Technetium Sorption Media Review

Author Name:
J.B. Duncan, S.E. Kelly, R.A. Robbins, R.D. Adams, M.A. Thorson / C.C. Haass
Washington River Protection Solutions, LLC / AEM Consulting, LLC
Richland, WA 99352
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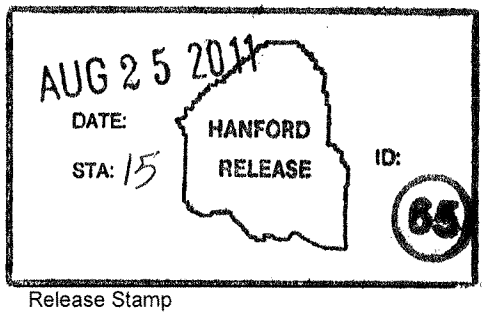
Abstract: This report presents information and references to aid in the selection of 99Tc sorption media for feasibility studies regarding the removal of 99Tc from Hanford's low activity waste. The report contains literature search material for sorption media (including ion exchange media) for the most tested media to date, including SuperLig 639, Reillex HPQ, TAM (Kruion), Purolite A520E and A530E, and Dowex 1X8.



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Technetium Sorption Media Review

Prepared for the U.S. Department of Energy

Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy

Office of River Protection under Contract DE-AC27-08RV14800

P.O. Box 850
Richland, Washington 99352

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF TERMS

^{99}Tc	Technetium-99 (99-Tc, Tc-99)
Al^{+3}	Aluminum
BNFL	British Nuclear Fuels, Ltd
BNI	Bechtel National, Inc.
BV	Bed volume
CC	Complex Concentrate
Ci	Curie
Cl	Chlorine
cP	Centipoise
Cr	Chromium
CV	Column volume
DF	Decontamination factor
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DSSF	Double-shell Slurry Feed
DST	Double-shell tank
Ecology	Washington State Department of Ecology
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
Eq	Equivalents
ES	Energy*Solutions*
ETF	Effluent Treatment Facility
F	Fluorine
FY	Fiscal year
g	Gram
gmol	Gram-mole
HFFACO	Hanford Federal Facility Agreement and Consent Order
HLW	High-level waste
hr	Hour
IDF	Integrated Disposal Facility
ILAW	Immobilized low-activity waste
IX	Ion exchange
K^+	Potassium
K_d	Distribution coefficient
λ	Column distribution ratio
LAW	Low-activity waste
LLW	Low level waste
M	Molar (gram-moles/liter)
ml	Milliliter
MT	Metric-tons
MVST	Melton Valley Storage Tanks
Na^+	Sodium
NEPA	National Environmental Protection Act
NO_2^-	Nitrite
NO_3^-	Nitrate

NPH	Normal paraffin hydrocarbon
OH^-	Hydroxide
ORNL	Oak Ridge National Laboratory
ORP	U.S. Department of Energy, Office of River Protection
PFD	Process Flow Diagram
PNNL	Pacific Northwest National Laboratory
PO_4^{-3}	Phosphate
PEG	Polyethylene glycol
PT	Pretreatment
ρ_b	Bulk density
R	Radiation absorbed dose (Rad)
Re	Rhenium
RPP	River Protection Project
SME	Subject Matter Expert
SO_4^{-2}	Sulfate
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SST	Single-shell tank
TBP	Tri-butyl phosphate
TcO_4^-	Pertechnetate
TPA	Tri-Party Agreement
TRL	Technology Readiness Level
TWRS	Tank Waste Remediation System
WRPS	Washington River Protection Solutions, LLC
WTP	Waste Treatment and Immobilization Plant

1 INTRODUCTION AND BACKGROUND

The U.S. Department of Energy (DOE), Office of River Protection (ORP) is responsible for management and completion of the River Protection Project (RPP) mission, which comprises both the Hanford Site tank farms and the Waste Treatment and Immobilization Plant (WTP). The RPP mission is to store, retrieve and treat Hanford's tank waste; store and dispose of treated wastes; and close the tank farm waste management areas and treatment facilities in a safe, environmentally compliant, cost-effective and energy-effective manner.

The Hanford Federal Facility Agreement and Consent Order (HFFACO or Tri-Party Agreement [TPA]) requires DOE to complete the RPP tank waste treatment mission by September 30, 2047. A key aspect of implementing that mission is to construct and operate the WTP (ORP-11242, Rev. 5, *River Protection Project System Plan)*. The WTP is a multi-facility plant that will separate and immobilize the tank waste for final disposition. The WTP Low-Activity Waste (LAW) Vitrification Facility is sized to treat about 40 to 50% of the approximately 60,000 to 80,000 metric tons (MT) of tank farm sodium waste requiring treatment by 2047.

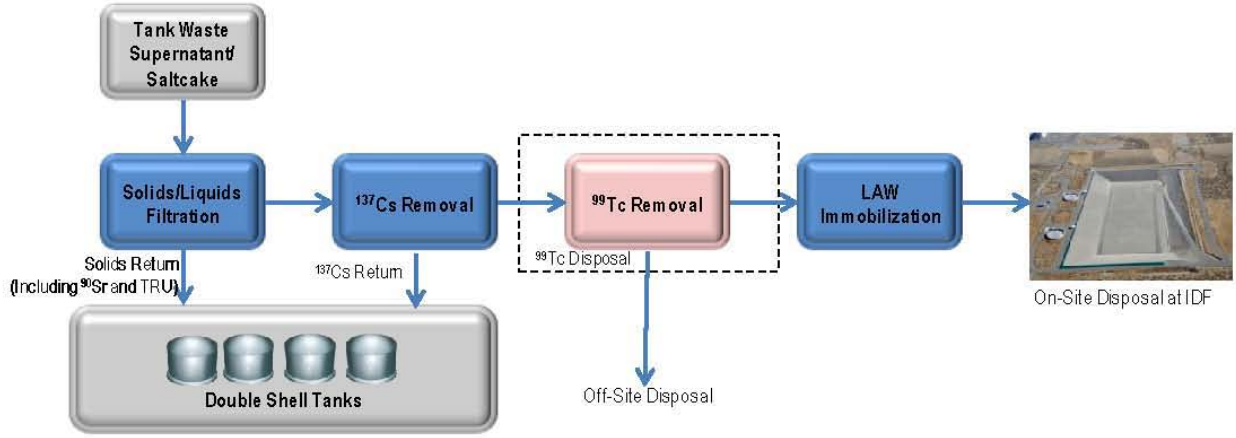
The RPP work scope is currently performed by two primary contractors: Washington River Protection Solutions (WRPS), the Tank Operations Contractor (TOC); and Bechtel National, Inc. (BNI), the WTP Construction and Commissioning Contractor. Washington River Protection Solutions is responsible for the construction, operation and maintenance activities necessary to store, retrieve and transfer tank wastes; provide supplemental pretreatment for tank waste; and provide second LAW treatment, storage and/or disposal of immobilized product and secondary waste streams. Bechtel National, Inc. is responsible for the design, construction, and commissioning of a WTP Pretreatment Facility, two vitrification facilities (one for high-level waste [HLW] and one for LAW), a dedicated analytical and radiochemical laboratory and supporting facilities to convert radioactive tank wastes into glass for long-term storage or final disposal.

The TOC will be responsible for WTP operations and decommissioning. The ORP defined the interface between the two major contractors in a series of interface documents. The primary waste interface document is 24590-WTP-ICD-MG-01-019, Rev. 4, *ICD-19 – Interface Control Document (ICD) for Waste Feed.* Iterative updates to 24590-WTP-ICD-MG-01-019 are anticipated as new information is generated.

The current RPP baseline plan (ORP-11242, Rev 5) assumes deployment of a supplemental treatment capability, with net capacity calculated such that LAW treatment does not drive the mission duration (approximately 60% of the LAW tank waste). The addition of a supplemental treatment capability, including pretreatment (if needed) and immobilization, results in a system where HLW treatment capacity is the exclusive driver for completion of the RPP mission. Without additional LAW treatment capacity, the mission would extend an additional 40 years beyond fiscal year (FY) 2047.

Figure 1-1 depicts the Supplemental Treatment Project configured to be deployed in the tank farms.

Figure 1-1. Simplified Supplemental Treatment Flow Diagram



Supplemental treatment refers to the pretreatment of supernatant (liquid) wastes from the double-shell tanks (DSTs), including dissolved saltcake retrieved from SSTs to the DSTs. Supplemental treatment includes two basic unit operations. The first operation removes insoluble constituents including actinides and strontium 90 (^{90}Sr). The separated solids will then follow the HLW treatment pathway. The second operation removes soluble cesium (focused on ^{137}Cs) from the liquid wastes. Provided the degree of removal of the actinides, ^{90}Sr, and ^{137}Cs is sufficient, the wastes can be solidified as immobilized LAW (ILAW). A Waste Incidental to Reprocessing (WIR) determination per DOE Manual 435.1-1, *Radioactive Waste Management Manual*, will be required to classify the wastes as LAW.

The unit operations for tank farm LAW pretreatment are similar to those for LAW pretreatment in the WTP. In the WTP, however, wastes are fed back into the system rather than returned to the DSTs as they would be in the tank farm case. Supplemental treatment technologies currently under consideration include crossflow filtration, rotary microfiltration, elutable spherical resorcinol formaldehyde ion exchange, and non-elutable crystalline silicotitanate ion exchange.

The WRPS Immobilization Project (Project No. T4S05) is responsible for identifying and implementing a process flowsheet that immobilizes the LAW fraction of Hanford's SST and DST waste. The product of the flowsheet, ILAW, will be one of three waste forms:

- Borosilicate glass;
- Mineral and binder;
- Grout.

The DOE plans to dispose of Hanford's ILAW as a mixed low-level waste (MLLW) by land disposal. It is the DOE's responsibility to ensure a cost effective approach is implemented.

Following pretreatment, where the SST and DST wastes are split into LAW and HLW fractions, technetium 99 (^{99}Tc) will be the limiting component for long-term disposal performance for immobilized LAW. Reducing the ^{99}Tc loading of the LAW stream has a direct impact on the leachability index of the immobilization product and the potential to use technologies that have difficulty incorporating and/or retaining ^{99}Tc.

The goal of this ^{99}Tc sorption media review is to present information and references to aid in the selection of a sorption media for feasibility studies for a ^{99}Tc removal system. The review does not select a specific sorption media with the expectation that it will be implemented into a ^{99}Tc removal system. All work performed to date regarding the capture of ^{99}Tc has shown that only ^{99}Tc in the pertechnetate form, TcO_4^- (where ^{99}Tc is in the +7 (VII) valence state), can be captured via sorption.

Feed to the Immobilization Project facility(s) is planned to be split roughly equally between the WTP and an additional treatment facility, to be provided by the Treatment Project (WRPS Project No. T4S01). Immobilized LAW will be disposed at a near-surface disposal site, such as the Integrated Disposal Facility (IDF) at Hanford. Due to past waste handling practices, leaking SSTs and the mobility of ^{99}Tc, ^{99}Tc retention is a major factor in the selection of an ILAW form. All of the waste forms under investigation as ILAW forms benefit from ^{99}Tc removal.

Employment of a sorption media has been selected as the best technology for removal of ^{99}Tc from the LAW immobilization feed stream. The goal of this review is to:

- Define ^{99}Tc ion exchange sorption media selection criteria required for implementation, including;
    - Characteristics;
    - Weighting for each characteristic;
- Identify potential ion exchange media, separated into two categories;
    - Elutable;
    - Non-elutable;
- Evaluate and rank sorption media using the defined characteristics and corresponding weighting.

The results from this review will aid in the development of a preliminary ^{99}Tc removal flowsheet to support the four immobilization technologies and a preferred waste disposal option.

