetium concentration	2.84E-04	M			
Potassium concentration	8.30E-02	M			
Hydroxide concentration	1.72	M			
Nitrate concentration	1.34	M			
Nitrite concentration	1.25	M			
Flow rate	14.2	mL/h or	3.1	BV/h	

VOA sample mass	28.216	g, taken from	4/18/02 15:39	to	4/18/02 17:12
SVOA sample mass	22.285	g, taken from	4/18/02 14:25	to	4/18/02 15:39

	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/g)
Feed 1	41498	300	6.351	1307
Feed 2	24595	180	6.480	1265
Feed 3	24305	180	6.351	1276
Feed 4	25043	180	6.480	1288
Feed 5	24289	180	6.351	1275
Feed 6	24916	180	6.480	1282
Feed 7	24084	180	6.351	1264
Feed 8	24669	180	6.480	1269
Average				1278

Effluent bottle mass (g)	Mass of effluent in bottle & VOA/SVOA (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/g)	C/C0 (%)	Total CPM in sample
446.4	119.6	4/15/02 9:07	4/15/02 16:15	13.41	100.6	21.9	12514	1800	6.164	4.931	68	5.294	417
700.0	373.2	4/15/02 16:35	4/16/02 7:00	14.07	308.3	67.0	36330	1800	5.976	4.781	203	15.854	1211
815.2	488.4	4/16/02 7:20	4/16/02 13:50	14.18	405.2	88.1	16278	600	5.908	4.726	276	21.556	1628
891.9	565.1	4/16/02 14:10	4/16/02 18:30	14.16	471.3	102.5	13832	420	5.980	4.784	330	25.852	1976
957.2	630.4	4/16/02 18:50	4/16/02 22:30	14.25	528.2	114.8	13735	420	5.848	4.678	336	26.250	1962
1102.5	775.7	4/16/02 22:50	4/17/02 7:00	14.23	649.2	141.1	18389	420	5.923	4.738	444	34.700	2627
1217.6	890.8	4/17/02 7:20	4/17/02 13:50	14.17	746.0	162.2	15035	300	5.843	4.674	515	40.263	3007
1292.7	965.9	4/17/02 14:10	4/17/02 18:30	13.86	811.1	176.3	17333	300	6.322	5.058	548	42.900	3467
1357.8	1031.0	4/17/02 18:50	4/17/02 22:30	14.20	867.9	188.7	16930	300	5.858	4.686	578	45.222	3386
1504.6	1177.8	4/17/02 22:50	4/18/02 7:08	14.15	990.1	215.2	19974	300	5.974	4.779	669	52.317	3995
1623.3	1296.5	4/18/02 7:28	4/18/02 14:05	14.35	1089.9	236.9	13141	180	6.071	4.857	722	56.449	4380
1677.7	1401.4	4/18/02 14:25	4/18/02 20:10	14.59	1178.7	256.2	14072	180	6.114	4.891	767	60.023	4691

Cycle 25 Elution

Effluent bottle tare 61.4 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample volume (mL)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
5.698	5.698	5.698	17.094	1.239	55844	900	0.096	0.096	38620	2.20E+05	220055	15.951	24.172
4.753	10.451	10.451	14.259	2.272	31811	300	0.095	0.095	66971	3.18E+05	538366	39.025	41.916
4.766	15.217	15.217	14.298	3.308	23048	300	0.097	0.097	47522	2.26E+05	764854	55.443	29.743
4.813	20.030	20.030	14.439	4.354	18995	300	0.097	0.097	39165	1.89E+05	953355	69.107	24.513
4.806	24.836	24.836	14.418	5.399	15294	300	0.097	0.097	31534	1.52E+05	1104907	80.093	19.737
4.703	29.539	29.539	14.109	6.422	11665	300	0.082	0.082	28451	1.34E+05	1238713	89.793	17.807
4.737	34.276	34.276	14.211	7.451	137349	300	4.737	4.737	5799	2.75E+04	1266183	91.784	3.630
4.692	38.968	38.968	14.076	8.471	164639	300	4.692	4.692	7018	3.29E+04	1299111	94.171	4.392
4.701	43.669	43.669	14.103	9.493	120839	300	4.701	4.701	5141	2.42E+04	1323279	95.923	3.218
4.724	48.393	48.393	14.172	10.520	81307	300	4.724	4.724	3442	1.63E+04	1339540	97.101	2.155