2 BASICS OF SORPTION MEDIA, TECHNETIUM, LOW-ACTIVITY WASTE, AND COLUMNS

This section contains basic information regarding the properties of sorption media and technetium.

2.1 ION EXCHANGE / RESIN / SORBENT MEDIA / SORPTION MEDIA

For the purpose of this report, all media will be referred to as sorption media, except in sections on specific sorption media. Terms such as "resin" and "ion exchange" have specific meaning to the chemical processing industry. Resin implies organic media; ion exchange implies the release of one ion from the surface of the media in coordination with the capture of another. In many cases, the media incorporates ions by adsorption, where no exchange of ions takes place. Therefore to facilitate a level discussion, a universal term will be used to describe the materials tested throughout the text -- "sorption media."

2.1.1 Sorption Media Size

Most sorption media are available in different size ranges, typically determined by the screening of the material through an upper bound mesh and a lower bound mesh. Table 2-1 aids in understanding media diameter verses mesh range.

Table 2-1. Reference Table for Conversion of Mesh Size to Inches or Micrometers

Mesh Range	Diameter of Particles	
	Inches	Micrometers
20 - 50	0.0331-0.0117	840-297
50 - 100	0.0117-0.0059	297-149
100 - 200	0.0059-0.0029	149-74
200 - 400	0.0029-0.0015	74-38
minus 400	< 0.0015	< 38

The size of the media used is important for two reasons: 1) the smaller the material, the greater the surface area available per unit volume; and 2) the smaller the media the higher the pressure drop through the column. Therefore size and pressure drop must be balanced. Uniformity of the size also plays a role in pressure drop, with columns containing beads with less variation in diameter and shape having less pressure drop across the column.

2.2 ELUTABLE AND NON-ELUTABLE SORPTION MEDIA

The disposal path for the ^{99}Tc will have a large influence in the sorption media chosen for use. The WTP planned to process ^{99}Tc through its HLW melter, requiring an elutable sorption media. SuperLig® 639 was chosen. If the selected disposal path is a separate waste stream that will

leave the ^{99}Tc on the sorption media, a non-elutable resin will be required. There are many different scenarios for ^{99}Tc disposal. The final review of sorption media will be divided between elutable and non-elutable material.

2.3 BATCH DISTRIBUTION COEFFICIENT AND COLUMN DISTRIBUTION RATIO

The batch distribution coefficient (K_d) is an equilibrium measure of the distribution of a chemical species between a solution and a solid sorbent material. The concentration of a sorbed species is difficult to define and determine. Therefore the coefficient is based on the solution being processed. The equation for K_d can be found in Table 3-2.

The column-distribution value, λ, represents the capacity of the sorption media in volumes of feed per volume of media. It is the ratio of the equilibrium concentration of targeted analyte TcO_4^- per unit volume on the sorption media to that in the equilibrated solution. For column load operations where kinetics are not limiting, λ is approximately the number of bed volumes (BVs) processed when the concentration of TcO_4^- in the effluent of a sorption column reaches 50% of the feed concentration ($C/C_0 = 0.5$); designated λ_{50}. The equation for λ_{50} can be found in Table 3-2.

When comparing K_d and λ_{50} values between research experiments, differences in experimental conditions are critical to note. Some of the factors that influence results are:

- Concentration of the target species (analyte);
- Resin to liquid ratio;
- Valence state of target species;
- Solution temperature;
- Resin particle size (if it affects equivalents/liter);
- Contact time (if not confirmed to be at equilibrium);
- Speciation;
- Concentration of competing ions;
- Concentration of ligands and complexants;
- Analytical techniques;
- Batch variability of the sorption media;
- pH.

In addition to these causes, the λ_{50} value may not coincide with 50% breakthrough during a column performance test for several reasons:

- Column design;
- Elution method;
- Flow rate;
- Sampling method;

- Solution density;
- Sorption media particle size.

Unfortunately the result of the variation in K_d and λ_{50} values with process parameters is such that comparison of sorbent media between differing experiments is difficult. Column design and operation will need to be robust enough to handle the broad spectrum of Hanford's LAW feed batches.

2.4 LOW-ACTIVITY WASTE FEED ENVELOPES

The WTP contract divides LAW into three types of feed, or envelopes. Much of the testing performed on sorbent media refers to the material tested in terms of its feed envelope classification. A very brief description of each feed type follows. (A more in-depth description can be found in 24590-WTP-RPT-PT-02-005, Rev 5, *Flowsheet Bases, Assumptions, and Requirements*.)

- LAW Envelope A: Tank waste supernatant requiring solids/liquid separation and Cs removal to meet the LAW glass specification.
- LAW Envelope B: Higher concentrations of Cs than envelope A or C. Also may contain higher levels of chlorine (Cl), chromium (Cr), iron (F), sulfate ($SO_{4)}$, and phosphate (PO_4).
- LAW Envelope C: Contains organically complexed ^{90}Sr and transuranic (TRU) waste requiring removal to meet the LAW glass specification. (These have been found to coincidentally contain substantial amounts of soluble ^{99}Tc that is not in the pertechnetate form.)

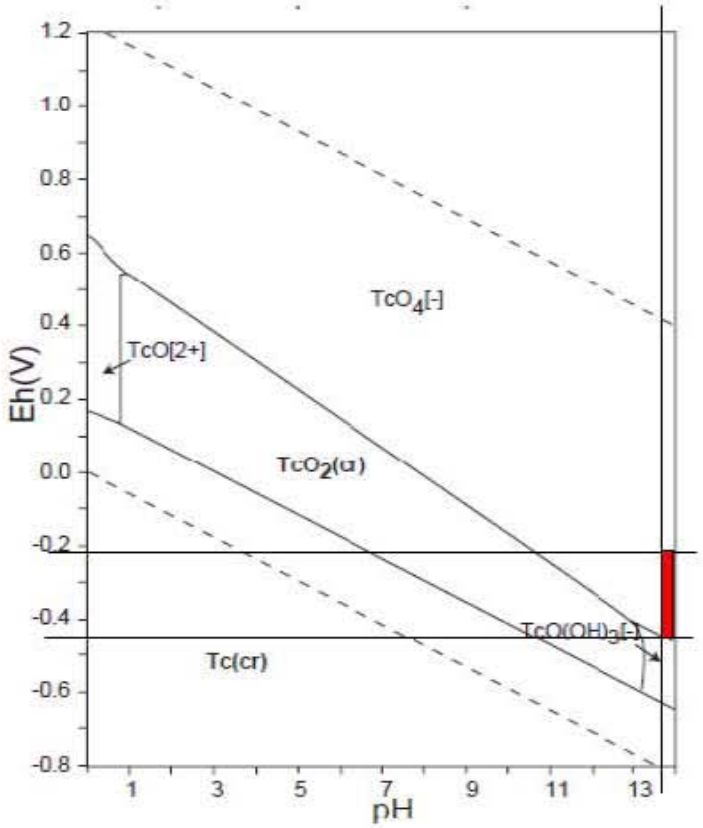
A supplemental immobilization facility will not likely divide LAW feeds in these same categories. Wastes high in organics will likely have a more selective processing path, e.g., all of them may be processed through the WTP LAW Vitrification facility or blended to meet feed requirements as a means of mitigating the presence of organics and ^{99}Tc IV.

2.5 POTENTIAL AND PH EFFECT ON TECHNETIUM SPECIES

The Eh-pH diagam presented in Figure 2-1 indicates the species of Tc encountered over a pH range of 0 to 13^+ ,and over the electropotential range of -0.8 V to 1.2 V, versus standard hydrogen electrode. Those Tc species that are solid are in bold and noted with (cr = crystalline).

From previous electrochemical corrosion studies, the open circuit potential of the Hanford SSTs and DSTs are in the cathodic range (from -229 to 400 mV vs. SCE)[1] and they have a pH range between13 and 14[+]. According to Figure 2-1, the Tc species that the supernate accommodate are soluble (red shaded area) and predominately TcO_4^-, with some Tc(V)oxy-hydroxide ($TcO(OH)_3^-$). Other oxidation states of ^{99}Tc have been reported in the complexant concentrate tanks, 241-AN-102 and 241-AN-106, designated Envelope C for WTP feed. It is beyond the scope of this study to elucidate the oxidative approach to destroy the complexant concentrate organics to drive non-pertechnetate species to the pertechnetate state.

Figure 2-1. Technetium Species (Guillaumont, et al., 2003)[2]



[1] RPP-RPT-38319, Rev 0, *Electrochemical Corrosion Tests for Tank 241-AP-105 Supernate Using Grab Samples 5AP-07-01, %AP-07-02A, 5AP-07-03A, and 5AP-07-04A*, October 2008, andRPP-RPT-34697, Rev. 0, *electrochemical Corrosion Report for Tanks 241-AW-103, 241-AZ-102, 241-AN-106, 241-AN-107, 241-AY-101, and 241-AY-102I*, August 2007, CH2M HILL Hanford Group, Inc., Richland, Washington.

[2] Presented in Atlas of Eh-pH Diagrams, Intercomparison of Thermodynamic Databases, Geological Survey of Japan Open File Report No. 419, National Institute of Advanced Industrial Science and Technology, Research Center for Deep Geological Environments, Naoto TAKENO, May, 2005.

3 IMMOBILIZATION SORPTION MEDIA EVALUATION CRITERA

Technetium removal from treated LAW is expected to be a one-step ion exchange process. Treated LAW will be stored as it exits WTP Pretreatment and the Supplemental Treatment Project facilities, then fed through ion exchange columns and into an immobilization feed tank(s).

Immobilization has assumed feed vector batches are based on the HTWOS run documented in SFV-2000, *FeedVectorWTP Realignment AOff BEL Gen-6.l-8.40-2010-O-07-at- 15-14-1ll.xlsx*. The feed composition review, Table 3-1, was performed using SVF-2023, *Immobilization System Hazard Category Source Term for Pre-Conceptual Candidate Technologies*. The concentrations listed in Table 3-1are by batch. For example, feed batch 103 has the highest concentration of ^{99}Tc at $1.2x10^{-4}$ moles/liter. Table 3-1 also contains feed parameters as outlined in RPP-SPEC-48094, Rev 0, *Immobilization Project Facility System Specification*. Only cations and anions of most concern are listed in Table 3-1.

Table 3-1. Feed Composition Properties

COMPOSITION (SVF-2023, by feed batch)					
ANALYTES	UNITS	MAXIMUM	MINIMUM	MEDIAN	AVERAGE
^{99}Tc	g-moles/liter	1.20E-04	4.36E-06	2.33E-05	3.85E-05
Al^{+3}	g-moles/liter	1.47E+00	3.98E-02	2.51E-01	3.71E-01
K^{+}	g-moles/liter	7.75E-01	3.60E-03	2.22E-02	5.95E-02
Na^{+}	g-moles/liter	9.40E+00	9.58E-01	3.98E+00	5.53E+00
NO_2^{-}	g-moles/liter	1.88E+00	1.42E-01	5.85E-01	8.66E-01
NO_3^{-}	g-moles/liter	4.03E+00	4.90E-01	1.67E+00	2.32E+00
OH^{-}	g-moles/liter	9.02E+00	1.77E-01	9.77E-01	1.43E+00
PO_4^{-3}	g-moles/liter	3.62E-01	1.40E-02	6.76E-02	1.04E-01
SO_4^{-2}	g-moles/liter	3.68E-01	1.39E-02	6.46E-02	9.90E-02

GENERAL PROPERTIES (RPP-SPEC-48094)	
Instantaneous Throughput *	422 Kg Na/hr
Nominal Throughput *	2600 MT Na/yr
pH	>12
Solids (wt %)	0 – 0.5
Specific Gravity	1 – 1.46
Viscosity (cP)	1 – 20

* Throughput is on a sodium (Na) basis.

Criteria for sorption media selection for use in the immobilization facility will need to account for four major categories: 1) technical performance, 2) cost, 3) schedule, and 4) safety and environmental impact. The criteria outlined in this section capture what is known about the sorption media selected for further review. Most of the information concerns technical development of each media, and can be used to evaluate the feasibility of implementing sorption media for ^{99}Tc removal.

Criteria impacting cost and schedule that DOE must consider, such as the ability to source the material and establish an intellectual property agreement to ensure that manufacture of the sorption media is possible at more than one facility, are not covered in this review since adequate information is not available and vendor reviews are not applicable to technical feasibility. Table 3-2 and Table 3-3 show parameters important to selection of sorption media and Hanford LAW feed characteristics critical for ensuring testing performed by a reference is applicable to the Immobilization Project. Criteria listed in Table 3-3 can be used to quickly evaluate the applicability of solutions used to test sorption media against Hanford's LAW.

Table 3-2. Criteria for Evaluation of Sorbent Media

CHARACTERISTIC	DESCRIPTION
Ability to supply amounts of ≥ 2000 lbs	The DOE must have the ability to procure sorption media for a long period of time. To ensure this the ability to have an intellectual property (IP) agreement with the vendor will be required or the equivalent material must be commercially available via multiple suppliers.
BV per Hour Operation	Implementation requirement that will be needed to size the ion exchange column(s).
Sorption media Cost per Pound (or ft^3)	The cost of sorption media consumed is an important factor for sorption media selection. Elutable sorption media will be able to factor in the number of cycles the sorption media may be regenerated to offset procurement costs.
Cost per Ci ^{99}Tc Removed	The total system cost; implementation costs for all aspects of ^{99}Tc removal need to be considers.
Elutable (loading cycles)	Depending on the ^{99}Tc disposal route chosen, whether the sorption media is elutable or non-elutable may be the most critical property of the sorption media. • Non-elutable sorption media need to tightly bind ^{99}Tc and not release it except under extreme conditions or long contact times. • Elutable sorption media need to employ an eluent that is safe to implement and produce a ^{99}Tc solution that is easily processed further into an immobilized waste form. The number of loading cycles (times the sorption media can be recharged) will also be a critical implementation factor.
Equivalents/L	The number of active reactant sites available for TcO_4^- capture will influence the size of the column required.
Storage, Shelf Life, & Handling Specifications	Typically sorption media have a long storage and shelf life. Some sorption media require storage at low temperature and corrosive solutions. The physical stability of sorption media is affected by the method of product handling. Deep sorption media beds, small diameter beds, high flow rates and agitation/frequent pumping contribute to sorption media degradation and breakage.
K_d[Tc]	$K_d = ((T_i - T_f) / T_f) \times (V / (M \times F))$

CHARACTERISTIC	DESCRIPTION
	Where: K_d = Equilibrium distribution coefficient, ml solution/g sorption media $T_{i,f}$ = Measured initial and final [Tc] in the solution (gmol/l) V = Volume of solution in test (ml) M = Mass of sorption media tested (wet basis) (g) F = Correction factor to convert sorption media mass to dry basis The equilibrium distribution coefficient (K_d) is a measure of the concentration of the ^{99}Tc in the sorption media that is in equilibrium with a particular concentration of ^{99}Tc in solution after exposure for an extended period of time (equilibrium is reached). The K_d can be used to indicate the expected volume of feed that can be treated by a column during a loading cycle. K_d is determined by experimentation and depends on many factors: solution temperature, pH, ionic strength of the solution, etc. Therefore, the K_d for LAW feed batches will vary. A sorption media with a high K_d is desired. Many of the sorption media reviewed do not have K_d's determined for them or testing parameters are not the same.
λ_{50}	The column distribution ratio is the batch distribution coefficient converted from mass to volume. The value obtained is roughly the number of BV that can be passed through the column prior to 50% breakthrough of the targeted analyte. $\lambda_{50(Tc)} = (K_d)(\rho_b)$ $\lambda_{50(Tc)}$ = the column distribution ratio for ^{99}Tc, volume feed per volume sorption media (ml solution / ml sorption media) K_d= Equilibrium distribution coefficient, ml/g sorption media ρ_b = the bulk density of the sorption media (g/ml) in the solution (or ~the bulk dry density adjusted for swelling)
Organic	Sorption media parameter that is not important for implementation in the ion exchange column, but could be critical depending on the disposal path chosen for the ^{99}Tc.
Particle Size	Sorption media performance parameter. Solute adsorption kinetics or speed generally increase as particle size decreases, however pressure drop through the ion exchange column increase as particle size decreases.
pH operating range	LAW will be fed at high pH (≥12).
Poisons	Anions, cations, molecules, and elements that occupy or prevent the occupation of sorption media active sites from being occupied by TcO_4^-.
Preparation Procedure	Method used process the sorption media from a stored stated to active state.
Radiological Stability and/or Gas Generation	Effects of radiation on the sorption media; often results in the evolution of gas, typically H_2, which poses a safety hazard. Since ^{99}Tc removal will be performed following filtering (removal of most ^{90}Sr) and Cs ion exchange, this characteristic should not be a determining factor for sorption media selection.
Sorption media Density (weight per unit volume)	Ion exchange column configuration and design will be influenced on the buoyancy of the sorption media in the feed solution.
Sorption media Disposal Route	Will be dependent on the ^{99}Tc disposal route chosen. If an elutable sorption media is selected then most likely the sorption media will be disposed of as a Class A type waste. If a non-elutable sorption media is chosen then the method of immobilization will dictate the sorption media disposal path.

CHARACTERISTIC	DESCRIPTION
Selectivity to ^{99}Tc	Affinity of the sorption media to pull ^{99}Tc out of the feed solution. It will vary based on feed ionic strength, poisons, feed temperature, and flow rate of the feed through the sorption media.
Stability of Spent Sorption media	The ability of the sorption media to not break down and strongly bind the Tc to its matrix is most important for a non-elutable.
Tc Disposal Route	The selected sorption media will need to support the selected ^{99}Tc disposal path, examples are: • Incorporation into HLW glass via vitrification → elutable or non-elutable sorption media could be chosen. • Disposed of in a grout matrix → non-elutable sorption media required.
Temperature operating range	The LAW feed may need to be feed to the ion exchange media at elevated temperatures to minimize precipitation. Implementation of sorption media that enables a robust operating range is desirable.
Technology Readiness Level (TRL)	Many sorption media will remove TcO_4^- from solution. For this review, those having proved their ability to perform well for Hanford SST and DST wastes will be assumed to require less process development.

Table 3-3. Ion Exchange Feed Solution Applicability Criteria[a]

PARAMETER	VALUE
Test Material	DOE tank waste or simulant (not necessarily Hanford tank waste)
Salt Content	≥ 3molar Na
pH	≥ 12
Target Analyte	^{99}Tc(VII) or Re(VII) (Rhenium) used
Target Analyte Concentration	4.36E-07 < [^{99}Tc] or [Re] <1.20E-03

Note: [a]Testing on simulants or wastes outside the criteria listed here is too far from the waste feed matrix from Hanford SST and DST waste to be considered as relevant.

Many of these criteria are not part of typical vendor specification sheets. Deploying ion exchange media for industrial applications requires testing to understand interactions between feed and sorption media, acquire meaningful decontamination factor (DF) values and understand poisons, gas generation, selectivity, eluent efficiency and loading. A much more inclusive set of information is required for final sorption media selection; see Table 3-4. However a total system review is not part of this report.

Factors most influential for economics for the system are cost of the sorption media, volume of treated waste before media disposal, cost for disposal of the sorption media and the ^{99}Tc, costs for disposition of storage/preparation/eluent chemicals and research required to achieve the required TRL level for conceptual design.

The implemented system also must provide a safe work environment that minimizes safety risks due to mechanical, chemical and radiological exposure, and minimize impacts to the environment. Important sorption media parameters affecting safety and environment are storage, handling, preparation and regeneration (eluent) chemicals. Gas generation from radiolysis should be minimal due to the removal of ^{90}Sr and ^{137}Cs from the feed stream. Co-absorption of other analytes (e.g. Chromium or actinides) could also impact the selection of a disposal path.

Key technical parameters examined for this report are those critical for ensuring a ^{99}Tc removal system using ion exchange is technically feasible. Most critical features for the sorption media will ensure ^{99}Tc removal targets can be met on Hanford SST and DST wastes. Vendor experience with feeds similar to tank waste is minimal, and testing sorption media with simulants can result in under- or over-estimating a sorption media's ability to perform in a complex, concentrated high pH feed. Therefore results from tests performed with tank waste weigh heavily on estimating the technical maturity of a given sorption media.

Table 3-4. Sorption Media Characteristics Required for a more In-Depth Evaluation

CRITERIA FOR A CRITICAL REVIEW OF SORPTION MEDIA		
ECONOMICS	SAFETY\ENVIRONMENTAL	TECHNICAL
• Cost per Ci ^{99}Tc Removed (for the system) • Sorption media Cost • Ability to Source Sorption media • Sorption media Disposal Route • Stability of Spent Sorption media • Storage, Shelf Life • Structure and Composition not a Trade Secret • Tc Disposal Route	• Eluant • Gas Generation • Handling Specifications • Preparation Procedure • Radiolysis • Co-adsorbed analytes	• BV per Hour • K_d [^{99}Tc] (Tc^{99} removal efficiency) • Type of sorption media (organic vs. inorganic) • Loading Cycles • Temperature Operating Range • Poisons • Preparation Procedure • Radiolysis • Sorption media Disposal Route • Selectivity to ^{99}Tc • ^{99}Tc Disposal Route • pH Range • ^{99}Tc Loading (moles ^{99}Tc per unit volume of sorption media) • Technical Maturity

3.1 ION EXHANGE / SORBENT MEDIA

Table 3-5 lists media that have been identified as possible ^{99}Tc removal candidates from past reports or a current literature search. The list does not include all potential sorption media, but lists those having potential to meet the Immobilization Project's requirements. An initial screening of media was performed to narrow the list of sorption media to those having the highest likelihood of success. Sorption media were screened on their ability to perform in a solution as characterized in Table 3-1. Those that have been successfully tested for removal of ^{99}Tc from Hanford's waste were carried forward as recommended by subject matter experts (SMEs). Review results from a 2002 WTP review were also considered[3]. The WTP review based sorption media recommendations on the ability of the media to meeting four criteria:

1. *The resin(s) must be chemically and structurally stable over their expected operational lifetime when in contact with the waste feed envelope definitions.*
2. *The defined structure and composition of the selected resin(s) shall not be a trade secret.*
3. *The selected resin(s) shall have been manufactured by a supplier of demonstrated ability (greater than 1 percent of expected annual need but not less than 75 gal).*
4. *The selected resin(s) shall have been demonstrated on simulated or actual alkaline (greater than 1.0M hydroxide), high ionic strength wastes.*

The WTP review led to the down-select of three resins – ABEC, Dowex 1x8, and Reillex HPQ – in addition to the baseline WTP resin for TcO_4^- removal – SuperLig®639. All of these resins have been tested with Hanford tank waste.

Table 3-5. Ion Exchange / Sorbent Media Initial Screening Results

ION EXCHANGE / SORBENT MEDIA	DISPOSITION	ION EXCHANGE / SORBENT MEDIA	DISPOSITION
ABEC 2000	**Selected for Review**	IONSIV IE-910	Not Selected for Review (SME)
ABEC 5000	Not Selected for Review (vendor recommendation)	Iron Sulfide	Not Selected for Review (WTP screening)
Activated Carbon	Not Selected for Review (WTP screening)	**Kurion TAM (Sn^{++} Apatite Sorption media)**	**Selected for Review**
Aliquat (tricaprylmethylammonium chloride)	Not Selected for Review (WTP screening)	LANL – TiO2/carbon beads	Not Selected for Review (WTP screening)
Amberlite IRA-400	Not Selected for Review (SEM)	**Prolite A-520E**	**Selected for Review**

[3] 24590-PTF-RPT-RT-02-001, Rev 0, *WTP PTF Alternative Resin Selection*, Bechtel National, Inc., Richland, Washington, 2002.