Effluent bottle mass (g)	Mass of eluate in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Counts	Count time (s)	Sample mass (g)	Sample activity (CPM/mL)	C/C0	Total CPM in sample
65.1	3.7	4/19/02 3:50	4/19/02 4:10	11.10	56.8	12.337	31177	300	4.657	1338.931	0.83803	6235
69.7	8.3	4/19/02 4:30	4/19/02 4:50	13.80	66.0	14.337	12285	300	4.601	534.014	0.33424	2457
74.1	12.7	4/19/02 5:10	4/19/02 5:30	13.20	75.0	16.310	10442	600	4.676	223.311	0.13977	1044
78.6	17.2	4/19/02 5:50	4/19/02 6:10	13.50	84.1	18.291	14423	1800	4.610	104.288	0.06527	481
83.1	21.7	4/19/02 6:30	4/19/02 6:50	13.50	93.3	20.275	6600	1800	4.629	47.526	0.02975	220
97.1	35.7	4/19/02 7:10	4/19/02 8:10	14.00	111.9	24.334	1491	1800	4.670	10.642	0.00666	50
111.3	49.9	4/19/02 8:30	4/19/02 9:30	14.20	130.8	28.440	393	1800	4.689	2.794	0.00175	13
125.3	63.9	4/19/02 9:50	4/19/02 10:50	14.00	149.4	32.483	259	1800	4.598	1.878	0.00118	9
139.4	78.0	4/19/02 11:10	4/19/02 12:10	14.10	168.1	36.551	269	1800	4.612	1.944	0.00122	9
153.2	91.8	4/19/02 12:30	4/19/02 13:30	13.80	186.4	40.525	187	1800	4.482	1.391	0.00087	6
167.3	105.9	4/19/02 13:50	4/19/02 14:50	14.10	205.2	44.609	99	1800	4.683	0.705	0.00044	3
167.3	129.0	4/19/02 15:10	4/19/02 16:49	14.01	232.9	50.640	358	1800	4.630	2.577	0.00161	12
167.3	152.2	4/19/02 17:09	4/19/02 18:50	13.76	260.4	56.601	172	1800	4.253	1.348	0.00084	6

SVOA sample mass 23.168 g, taken from 4/19/02 17:09 to 4/19/02 18:50

VOA sample mass 23.113 g, taken from 4/19/02 15:10 to 4/19/02 16:49

Cycle 25 Operational Details and Activity Balance

Data							
Density of 0.25M NaOH	1.0095	g/mL					
Density of 0.1M NaOH	1.0039	g/mL					
Regeneration							
Tare mass of effluent bottle	25.3	g					
Final mass of effluent bottle	54.3	g					
Mass of feed processed	29	g, or	28.7	mL			
Start date and time	4/15/02 7:07						
Finish date and time	4/15/02 9:07						
Average flow rate	14.4	mL/h or	3.1	BV/h			
Bed volume	4.6	mL					
Feed							
Starting mass of feed bottle	1946	g					
Final mass of feed bottle	453.1	g					
Mass of feed processed	1493	g or	1185	mL			
Average flow rate	14.2	mL/h or	3.1	BV/h			
Feed activity concentration	1278.2	CPM/g					
Total activity processed	1.91E+06	CPM					
Simulated LAW Effluent							
Total acitvity in samples	32746.5	CPM					
Estimated activity in VOA/SVOA samples	26463.3						
Activity in bulk composite sample	69693	counts in	1800	seconds of mass	6.198	g	
Composite bulk activity concentration	374.8	CPM/g					
Total mass of effluent	1351	g					
Total activity in bulk effluent	506336.8	CPM					
Total activity in simulated LAW effluent	5.66E+05	CPM, or	29.6%	of feed			
Feed Displacement							
Tare mass of effluent bottle	14.7	g					
Final mass of effluent bottle	47.5	g					
Mass of feed processed	32.8	g or	28.4	mL			
Start date and time	4/18/02 20:30						
Finish date and time	4/18/02 22:30						
Average flow rate	14.2	mL/h or	3.1	BV/h			
Activity in bulk composite sample	73470	counts in	900	seconds of mass	5.745	g	
Composite bulk activity concentration	852.6	CPM/g					
Total activity in effluent	2.80E+04	CPM, or	1.5%	of feed			
Water Rinse							
Tare mass of effluent bottle	14.4	g					
Final mass of effluent bottle	28.7	g					
Mass of feed processed	14.3	g, or	14.0	mL			
Start date and time	4/18/02 22:31						
Finish date and time	4/18/02 23:31						
Average flow rate	14.0	mL/h or	3.0	BV/h			
Activity in bulk composite sample	102983	counts in	900	seconds of mass	5.107	g	
Composite bulk activity concentration	1344.3	CPM/g					
Total activity in effluent	1.92E+04	CPM, or	1.0%	of feed			
Elution							
Total mass of eluant processed	260	g					
Start date and time	4/19/02 0:30						
Finish date and time	4/19/02 19:10						
Average flow rate	13.95	mL/h, or	3.0	BV/h			
Total acitvity in samples	1.35E+06	CPM					
Activity in bulk composite sample	29530	counts in	1800	seconds of mass	5.088	g	
Composite bulk activity concentration	193.5	CPM/g					
Total mass of effluent	152.181	g					
Total activity in bulk effluent	29441.2	CPM					
Total activity in simulated LAW effluent	1.38E+06	CPM, or	72.3%	of feed			
Total							
Total activity in all effluents	1992261.1	CPM					
Total activity in feed	1908187.3	CPM					
Activity recovery, as fraction of feed	104.4%						

CYCLE 26 - SIMULATED AN-105 LAW PROCESSING

Effluent bottle tare	299	g		
Feed density	1.250	g/mL		
Bed volume in 0.25M NaOH	4.6	mL		
Technetium concentration	2.84E-04	M		
Potassium concentration	9.51E-02	M		
Hydroxide concentration	1.72	M		
Nitrate concentration	1.23	M		
Nitrite concentration	1.21	M		
Flow rate	14.7	mL/h or	3.2	BV/h

	Count rate (CPM)	Count time (seconds)	Sub-sample mass (g)	Sample activity (CPM/g)
Feed 1	97427	180	0.1209	805848
Feed 2	97674	180	0.1210	807223
Average				806535

Effluent bottle mass (g)	Mass of effluent in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of feed processed (mL)	Bed volumes of feed processed	Sample mass (g)	Sub-sample mass (g)	Count time (seconds)	Count rate (CPM)	Sample activity (CPM/g)	C/C0 (%)	Total CPM in sample
412.0	113.0	5/13/02 9:34	5/13/02 16:20	13.36	95.1	20.7	5.854	0.1216	180	63	515	0.064	3017
678.5	379.5	5/13/02 16:40	5/14/02 7:53	14.01	313.2	68.1	6.156	0.1207	180	794	6581	0.816	40513
769.3	470.3	5/14/02 8:13	5/14/02 13:09	14.72	390.7	84.9	6.073	0.1201	180	1794	14935	1.852	90699
851.2	552.2	5/14/02 13:29	5/14/02 18:00	14.51	461.6	100.4	6.746	0.1202	180	3078	25605	3.175	172728
927.8	628.8	5/14/02 18:20	5/14/02 22:30	14.71	527.9	114.8	6.206	0.1194	180	4827	40424	5.012	250874
1098.7	799.7	5/14/02 22:50	5/15/02 7:52	15.14	669.7	145.6	6.374	0.1194	180	9862	82596	10.241	526469
1184.0	885.0	5/15/02 8:12	5/15/02 12:48	14.83	743.0	161.5	6.330	0.1226	180	13689	111656	13.844	706781
1278.4	979.4	5/15/02 13:08	5/15/02 18:00	15.52	823.5	179.0	6.247	0.1201	180	17296	144016	17.856	899667
1355.5	1056.5	5/15/02 18:20	5/15/02 22:30	14.80	890.2	193.5	6.216	0.1222	180	20957	171495	21.263	1066013
1508.7	1209.7	5/15/02 22:50	5/16/02 7:38	13.93	1017.8	221.3	6.406	0.1175	180	26865	228636	28.348	1464641
1610.6	1311.6	5/16/02 7:58	5/16/02 13:01	16.14	1104.5	240.1	6.372	0.1187	180	32205	271312	33.639	1728798
1685.3	1386.3	5/16/02 13:21	5/16/02 17:00	16.37	1169.3	254.2	6.318	0.1195	180	35178	294374	36.499	1859855
1746.1	1447.1	5/16/02 17:20	5/16/02 20:32	15.20	1223.5	266.0	7.019	0.1174	180	37745	321508	39.863	2256662