ION EXCHANGE / SORBENT MEDIA	DISPOSITION
Amberlite IRA-904	Not Selected for Review (SME)
Amberlite XE-238	Not Selected for Review (WTP screening)
Azaphosphane-based media	Not Selected for Review (WTP screening)
Bio-Rad AG 1-x8	Not Selected for Review (SME)
Bio-Rad MSZ-1	Not Selected for Review (WTP screening)
BiQuat RO-02-119	Not Selected for Review (WTP screening)
BiQuat VP-02-217	Not Selected for Review (WTP screening)
Boehmite, synthetic aluminum oxyhydroxide gel	Not Selected for Review (WTP screening)
Cross-linked Polyvinyl Pyridine	Not Selected for Review (WTP screening)
Crypt-DER	Not Selected for Review (WTP screening)
Dowex 1X8	**Selected for Review**
Dowex 2X8	Not Selected for Review (WTP screening)
Duolite CS-100	Not Selected for Review (SME)
Forager Sponge	Not Selected for Review (WTP screening)

ION EXCHANGE / SORBENT MEDIA	DISPOSITION
Prolite A-530E	**Selected for Review**
Prolite A-532E	Not Selected for Review (SME)
Reillex 402	Not Selected for Review (WTP screening)
Reillex HP	Not Selected for Review (WTP screening)
Reillex – HPQ	**Selected for Review**
Sr-SPEC	Not Selected for Review (WTP screening)
SuperLig 639	**Selected for Review**
Sybron Ionac Sr-3	Not Selected for Review (WTP screening)
Sybron Ionac SR-6	Not Selected for Review (WTP screening)
Sybron Ionic SR-7	Not Selected for Review (SME)
TEVA	Not Selected for Review (WTP screening)
TRU-SPEC	Not Selected for Review (WTP screening)
Zero-valence Iron filings/beads	Not Selected for Review (WTP screening)
-	-

3.2 SORPTION MEDIA INFORMATION

The following tables contain information on sorption media selected as candidates for the feasibility study. Several of the characteristics listed in Table 3-6 are unknown and therefore not listed in the sorption media property tables. For example, ^{99}Tc disposal routes can have many different paths and costs. Characteristics not carried forward to the sorption media properties review are:

- Cost of the system per Ci ^{99}Tc removed;
- Trade status of structure and composition.

Many of the characteristics were binned in more than one of the three categories (economic, safety and technical). For the properties table, these characteristics have been placed in the bin most impacted.

Table 3-6. Sorption Media Properties

SORPTION MEDIA PROPERTY	ABEC-2000®	DOWEX® 1-X8	PUROLITE		TAM - SnII Apatite Microspheres (Kurion, Inc.)	REILLEX HPQ	SUPERLIG 639
			A520E	A530E			
Economics							
Ability to supply amounts of ≥ 2000 lbs	Will require scale up development but is a technological possibility. (G)		Yes (T)	Yes (T)	Yes (I)	Yes (U)	Yes (B)
BV per Hour Operation	Estimate 45 – 60 BV/hr (G)		Depends on concentration of competing anions (T)	Depends on concentration of competing anions (T)	Depends on application (I)		99% ^{99}Tc removal for 20% of λ_{50} at 3 BV/hr in AP-101 (W) 99% ^{99}Tc removal for 43% of λ_{50} at 3 BV/hr in AZ-101 (Y) 99% ^{99}Tc removal for 40% of λ_{50} at 3 BV/hr in AW-101 (D)
Cost per Pound (or ft^3)	~30 – 60 $/lbm @ 0.8 g/ml (~200 – 400 $/gallon) (G)	Between 160 to 186 $/lbm (Q) and WRPS estimator		~$5.70/ lbm @ 0.67 g/ml (~$238/ft^3)	To be specified. (I)	~$68/lb @ .88 g/ml (150$/Kg) (U)	Vendor states that cost per lb is dependent on volume and commercial terms (V)
Loading Cycles	Estimate 20 loading cycles for the resin but actual results will depending on the effects of radiolytic damage to the resin. (G)		Single use disposable resin (T)	Single use disposable resin (T)	Single use disposable resin (I)		Up to 200, depending on radiation exposure, but ≥ 50 loading cycles expected for LAW feed (V)
Storage, Shelf Life	Anticipate greater than 2 years of shelf life under environmentally controlled conditions. (G)		5 years (T)	5 years (T)	Indefinite (I)		5-10 years, ambient air, dry or wet (V)
Safety							
Eluant	Water, dilute saline or dilute acid (G)	1) 4 M HNO_3: 15 BV; ~ 0% resiual TC on resin (A) 2) 1 M NaOH, 1 M ethylene diamine, 0.005 M Sn(II): ~ 15 BV; ~0% residual ^{99}Tc on resin (A) 3) 1M NaOH, 0.1M ethylene diamine, 0.01M Sn(II): ~15BV; 25% residual ^{99}Tc on resin (A)	Non-elutable (T)	Non-elutable (T)	Non-elutable (I)	8 M HNO_3 (A) 6 BV of 1 M NaOH, 1 M ethylene diamine, 0.005 M $SnCl_2$ (A) (N)	Water, optimal at 70°C (B)
Handling Specifications	Resin will shrink and swell up to 30% depending on ionic strength of solutions passed through the resin bed. (G)				No special specs (I)		No special requirements – resin is handled similarly to standard IX resin (B)
Preparation	ABEC® resin should be preconditioned with a basic		Backwash to classify bed and then rinse (T)	Backwash to classify bed and then rinse (T)	Sn II substitution for Ca in Hydroxy Apatite (CaPO4)		Hydrate in water for 30 minutes

Table 3-6. Sorption Media Properties

SORPTION MEDIA PROPERTY	ABEC-2000®	DOWEX® 1-X8	PUROLITE		TAM - SnII Apatite Microspheres (Kurion, Inc.)	REILLEX HPQ	SUPERLIG 639
			A520E	A530E			
Procedure	solution of similar molarity prior to loading waste solutions (G)				Microsphere production. Glass substrate initiator. (I)		
Radiological Stability and/or Gas Generation	There is potential for CO_2 evolution from radiolysis of the resin (G) Small K_d reduction at 130M Rads Irradiation (A)	16% K_d reduction at 100M Rads Irradiation (A)			Extreme rad stability. No know gas generation. (I)	Good Radiolytic Stability observed at 1,000M Rads (A)	Organic resin so does have potential for gas generation, but providing Cs is removed prior to ^{99}Tc removal, it will not suffer any significant radiolytic degradation resulting in gas generation ($1x10^8$ Rad) (R)
Process Technical Parameters							
Equivalents/L	0.8 eq / L (G)	1.2 eq/L (Cl^-, by wetted volume) (F)	0.9 eq/L min.(T)	0.6 eq/L min. (T)	~ 2.25-2.50 eq/L (I)	4 eq/kg dry (U)	
K_d [^{99}Tc]	Depends on concentrations of other analytes, but improves with higher concentration of anions (G) 141-160 ml/g and λ_{50} breakthrough as 40-60BV at 10BV/hr (A) 410 ml/g SY-101 waste (P)	~12.3 mg ^{99}Tc per cm^3 1850 ml solution/g resin (H)	From simulated SY-102 waste spiked with ^{99}Tc (J): • 30 min = 371 ml/g • 2 hour = 585 ml/g • 6 hour = 620 ml/g From simulated DSSF waste spiked with ^{99}Tc (K): • 30 min = 189 ml/g • 2 hour = 392 ml/g • 6 hour = 527 ml/g From simulated NCAW waste spiked with ^{99}Tc (L): • 30 min = 329 ml/g • 2 hour = 660 ml/g • 6 hour = 782 ml/g	49,879 ml/g for ETF waste matrix (O)	pH 8.6 WTP Recycle Surrogate: 6.19E+01 (I) pH 13.2 At tank AN-104 Surrogate: 6.94E+02 (I)	Removal = 93%, Removal from a composite of double shell slurry feed (M) DF = 1100 ^{99}Tc-m tracer in AW-101 waste (N) DF = 6 AW-101 waste (N) 917 ml solution/g resin, Simulated ORNL newly generated liquid low-level waste solution 1A, (H) Simulated SY-102 waste spiked with ^{99}Tc (J): • 30 min = 314 ml/g • 2 hour = 372 ml/g • 6 hour = 370 ml/g From simulated DSSF waste spiked with ^{99}Tc (K): • 30 min = 254 ml/g • 2 hour = 293 ml/g • 6 hour = 332 ml/g From simulated NCAW waste spiked with ^{99}Tc (L): • 30 min = 382 ml/g • 2 hour = 459 ml/g • 6 hour = 445 ml/g	99-99,9% removal of ^{99}TcVII for Hanford SST and DST waste envelope A, B, and C (note that ^{99}Tc in envelope A waste is ~97% ^{99}TcIIV and ~30% in envelope C waste) (B) DF factor is ~400 for ^{99}TcVII F factor = 0.9931 (X) Note: Many more K_d values are listed for SuperLig 639 in section 3.2.7.
Organic	Yes (G)	Yes: Styrene-DB, Gel (F)	Yes (T)	Yes (T)	No (I)		Yes
Particle Size	30-60 mesh (~250-600 micron) (G)	20-50 mesh (~300-850 micron) (Q)	16-50 mesh (~300 – 1200 micron) (T)	16-50 mesh (~300 – 1200 micron diameter) (T)	20-50 mesh. (~300-850 micron) (I)	81% of beads were 260 – 450 µm (N)	25- 35 mesh (~500 – 700 micron) 26% 600 to 1000 µm; 60% 425 to 600 µm, 11% 300 to 425 µm (X)
pH operating range	6 to 14+ (G)	0 to 14 (Q)	0 to 14 (T)	Stable: 0 to 14 (C)	6.5 to14 (not for acidic	The vendor reports that there is a week	No limit in acidic, neutral or basic range.

Table 3-6. Sorption Media Properties

SORPTION MEDIA PROPERTY	ABEC-2000®	DOWEX® 1-X8	PUROLITE		TAM - SnII Apatite Microspheres (Kurion, Inc.)	REILLEX HPQ	SUPERLIG 639
			A520E	A530E			
	Good chemical resistance to alkaline solutions (A)	Good chemical resistance to alkaline solutions (A)		Operating: 4.5 to 8.5 (C)	conditions) (I)	hydrogen bond that would be lost in basic solutions. They recommend pH < 7. They do not know of negative effects from the weak bond reacting in high pH solutions. (U) Good chemical resistance to alkaline solutions (A)	Optimal removal in high pH, high salt concentration solutions (V)
Poisons	Reducing agents capable of reducing ^{99}Tc(VII) will reduce the ^{99}Tc(IV) which will not be retained by the resin (G)		Competing anions are SO_4, Cl, HCO_3, NO_3, and U (T)	Competing anions SO_4, Cl, HCO_3, NO_3, and U (T)	Neither salts nor chelants seem to have an affect (I)		None known or found in testing with Hanford tank waste. Feed must be clarified prior to delivery IX column, otherwise as solids block access of TcO_4^- to resin ligand sites (V)
Resin Density (weight per unit volume)	0.8 g/mL in H_2O and 1.1 g/mL in 6M KOH (G)	0.705g/ml (44 lbm/ft^3) at ~39-45% water ρ = 0.41g/ml dry density (F) Packed bed yield volume 7.5ml, dry resin used 2.84g ρ_b = 0.38g resin/ml resin in solution (H) Floats in 5.6M NaOH (1.27 g/L) (A)	0.675-0.705 g/ml ρ_b = 0.351 g/ml (J)	0.670 g/ml (0.335 g/ml dry)	~ 1.37 g/ml (dry) (I)	0.88 g/ml at ~50% water (25.2 Kg/ft^3) ρ = 0.585 g/ml dry (N) ρ = 0.538 g/ml wet (N) ρ_b = 0.352 g/ml (J) Likely floats in Feed Solution (A)	1.147 g/ml wet (B) 0.478 g/ml bulk dry (B) 1.07 grams of dry solids divided by the volume of wet resin particles (X)
Selectivity to ^{99}Tc	The resin has good selectivity for ^{99}Tc(VII) but will co-extract I^- and Re(VII) (G)				Extremely specific at high salt molarity and high pH (I)		Virtually infinite selectivity over OH^-, Cl^-, F^-, & Br^-. NO_3^- is the primary competitor (V)
Temperature operating range	10°C – 50°C (G)	66°C Maximum (Q)	5 – 60°C (T)	5 – 60°C (T)	Made from glass microspheres at high temperatures. So none known. (I)		5 – 40°C LAW feed not to exceed 77°F (25°C) (B)
λ_{50}	λ_{50} breakthrough as 40-60 BV at 10BV/hr for Hanford waste	703 ml solution/ml resin in column (H)	λ_{50} = 130 ml solution/ml sorbent media for SY-102 simulant, 30min contact time (J) λ_{50} = 205 ml solution/ml sorbent media for SY-102 simulant, 2hr contact time (J)	1.6E04 ml solution/ml resin (for ETF waste matrix; dilute compared to expected LAW feed) (O)	9.5E02 ml solution/ml dry resin for AN-104 surrogate	λ_{50} = 111 BV ^{99}Tc-m tracer in AW-101 waste (J) λ_{50} = 131 BV AW-101 waste (N) λ_{50} = 88 ml solution/ml sorbent media for SY-102 simulant, 30min contact time (J)	Tank 44 F sample (reported as similar to Hanford envelop A) resulted in approximately 89.4% Tc removal (^{99}Tc K_d = 950.1 mL/g), λ_{50} ~ 500 BV in AP-101 (W) λ_{50} ~ 360 BV in AZ-101 (Y) λ_{50} = 213 BV in AW-101 (D)

Table 3-6. Sorption Media Properties

SORPTION MEDIA PROPERTY	ABEC-2000®	DOWEX® 1-X8	PUROLITE		TAM - SnII Apatite Microspheres (Kurion, Inc.)	REILLEX HPQ	SUPERLIG 639
			A520E	A530E			

REFERENCES (questionnaires are located in Appendix B)

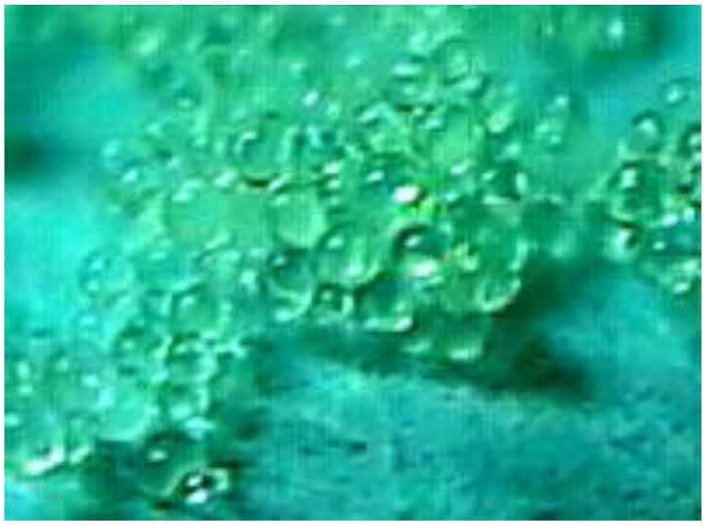
A. 24590-PTF-RPT-RT-02-001, Rev 0, *WTP PTF Alternative Resin Selection*, Bechtel National, Inc, Richland, WA
B. 24590-WTP-RPT-PT-02-005, Rev 1, *Flowsheet Bases, Assumptions, and Requirements*, Bechtel National, Inc., Richland, Washington, 2002.
C. Baker Corp™ product brochure (http://www.bakercorp.com/pdfs/A-530E.pdf).
D. BNFL-RPT-016 Rev 0., *Small Column Testing of SuperLig® 639 for Removing ^{99}Tc From Hanford Tank Waste Envelope A (Tank 241-AW-101)*, Battelle, Pacific Northwest Division, Richland, Washington, 2000.
E. DE-AC21-97MC33137--43, Separation, Concentration, and Immobilization of Technetium and Iodine from Alkaline Supernate Waste, Eichrom Industries, Inc, Darien, Illinois, 1998.
F. DOW® Vendor Information (http://www.dowwaterandprocess.com/products/ix/dx_1x8.htm)
G. Eichrom Technologies LLC questionnaire.
H. K/TCD-1141, Simulated ORNL newly generated liquid low-level waste solution 1A, pH 13,
I. Kurion, Inc. questionnaire (Kurion homepage: http://www.kurion.com)
J. LA-12654 Rev., *Distributions of 14 Elements on 63 Selected Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Suprnate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.
K. LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.
L. LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.
M. PNNL-11386, *Technetium in Alkaline, High-Salt, Radioactive Tank Waste Supernate: Preliminary Characterization and Removal*, D. L. Blanchard, Jr, et. Al., Pacific Northwest National Laboratory, Richland, Washington, January 1997.
N. PNNL-11398, *Technetium Removal Column Flow Testing with Alkaline, High Salt, Radioactive Tank Waste*, D. L. Blanchard, Jr, et. Al., Pacific Northwest National Laboratory, Richland, Washington, November 1997.
O. RPP-RPT-23199, Rev 0, *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins*, J. B. Duncan, 2004.
P. RR196, *New Technologies for Metal Ion Separations: Aqueous Biphasic Extraction Chromatography (ABEC). Part I. Uptake of Pertechnetate*, Department of Chemistry, Northern Illinois University, DeKalb, Illinois, Argon National Laboratory, Argon, Illinois, 1996.
Q. Sigma-Aldrich (Fluka) (http://www.sigmaaldrich.com/catalog/ProductDetail.do?lang=en&N4=44324|FLUKA&N5=SEARCH_CONCAT_PNO|BRAND_KEY&F=SPEC)
R. SRTC-BNFL-013 Rev 0, *Evaluation of the Radiation Stability of SuperLig® 639*, Westinghouse Savannah River Company, Aiken, South Carolina, 1997.
S. TAM Sn(II) Apatite Microspheres
T. The Purolite Company questionnaire (Purolite® homepage: http://www.purolite.com).
U. Vertellus® questionnaire (Vertellus® homepage: http://www.vertellus.com)
V. IBC® Advanced Technologies questionnaire.
W. WTP-RPT-030, Rev 0, Small Column Testing of SuperLig® 639 for Removing ^{99}Tc from Hanford Tank Waste Envelope A (Tank 241-AP-101), Battelle, Pacific Northwest Division, Richland, Washington, 2002.
X. WTP-RPT-031, Rev 1, Small Column Testing of SuperLig 639 for Removing ^{99}Tc from Hanford Tank Waste 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids (Envelope D) Wash and Permeate Solutions, Battelle, Pacific Northwest Division, Richland, Washington, 2004.
Y. WTP-RPT-058, Rev 1, Small Column Testing of SuperLig® 639 for Removing ^{99}Tc from Hanford Tank Waste Envelope B (Tank 241-AZ-101), Battelle – Pacific Northwest Division, Richland, Washington, 2004.

3.2.1 ABEC™ 2000 (Eichrom)

Aqueous Biphasic Extraction Chromatography (ABEC)™[4] resins have been demonstrated to selectively extract pertechnetate anions from alkaline radioactive waste. ABEC resins consist of monomethylated polyethylene glycol (PEG) bonded onto cross-linked chloromethylated polystyrene-1%-divinyl-benzene backbone. The 2000 designation refers to the molecular weight of the PEG attached to the polystyrene support.

The resin behaves like an aqueous biphasic system (ABS), retaining chaotropic ions (such as $TcO4^-$, which interfere with stabilizing intramolecular interactions mediated by non-covalent forces such as hydrogen bonds, van der Waals forces, and hydrophobic effects) in the presence of high ionic strength solutions of water-structuring anions (such as SO_4^{2-}, CO_3^{2-}, OH^-). Resin uptake of $TcO4^-$ increases as the concentration of water structuring salt increases. The highest K_d value for ABEC-2000 with Hanford waste was 410 ml/g, obtained for testing with Tank SY-101 waste. After loading, the resins are regenerated by elution with water.

Figure 3-1. ABEC 2000 Resin



3.2.1.1 Overview of Literature Reports for ABEC 2000

a) Industrial & Engineering Chemistry Research, 38, 1683-1689, *Flowsheet Feasibility Studies Using ABEC Resins for Removal of Pertechnetate from Nuclear Wastes,* Eichrom Industries, Inc., Darien, Illinois, University of Alabama, Tuscaloosa, Alabama, and Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1999.

   This report presents information regarding ABEC G2 sorption media. It is not known whether this media is a forerunner to ABEC 2000. The article contains a basic flowsheet for another ^{99}Tc disposal system path -- removal of ^{99}Tc from LAW using ABEC G2, elution with water, then capture and disposal on a Purolite™[5] sorption media.

[4] ABEC resins are trademarked products of Eichrom Technologies, Inc., of Lisle, Illinois.

[5] Purolite resins are trademarked products of The Purolite Company of Bala Cynwyd, Pennsylvania.

b) RR196, *New Technologies for Metal Ion Separations: Aqueous Biphasic Extraction Chromatography (ABEC). Part I. Uptake of Pertechnetate*, Department of Chemistry, Northern Illinois University, DeKalb, Illinois, Argonne National Laboratory, Argonne, Illinois, 1996.

   This report is an overview of synthesis and uptake properties of several ABEC Resins (350, 750, 2000, and 5000) and a summary of experiments performed to show that 1) resin uptake of $TcO4^-$ increases as the concentration of the water-structuring salt increases, 2) resin uptake increases as ΔG_{hyd} of the water-structuring anions becomes more negative, 3) resin uptake increases as the molecular weight of the polymer increases, and 4) no uptake occurs from salt solutions that do not contain a sufficient concentration of bi-phase forming salt. Data for three different waste simulants (Tank SY-101, neutralized current acid waste, and SST waste) is presented as well as other studies of various salt solutions and pH solutions.

c) DE-AC21-97MC33137--43, *Separation, Concentration, and Immobilization of Technetium and Iodine from Alkaline Supernate Waste*, Eichrom Industries, Inc, Darien, Illinois, 1998.

   This report describes work to synthesize an improved version of the ^{99}Tc selective resin to resolve performance issues of the original ABEC-5000 resin, including research to investigate the influence of certain copolymer substrate properties on the physical properties and uptake performance of ABEC resins. Properties included degree of cross-linking, copolymer bead porosity and number of potential sites for attachment of PEG. The report also includes a flowsheet for stabilization and disposal of ^{99}Tc by loading the ^{99}Tc which has been stripped from the ABEC resin with water onto a commercial silica-based anion exchange resin, NUCLEOSIL™[6] and then encapsulating it within a hydrous titanium oxide matrix. Waste streams include actual Hanford tank waste from Tank AW-101, (a Cs-decontaminated, double-shell slurry feed (DSSF) composite), three different Hanford tank waste simulants, actual waste samples from Melton Valley Storage Tanks (MVSTs) W-29 and W-3 at the DOE's Oak Ridge National Laboratory (ORNL), and waste simulant solutions from two British Nuclear Fuels, Ltd. (BNFL) locations—Capenhurst and Sellafield—in the United Kingdom.