Cycle 26 Elution

Effluent bottle tare 45.6 g

Eluant mass processed (g)	Cumulative eluant mass processed (g)	Cumulative eluant volume processed (mL)	Volume flow rate (mL/hr)	Bed volumes of eluant processed	Sample mass in diluent (g)	Diluent and sample mass (g)	Diluted sub-sample mass (g)	Count rate (CPM)	Sample activity (CPM/mL)	Total CPM in collected fraction	Cumulative CPM collected	Cumulative % of Tc collected	C/C0
5.774	5.774	5.774	17.322	1.255	0.097	5.144	0.099	78429	42271815	2.44E+08	244077460	20.884	41.929
4.903	10.677	10.677	14.709	2.321	0.098	5.151	0.099	116892	62434364	3.06E+08	550193146	47.077	61.928
5.136	15.813	15.813	15.408	3.438	0.099	5.132	0.099	61428	32456033	1.67E+08	716887334	61.340	32.193
5.099	20.912	20.912	15.297	4.546	0.098	5.144	0.100	53062	27963391	1.43E+08	859472666	73.541	27.737
5.184	26.096	26.096	15.552	5.673	0.099	5.157	0.100	43696	22923694	1.19E+08	978309096	83.709	22.738
5.156	31.252	31.252	15.468	6.794	0.098	5.115	0.088	30107	17912481	9.24E+07	1070665851	91.611	17.767
5.087	36.339	36.339	15.261	7.900			0.097	925460	9540825	4.85E+07	1119200026	95.764	9.464
5.152	41.491	41.491	15.456	9.020			0.095	503776	5302905	2.73E+07	1146520594	98.102	5.260
5.127	46.618	46.618	15.381	10.134			0.097	240880	2483299	1.27E+07	1159252468	99.191	2.463
5.055	51.673	51.673	15.165	11.233			0.093	107947	1158230	5.85E+06	1165107319	99.692	1.149

Effluent bottle mass (g)	Mass of eluate in bottle (g)	Start time	Finish time	Volume flow rate (mL/hr)	Volume of eluant processed (mL)	Bed volumes of eluant processed	Sample mass (g)	Sub-sample mass (g)	Count time (seconds)	Count rate (CPM)	Sample activity (CPM/mL)	C/C0
50.4	4.8	5/17/02 4:15	5/17/02 4:35	14.40	61.7	13.407	5.197	0.0927	180	26509	285965.480	0.28365
55.6	10.0	5/17/02 4:55	5/17/02 5:15	15.60	71.9	15.637	5.062	0.0958	180	5501	57425.157	0.05696
60.7	15.1	5/17/02 5:35	5/17/02 5:55	15.30	82.2	17.874	5.189	0.0961	180	1278	13295.213	0.01319
65.5	19.9	5/17/02 6:15	5/17/02 6:35	14.40	92.2	20.038	5.153	0.0991	180	832	8395.560	0.00833
70.6	25.0	5/17/02 6:55	5/17/02 7:15	15.30	102.3	22.230	4.983	0.0931	180	424	4554.243	0.00452
85.6	40.0	5/17/02 7:35	5/17/02 8:35	15.00	122.2	26.569	4.961	0.0989	180	357	3606.370	0.00358
100.3	54.7	5/17/02 8:55	5/17/02 9:55	14.70	141.8	30.836	4.927	0.0968	180	160	1652.893	0.00164
114.8	69.2	5/17/02 10:15	5/17/02 11:15	14.50	161.1	35.022	4.758	0.0960	180	137	1430.521	0.00142
130.1	84.5	5/17/02 11:35	5/17/02 12:38	14.57	181.2	39.401	4.842	0.0961	180	112	1165.453	0.00116
144.2	98.6	5/17/02 12:58	5/17/02 13:55	14.84	200.1	43.494	4.728	0.0980	180	123	1258.469	0.00125
158.9	113.3	5/17/02 14:15	5/17/02 15:15	14.70	219.7	47.751	4.883	0.0968	180	89	919.421	0.00091
173.4	127.8	5/17/02 15:35	5/17/02 16:35	14.50	239.1	51.980	4.950	0.0967	180	82	844.571	0.00084
188.1	142.5	5/17/02 16:55	5/17/02 17:55	14.70	258.7	56.243	4.912	0.0966	180	80	828.157	0.00082
198.5	152.9	5/17/02 18:15	5/17/02 18:55	15.60	274.0	59.570	4.906	0.0947	180	57	601.901	0.00060