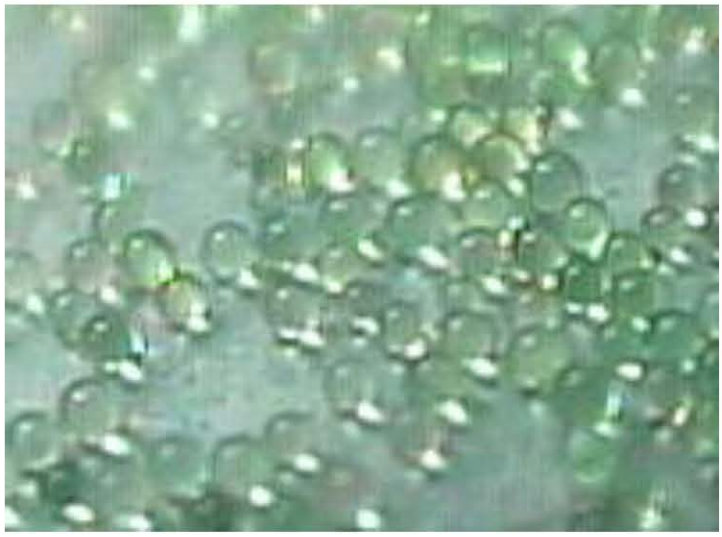
3.2.2 Dowex™ 1-X8 (Dow Chemical)

Dowex™[7] 1-X8 is a Type 1 strongly basic anion exchange resin. Structurally it is a quaternary amine based resin on a cross-linked (8%) styrene divinyl-benzene backbone. The resin is spherical and floats in 5.6 molar (M) NaOH (1.27 g/L). It has good chemical resistance to alkaline solutions. Its typical eluent is 4M nitric acid (HNO_3)

[6] Nucleosil resins are trademarked products of W.R. Grace and Company of Columbia, Maryland.

[7] Dowex is a trademarked product of the Dow Chemical Company of Midland, Michigan.

Figure 3-2. Dowex™ 1-X8 Resin



3.2.2.1 Overview of Literature Reports for Dowex™ 1-X8

Dowex 1-X8 has been reviewed by the WTP for Tc removal from LAW feedafter Cs removal. However, that report (24590-PTF-RPT-RT-02-001, Rev 0, *WTP PTF Alternative Resin Selection*) is business sensitive and has not been made available for WRPS review.

a) K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*, ORNL Chemical Technology Division, W. D. Bostick, et. Al, (Oak Ridge National Laboratory, Oak Ridge, Tennessee,1995).

   This reference is not directly applicable to immobilization of Hanford's LAW. The nitrate (NO_3^-) and salt concentrations for the simulant used are too low.

   Oak Ridge National Laboratory also reviewed Dowex 1-X8 for ^{99}Tc removal from its Newly-Generated Liquid Low-Level Waste. The resin was tested on two waste simulants. The simulant with the highest pH and salt concentrations is listed in Figure 3-3. Although the simulant has high pH, the concentrations of the salts are too low for accurate comparison with Hanford wastes. Regarding use of this resin on Hanford waste, the report comments:

   > *"It should be noted that loading of ^{99}Tc on Type 1 strongly basic anion exchange resin (such as Dowex™ 1 -X8) is adversely affected by high concentrations of competing nitrate ion; this situation could occur if NGLLLW is blended with a relatively large proportion of high-nitrate legacy waste from the Melton Valley Storage Tanks"*

   Another comment of interest is the finding regarding completely loading the sorption media with ^{99}Tc. Based on the ORNL simulant and testing, Dowex 1-X8 laden with ^{99}Tc would hold 170 Ci ^{99}Tc/m^3.

Figure 3-3. Newly-Generated Liquid Low-Level Waste Simulate Composition (K/TCD-1141)

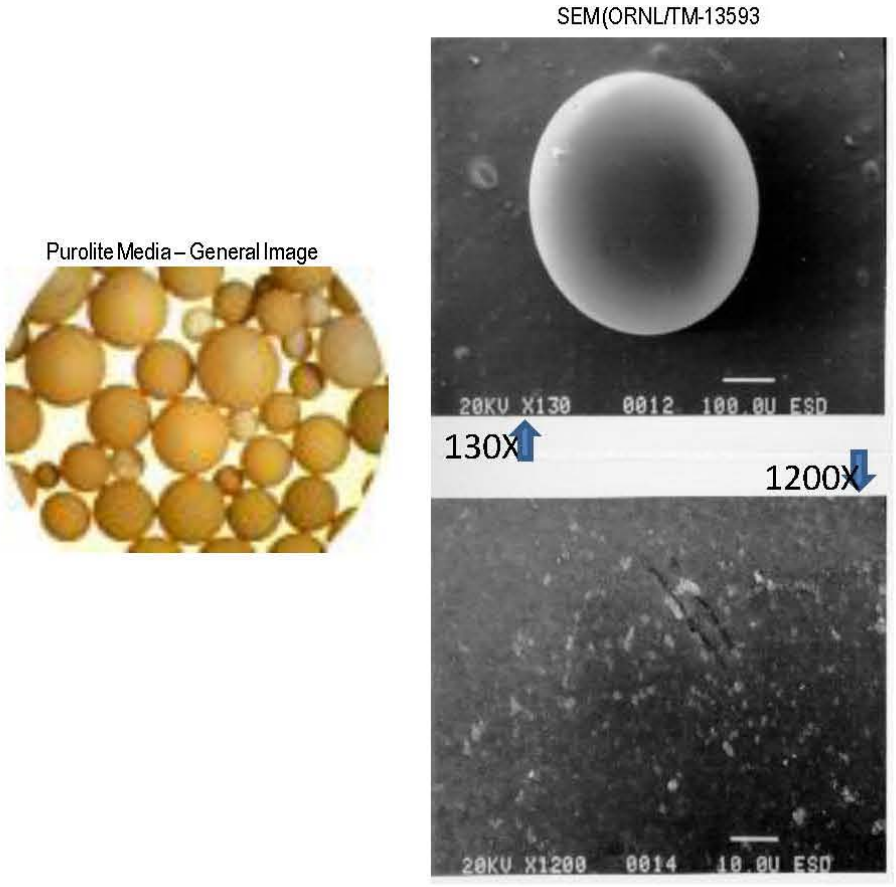
Table 1. Composition of Simulated NGLLLW[a]

Component or Property	Value
NaOH	0.125 mol/L (5.0 g/L)
Na_2CO_3	0.10 mol/L (10.6 g/L)
$NaNO_3$	0.06 mol/L (5.1 g/L)
NaCl	0.034 mol/L (2.0 g/L)
LiCl	0.025 mol/L (1.06 g/L)
$NaAlO_2$	0.012 mol/L (0.98 g/L)
Solution pH	~13 standard units
Solution density	~1.07 g/L

[a] Based upon Table 4.1 in Arnold, et al. (1994), as amended (D. T. Bostick, personal communication, November 14, 1994).

3.2.3 Purolite™ A520E

Figure 3-4. Purolite™ A520E



Purolite A520E is a strong base anion resin designed for the removal of nitrates from water for potable processes. It is a macroporous polystyrene crosslinked with divinylbenzene, and the functional group is a Type 1 quaternary ammonium pendant group. Macroporous resins are highly cross-linked polymers penetrated by open spaces through which solutions are able to flow. It has an exchange capacity of 0.9 eq/L in the chloride form, specific gravity of 1.07, and particle size range of 300 to 1200 microns. (Purolite Literature http://www.purolite.com/default.aspx?RelID=606288&ProductID=223)

3.2.3.1 Overview of Literature Reports for Purolite™ A520E

a) LA-12654 Rev., *Distributions of 14 Elements on 63 Selected Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

   The alkaline simulant used for this work is slightly low in ionic strength to be directly applicable to the processing of LAW waste and removal of ^{99}Tc. The simulant was based from on Tank SY-102, so it is applicable to some portion of Hanford's LAW feed. Three simulants where tested with only the alkaline solution of interest, its matrix is shown in Figure 3-5. The results of the study with respect to ^{99}Tc and Purolite 520E are best presented by review of Figure 3-6 and Figure 3-7. Elution of sorption media was not investigated.

Figure 3-5. Tank SY-102 Alkaline Supernate Simulant (Table 2, LA-12654, Rev.)

Table 2. Compositions of Hanford Tank 102-SY Simulant Solutions

(Acid-Dissolved Sludge and Acidified Supernate compositions removed to minimize confusion)	**Alkaline Supernate**
Cations[a]	
Na	2.2 M
Mg	none
Al	0.16 M
Si	0.0024 M
Ca	0.0069 M
Cr(III)	none
Cr(VI)	0.0051 M
Mn	none
Fe	0.0061 M
Ni	BDL
Cu	BDL
Se	BDL
Sr	BDL
Pb	BDL
Th	BDL
U	BDL
^{239}Pu	BDL
^{238}Pu	none
Anions[b]	
F	0.21 M
Cl	0.102 M
NO_3	1.31 M
PO_4	0.061 M
SO_4	0.022 M
pH	13.85
calculated H^+	—
calculated OH^-	0.7 M

[a]Determined by inductively coupled plasma/mass spectrometry (ICP/MS).
[b]Determined by ion chromatography (IC).
[c]Below detection limit.

Figure 3-6. Results by Adsorber for Technetium (LA-12654 Rev.)

Table 8. Technetium Distribution Data (Cont.)

Solution	Absorber	Kd Value for Specified Time		
		30 min	2 h	6 h
Alkaline Supernate	Aliquat™ 336	417	614	651
	Purolite™ A-520-E	371	585	620
	Reillex™ HPQ	314	372	370
	Sybron™ $(Et)_3N$ resin	279	446	521
	Sybron™ $(Pr)_3N$ resin	262	277	554
	Ionac™ SR-3	222	272	258
	Ionac™ SR-6	191	385	520
	Sr-Spec™	82	81	76
	Cyanex™ 923	80	116	110
	Crypt-DER	31	38	38
	DHDECMP	21	23	21
	LIX™-26	21	23	22
	DHDECMP-DIPB	14	14	13
	TRU-Spec™	7.6	7.5	7.2
	CMPO-DIPB	4.5	6.8	7.6
	Tannin	4.3	5.4	4.0
	Bone char	2.9	5.1	4.9

Figure 3-7. Purolite™ A520E Distribution Coefficients by Analyte (LA-12654 Rev.)

Table 34. Purolite™ A-520-E Anion Exchange Resin: Distribution of 14 Elements from Three Simulant Solutions for Hanford Tank 102-SY

Solution	Element	Kd Value for Specified Time		
		30 min	2 h	6 h
Alkaline Supernate	Ce	<0.1	0.2	<0.1
	Cs	0.8	0.2	0.3
	Sr	0.5	1.2	1.5
	Tc	371	585	620
	Y	0.5	1.2	2.0
	Cr	0.8	0.3	0.6
	Co	1.0	0.3	0.4
	Fe	0.4	0.4	1.0
	Mn	<0.1	0.2	1.1
	Zn	0.3	<0.1	<0.1
	Zr	0.8	0.3	0.6
	U	0.8	0.7	0.8
	Am	<0.1	<0.1	<0.1

b) LA-12863, Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF), Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

This report is directly applicable to ^{99}Tc removal from Hanford's LAW waste stream. The study builds off of previous work performed by LANL. The simulant used is based off double shell slurry feed (DSSF), Figure 3-8. Results for Purolite A520E are best represented by Figure 3-9 and Figure 3-10.

Figure 3-8. DSSF Simulant Composition (LA-12863)

Table 2. Composition of Simulated Hanford DSSF Solution Used in This Study

	Concentration (M)
Cations	
Na	7.0
K	0.945
Cs	7.0×10^{-5}
Al	0.721
Anions	
Cl	0.102
NO_3	3.52
NO_2	1.51
PO_4	0.014
SO_4	0.008
CO_3	0.147
OH^- (total)	4.63
OH^- (free)	1.75
Theoretical	pH = 14.56
Measured	pH = 14.0

Figure 3-9. Results by Adsorber for Technetium (LA-12863)

Table 8. Technetium Distribution Data

Absorber	Kd Value for Specified Time		
	30 min	2 h	6 h
Reillex™ HPQ	254	293	332
Purolite™ A-520-E	189	392	527
Aliquat™ 336	177	464	524
Sybron $(Et)_3N$	167	401	471
Cyanex™ 923	121	244	230
Ionac™ SR-3	115	279	312
Sybron $(Pr)_3N$	96	257	390
Ionac™ SR-6	45	105	188
Nusorb™ LP-70-S	15	24	26

Figure 3-10. Purolite™ A520E Distribution coefficients by Analyte (LA-12863)

Table 38. Purolite™ A-520-E Anion Exchange Resin: Distribution of 15 Elements from Simulated Hanford DSSF Solution

Element	Kd Value for Specified Time		
	30 min	2 h	6 h
Ce	5.4	6.0	19
Cs	0.2	<0.1	<0.1
Sr	0.4	0.4	0.4
Tc	189	392	527
Y	2.8	3.4	4.3
Cr	<0.1	<0.1	0.1
Co	0.3	0.4	0.7
Fe	0.2	1.0	1.4
Mn	0.5	1.0	1.5
Ni	0.6	0.9	1.5
V	<0.1	<0.1	<0.1
Zn	<0.1	0.2	0.6
Zr	0.6	1.4	1.5
U	<0.1	0.4	0.7
Am	4.9	5.4	8.8

c) LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

This report is directly applicable to ^{99}Tc removal from Hanford's LAW waste stream. The study builds off of previous work performed by LANL. The simulant used is based off neutralized current acid waste (NCAW), Figure 3-11. Results for Purolite A520E are best represented by Figure 3-12 and Figure 3-13.

Figure 3-11. NCAW Simulant Composition (LA-12889)

Table 2. Composition of Simulated Hanford NCAW Solution Used in This Study

	Concentration (M)
Cations	
Na	4.987
K	0.120
Rb	5.0×10^{-5}
Cs	5.0×10^{-4}
Al	0.430
Anions	
F	0.089
NO_3	1.669
NO_2	0.43
PO_4	0.025
SO_4	0.15
CO_3	0.23
OH^-(total)	3.4
OH^-(free)	1.68
Theoretical	pH = 14.52
Measured	pH = 14.2

Figure 3-12. Results by Adsorber for Technetium (LA-12889)

Table 7. Technetium Distribution Data

	Kd Value for Specified Time		
Absorber	**30 min**	**2 h**	**6 h**
TEVA-Spec™	1101	1259	1209
Aliquat™ 336	455	679	775
Reillex™ HPQ	382	459	445
Purolite™ A-520-E	329	660	782
Sybron $(Et)_3N$	303	571	739
Ionac™ SR-3	227	385	407
Sybron $(Pr)_3N$	218	488	705
Cyanex™ 923	185	212	188
Ionac™ SR-6	127	308	544
Nusorb™ LP-70-S	31	46	47
SRS RF BSC-187	5.0	33	232
Tannin	4.7	15	62

Figure 3-13. Purolite™ A520E Distribution coefficients by Analyte (LA-12889)

Table 37. Purolite™ A-520-E Anion Exchange Resin: Distribution of 12 Elements from Simulated Hanford NCAW Solution

	Kd Value for Specified Time		
Element	**30 min**	**2 h**	**6 h**
Cs	0.1	0.2	0.1
Sr	<0.1	<0.1	<0.1
Tc	329	660	782
Y	1.4	1.5	1.6
Cr	0.1	0.2	0.2
Co	0.6	0.7	0.6
Fe	0.7	1.2	1.2
Mn	0.9	1.3	1.3
Ni	0.6	0.7	0.4
V	0.6	0.7	0.6
Zn	0.5	0.6	0.5
Zr	0.8	0.9	0.8

d) ORNL/TM-13593, *A Field Trial of Novel Bifunctional Resins for Removing Pertechetate (TcO4-) from Contaminated Groundwater*, Oak Ridge National Laboratory, Lockheed Martin Energy Research Corporation, Oak Ridge, Tennessee, 1998.

Testing was performed on groundwater and is not directly applicable to Hanford's LAW feed. Of possible note is that $SO4^{-2}$ was retained in the sorption media.

3.2.4 Purolite™ A530E

Purolite A530E has been investigated by DOE contractors in several different programs for remediation of ^{99}Tc. The sorption media is strong base anion, crosslinked with divinylbenzene. The formulation is selective for hydrophobic anions. The result is a sorption media that has high selectivity to perchlorate and pertechnetate ions. The bonding strength of media to pertechnetate makes elution difficult, and the vendor recommends a single pass system. The Purolite A530E is based on the biquat resin invented at ORNL by Gu, et al.[8] Like the Purolite A520E, it is a macroporous resin with a polystyrene crosslinked with divinylbenzene. The functional group is a quaternary ammonium pendant group. The resin is for perchlorate and pertechnetate removal. It has a capacity of 0.6 eq/L, a particle size of 300 to 1200 microns, and specific gravity of 1.7. (http://www.purolite.com/default.aspx?RelID=606288&ProductID=333)

3.2.4.1 Overview of Literature Reports for Purolite™ A530E

a) PNNL-19681, *Tc-99 Ion Exchange Resin Testing, Pacific Northwest Laboratory*, Pacific Northwest National Laboratory, Richland, Washington, 2010.

Testing was performed for CH2M Hill Central Plateau Remediation Company for removal of ^{99}Tc from groundwater. Although the solution processed was not applicable to Hanford LAW, the results of the work performed may be applicable depending on the method of disposal chosen for ^{99}Tc.

Goals for the work were to evaluate release of ^{99}Tc from the spent ion exchange resin after several years of storage, whether hot water stripping could be used to remove carbon tetrachloride from the spent resin without release of ^{99}Tc, and whether the sorption media could be encapsulated into a cementitious waste form. If it could be incorporated, what would the release rate of the monolith be due to weathering? The leachability study showed less than 0.02% of the ^{99}Tc released. The Purolite A530E also held onto the ^{99}Tc through the hot water wash. Encapsulation of spent resin in a cementitious material was not conclusive, and further testing is required to determine physical degradation caused by moisture loss and the effect of this degradation process on the release of ^{99}Tc.

b) RPP-RPT-23199, Rev 0, *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins,* CH2MHill Hanford Co. Richland, Washington, 2004.

[8] Gu, B.; G.M. Brown, P.V. Bonnesen, L. Liang, B. A. Moyer, R. Ober, and S. D. Alexandrotos, 2000, "Development of Novel Bifunctional Anion-Exchange Resins with Improved Selectivity for Pertechnetate Sorption from Contaminated Groundwater," Environmental Science and Technology, (Washington, DC) 34B, 1075-1080.

The goal of work documented here was to evaluate and compare candidate anion exchange resins for their capacity to remove ^{99}Tc from Basin 44 Reverse Osmosis (RO) reject stream. Due to the makeup of the solution processed, this work is not applicable to Hanford's LAW.

c) RPP-RPT-39195, Rev 1, *Assessment of Technetium Leachability in Cement-Stabilized Basin 43 Groundwater Brine,* Washington River Protection Solutions, Richland, Washington, 2009.

The solution tested was ~2.1 M sodium (Na), formulated to match the anticipated Basin 43 waste from the Effluent Treatment Facility (ETF), and is not directly applicable to Hanford's LAW. The report does show Purolite A530E as having a good leach index for ^{99}Tc.

3.2.5 Reillex™ HPQ (Vertellus®)

Reillex™[9] HPQ is a quaternary amine based resin on a cross-linked styrene divinyl-benzene backbone. The resin is in the form of spherical beads. The resin sinks in deionized water but will likely float in LAW feed. The resin is elutable with either 8 M HNO_3 or a 1M sodium hydroxide (NaOH), 1M ethylene diamine, 0.005M tin (Sn)(II) solution. The harsh eluants required for stripping may allow this media to perform as a non-elutable.

Figure 3-14. Reillex™ HPQ Resin

There is some concern with the vendor regarding degradation the sorption media at the pH range required for processing LAW feed. The concern has not been observed by the vendor or in testing performed on LAW feed.

3.2.5.1 Overview of Literature Reports for Reillex™ HPQ

a) CONF-9505101--1, *Batch Test Equilibration Studies Examining the Removal of Cs, Sr, and Tc from Supernatants from ORNL Underground Tanks by Selected Ion Exchangers*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1995.

Based on information provided in the report on the solutions tests, this report is applicable to the capture of ^{99}Tc by sorbent media from Hanford's LAW. The solution used for this work was supernatant samples from MVSTs W-29, see Table 3-7.

[9] Reillex products are trademarked by Vertellus Specialties, Inc., of Indianapolis, Indiana.

Table 3-7. Solution Properties (CONF-9505101—1)

Parameter	Units	W-29
NO3	gmol/L	4.5
Na	gmol/L	4.4
^{99}Tc	Ci	5.41E-07
Density	g/ml	1.226
pH	pH	13.2

Note: Units for NO_3^-, Na and ^{99}Tc have been converted to match those in Table 3-1.

The ^{99}Tc concentration was adjusted to a concentration near the average of 17 Hanford underground storage tanks. The report looked at four sorbent media for ^{99}Tc removal, as shown in Figure 3-15.

Figure 3-15. ^{99}Tc Batch Adsorption Data for MVST W-29 Supernate (CONF-9505101—1)

	Mixing time (h)			
	(2)		(24)	
Exchanger[b]	D (mL/g)	% R	D (mL/g)	% R
Reillex™ HPQ[c]	282	60	624	76
Reillex™ HPQ[d]	149	44	511	72
Reillex™ 402[c]	430	69	786	80
Reillex™ 402[d]	349	64	356	66
Amberlite™ IRA-904[c]	186	48	628	76
Amberlite™ IRA-904[d]	286	59	535	74
Amberlite™ IRA-400[c]	88	31	412	68

[a]Descriptions of the W-29 supernatant stock solution preparation and the batch-test procedure are given in the section entitled "TEST PROCEDURES."
[b]The ion exchangers are discussed in the section entitled "Exchangers Tested for Technetium."
[c]Hydroxide form of exchanger.
[d]Nitrate form of exchanger.

b) CONF-970148—3, Comprehensive Supernate Treatment, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1996.

Waste tested were from Oak Ridge National Laboratory MVST farm tanks W-25, W-27, and W-29. Waste was processed to remove ^{137}Cs first, ^{90}Sr second, and then ^{99}Tc using Reillex HPQ. Lambda-50 (λ_{50}) was stated as 45 BV. Elution was performed in 7 BV using a solution of stannous chloride, ethylenediamine, and sodium hydroxide.

c) Environmental Science & Technology, 34, 3761-3766, *Development of Bifunctional Anion-Exchange Resins with Improved Selectivity and Sorptive Kinetics for Pertechnetate: Batch-Equilibrium Experiments*, Oak Ridge National Laboratory, Oak

Ridge, Tennessee, and University of Tennessee, Knoxville, Tennessee, 2000.

Work was performed on groundwater, not directly applicable to Hanford LAW. Good technical information regarding sorption media.

d) K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*, Oak Ridge National Laboratory Chemical Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1995.

The results of the work performed are not representative to LAW feed mainly due to the differences in pH between the Newly Generated Liquid Low-Level Waste solution, ~7.4, and LAW feed ≥12. Results did show good K_d for Purolite A-530E, IONAC SR-7, and Reillex HPQ.