Cycle 26 Operational Details and Activity Balance

Data						
Density of 0.25M NaOH	1.0095	g/mL				
Density of 0.1M NaOH	1.0039	g/mL				
Regeneration						
Tare mass of effluent bottle	14.2	g				
Final mass of effluent bottle	46.4	g				
Mass of feed processed	32.2	g, or	31.9	mL		
Start date and time	5/13/02 7:18					
Finish date and time	5/13/02 9:34					
Average flow rate	14.1	mL/h or	3.1	BV/h		
Bed volume	4.6	mL				
Feed						
Starting mass of feed bottle	2058	g				
Final mass of feed bottle	515	g				
Mass of feed processed	1543	g or	1225	mL		
Average flow rate	14.7	mL/h or	3.2	BV/h		
Feed activity concentration	806535.5	CPM/g				
Total activity processed	1.24E+09	CPM				
Simulated LAW Effluent						
Total acitvity in samples	11066717.8	CPM				
Activity in bulk composite sample	11278.3	counts in	60	seconds of mass	0.116	g
Composite bulk activity concentration	97226.7	CPM/g				
Total mass of effluent	1447	g				
Total activity in bulk effluent	140696792.5	CPM				
Total activity in simulated LAW effluent	1.52E+08	CPM, or	12.2%	of feed		
Feed Displacement						
Tare mass of effluent bottle	14.6	g				
Final mass of effluent bottle	49.3	g				
Mass of feed processed	34.7	g or	31.0	mL		
Start date and time	5/16/02 20:52					
Finish date and time	5/16/02 22:52					
Average flow rate	15.5	mL/h or	3.4	BV/h		
Activity in bulk composite sample	49840.3	counts in	60	seconds of mass	0.112	g
Composite bulk activity concentration	445002.7	CPM/g				
Total activity in effluent	1.54E+07	CPM, or	1.2%	of feed		
Water Rinse						
Tare mass of effluent bottle	14.6	g				
Final mass of effluent bottle	29.8	g				
Mass of feed processed	15.2	g, or	16.0	mL		
Start date and time	5/16/02 22:54					
Finish date and time	5/16/02 23:54					
Average flow rate	16.0	mL/h or	3.5	BV/h		
Activity in bulk composite sample	122489	counts in	60	seconds of mass	0.0951	g
Composite bulk activity concentration	1288002.1	CPM/g				
Total activity in effluent	1.96E+07	CPM, or	1.6%	of feed		
Elution						
Total mass of eluant processed	274	g				
Start date and time	5/17/02 0:55					
Finish date and time	5/17/02 19:15					
Average flow rate	14.95	mL/h, or	3.2	BV/h		
Total acitvity in samples	1.17E+09	CPM				
Activity in bulk composite sample	2359.33	counts in	60	seconds of mass	0.1003	g
Composite bulk activity concentration	23522.7	CPM/g				
Total mass of effluent	152.9	g				
Total activity in bulk effluent	3596625.7	CPM				
Total activity in simulated LAW effluent	1.17E+09	CPM, or	93.9%	of feed		
Total						
Total activity in all effluents	1355486679.8	CPM				
Total activity in feed	1244484236.8	CPM				
Activity recovery, as fraction of feed	108.9%					

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