Oak Ridge National Laboratory reviewed Reillex HPQ for ^{99}Tc removal from its Newly-Generated Liquid Low-Level Waste. The resin was tested on two waste simulants. The simulant with the highest pH and salt concentrations is listed in Figure 3-3. Although the simulant has high pH, the concentrations of the salts are too low for accurate comparison with Hanford wastes. The report states the assumption that Reillex HPQ would perform well for a high salt concentration feed matrix.

e) RPP-RPT-23199, Rev 0, *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins,* CH2MHill Hanford Co., Richland, Washington, 2004.

The goal of work documented here was to evaluate and compare candidate anion exchange resins for their capacity to remove ^{99}Tc from Basin 44 Reverse Osmosis (RO) reject stream. Due to the makeup of the solution processed this work is not applicable to Hanford's LAW.

f) PNNL-11386, *Technetium in Alkaline, High-Salt, Radioactive Tank Waste Supernate: Preliminary Characterization and Removal*, Pacific Northwest National Laboratory, Richland, Washington, November 1997.

Work performed for this report directly supports the removal of ^{99}Tc from Hanford's LAW Immobilization feed.

The report is initial work performed by Pacific Northwest National Laboratory (PNNL) to study ^{99}Tc removal from Hanford tank waste supernate and ^{99}Tc oxidation state in the supernate. Actual SST and DST tank wastes were used.

- A composite DSSF:
  - 70% from Tank AW-101;
  - 20% from Tank AP-106;
  - 10% from Tank AP-102.
- Waste from Tanks AN-107, SY-101, ANS SY-103 that are distinguished by having a high concentration of organic complexants (complexant concentrate or CC waste type, often referred to as LAW waste feed envelop C).

Reillex HPQ was effective for ^{99}Tc removal from the composite DSSF waste, removing 93% on the first contact. The resin was ineffective for ^{99}Tc removal from the three CC wastes studied. Technetium removal from the CC wastes was in all cases less than 50%. The conclusion was that to remove ^{99}Tc from these wastes, the oxidation state of the ^{99}Tc species must be adjusted to create $TcO4^-$.

g) PNNL-11398, *Technetium Removal Column Flow Testing with Alkaline, High Salt, Radioactive Tank Waste*, Pacific Northwest National Laboratory, Richland, Washington, November 1997.

Hanford DST Waste from Tank AW-101 diluted to 5M Na with water. Waste was spiked with ^{99m}Tc in $TcO4^-$ form. The DF for recovery of ^{99m}Tc was 1,100; DF of ^{99}Tc from waste was six. Waste had more non-pertechnetate fraction than estimated based on organic concentration of waste (~2.5 g total organic compounds/L)

h) LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

The alkaline simulant used for this work is slightly low in ionic strength to be directly applicable to the processing of LAW waste and removal of ^{99}Tc. The simulant was based from on Tank SY-102, so it is applicable to some portion of Hanford's LAW feed. Three simulants where tested with only the alkaline solution of interest here, its matrix is shown in Figure 3-5. The results of the study with respect to ^{99}Tc and Reillex HPQ are best presented in Figure 3-6 and Figure 3-16. Elution of sorption media was not investigated.

Figure 3-16. Reillex™ HPQ Distribution Coefficients by Analyte (LA-12654 Rev.)

Table 32. Reillex™ HPQ Anion Exchange Resin: Distribution of 14 Elements from Three Simulant Solutions for Hanford Tank 102-SY

		Kd Value for Specified Time		
Solution	**Element**	**30 min**	**2 h**	**6 h**
Alkaline Supernate	Ce	<0.1	0.7	1.0
	Cs	<0.1	<0.1	<0.1
	Sr	0.4	0.6	0.6
	Tc	314	372	370
	Y	2.3	3.4	4.1
	Cr	0.1	0.2	0.2
	Co	2.2	2.7	2.7
	Fe	3.4	3.7	4.4
	Mn	14	18	26
	Zn	<0.1	<0.1	<0.1
	Zr	1.3	1.5	1.8
	U	0.2	0.4	0.7
	Am	4.5	7.5	21

i) LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

This report is directly applicable to ^{99}Tc removal from Hanford's LAW waste stream. The study builds off of previous work performed by LANL. The simulant used is based off neutralized current acid waste (NCAW), Figure 3-8. Results for Reillex HPQ are best represented by Figure 3-9 and Figure 3-17.

Figure 3-17. Reillex™ HPQ Distribution Coefficients by Analyte (LA-12863)

Table 39. Reillex™ HPQ Anion Exchange Resin: Distribution of 15 Elements from Simulated Hanford DSSF Solution

	Kd Value for Specified Time		
Element	**30 min**	**2 h**	**6 h**
Ce	<0.1	1.2	7.4
Cs	2.4	0.5	0.5
Sr	2.8	0.7	0.8
Tc	254	293	332
Y	5.3	11	25
Cr	2.5	0.7	0.8
Co	1.9	1.1	1.6
Fe	2.5	1.8	2.3
Mn	4.1	8.5	12
Ni	<0.1	2.5	10
V	1.4	0.3	0.3
Zn	1.6	0.6	0.9
Zr	1.7	1.4	2.3
U	1.5	0.4	0.9
Am	3.9	5.7	10

j) LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

This report is directly applicable to 99Tc removal from Hanford's LAW waste stream. The study builds off of previous work performed by LANL. The simulant used is based off neutralized current acid waste (NCAW), Figure 3-11. Results for Reillex HPQ are best represented by Figure 3-12 and Figure 3-18.

Figure 3-18. Reillex™ HPQ Distribution Coefficients by Analyte (LA-12889)

Table 38. Reillex™ HPQ Anion Exchange Resin: Distribution of 12 Elements from Simulated Hanford NCAW Solution

	Kd Value for Specified Time		
Element	**30 min**	**2 h**	**6 h**
Cs	0.1	<0.1	<0.1
Sr	0.2	0.3	0.3
Tc	382	459	445
Y	2.3	3.4	4.0
Cr	<0.1	<0.1	<0.1
Co	0.2	0.2	0.3
Fe	1.1	1.0	1.0
Mn	1.5	1.9	2.3
Ni	2.2	2.5	5.1
V	<0.1	<0.1	<0.1
Zn	<0.1	0.1	0.1
Zr	0.4	0.8	0.8

k) WHC-SD-WM-TI-699, Rev. 1, *Technical Basis for Classification of Low-Activity Waste Fraction from Hanford Site Tanks*, Westinghouse Hanford Company, Richland, Washington, 1996.

The report has a section on "Technology Options" for "Technetium-99 Removal". The implementation of sorption media looked at Reillex-HPQ, eluted with 6 M HNO3. The conclusion was that the method was only applicable for removal of Tc(VII), and therefore not technically feasible for their goals.

l) WHC-SD-WM-TI-718, *Technetium Removal: Preliminary Flowsheet Option*s, Westinghouse Hanford Company, Richland, Washington, 1995.

Work document contains a preliminary investigation for flowsheets targeting the removal of ^{99}Tc from Hanford's tank wastes. Several different ^{99}Tc removal technologies were reviewed: sorption, precipitation, volatilization, and alkaline sulfide precipitation. Reillex™ HPQ sorption media was selected for their flowsheet work with two eluants reviewed – 1) nitric acid and 2) a solution of stannous chloride, ethylenediamine, and sodium hydroxide.

m) WSRC-MS-98-00601, *Pretreatment/Radionuclide Separations of Cs/Tc from Supernates*, Westinghouse Savannah River Company, Aiken, South Carolina, 1998.

The document is a brief status on separations work for Cs and ^{99}Tc. The report states that an algorithm was developed to predict K_d values for Reillex HPQ regarding Hanford's supernates with values ranging from 500 – 600 for most; lower for supernates containing CC. Elution was stated as requiring a strong HNO_3 solution, with 8 M HNO_3 not having complete removal. Complete elution was achieved with a Sn(II) and ethylenediamine solution.

n) WSRC-TR-99-00317, *Qualification of Reillex™ HPQ Anion Exchange Resin for Use in SRS Processes*, William J, Crooks III, et. Al., Westinghouse Savannah River Company, Aiken, SC, 2000.

The report documents testing required for using Reillex in HNO_3 solution at the DOE's Savannah River Site (SRS) for the loading of plutonium (Pu). Therefore the data presented is not readily applicable to Hanford's LAW feed. Testing was performed to understand low temperature exotherms from the diethylbenzene - 8 M HNO_3 reaction. A low-temperature exotherm was observed, generating nitric oxide (NO), carbon dioxide (CO2), and a mixture of mono- and dicarboxylic acids as reaction products. One conclusion is that Reillex HPQ contains a small amount of easily-oxidized material. A pretreatment process was developed to remove oxidizable constituents of the media, which showed comparable particle size distribution and Pu loading performance. Since TcO_4^- is elutable from Reillex HPQ with 8M HNO3, it may be applicable for understanding the safety of the system during elution and the number of time the sorption media could be regenerated.

3.2.6 TAM™ or Sn(II) Apatite Microspheres (Kurion, Inc)

TAM™[10] was developed to take advantage of the properties of Sn(II)apatite on a sorption media base. This product is fairly new and not much literature is available for it. Both articles below concern the media (Sn(II)apatite), but not in a sorption media form as presented by Kurion. Kurion replied fully to a questionnaire regarding its product. The questionnaire coupled with results from testing on more dilute solutions showing that Sn(II)apatite binds ^{99}Tc well to its matrix, resulted in its inclusion in this study.

3.2.6.1 Overview of Literature Reports for TAM

a) PNNL-14208, *Selection and Testing of "Getters" for Adsorption of Iodine-129 and Technetium-99: A Review*, Pacific Northwest National Laboratory, Richland, Washington, 2003.

The goal of this study was to identify suitable "getter" materials that can immobilize or delay the transport of anionic radionuclides (such as ^{129}I and $^{99}TcO4$) that would be released from physically and chemically degrading waste packages. The solutions tested are not applicable to Hanford's LAW.

b) RPP-RPT-39195, *Assessment of Technetium Leachability in Cement-Stabilized Basin 43 Groundwater Brine*, Washington River Protection Solutions, Richland, Washington, 2009.

The solution tested was ~2.1 M Na, was formulated to match the anticipated Basin 43 waste from the ETF, and is not directly applicable to Hanford's LAW. The report does show Sn(II)apatite as having a good leach index for ^{99}Tc.

[10] TAM products are manufactured by Kurion, Inc. of Irvine, California.

3.2.7 SuperLig® 639 (IBC Advanced Technologies, Inc.)

Figure 3-19. SuperLig® 639 Resin

SuperLig®[11] 639 was selected by BNFL as the ^{99}Tc ion exchange media for the ^{99}Tc removal column as part of the Tank Waste Remediation System (TWRS now known as WTP) project. The ^{99} removal process step was later removed with the implementation of an alternative ^{99}Tc immobilization strategy. Up to that, point SuperLig 639 was extensively tested at laboratory scale on simulants and actual waste representative of three envelopes of waste feed (A, B and C). The composition of these envelopes is found in 24590-WTP-RPT-PT-02-005, Rev 1. The key parameter of the three envelopes regarding ^{99}Tc removal is organic content. Tanks with relatively high organic content were designated as containing envelop C waste. Roughly 70% of the ^{99}Tc found in envelope C is not in the VII oxidation state, and not amenable to capture via sorption media. The SuperLig 639 resin was extensively tested at pilot scale, and its radiation resistance has also been evaluated.

The active component in the resin is a complexant specifically designed to remove ^{99}Tc in its +7 (VII) oxidation state, TcO_4^-. The beads are of sufficiently high density such that they do not float in media 1.25 to 1.27 g/cc.

The resin has been tested at lab scale and pilot scale. Key findings are:

- The resin shows a high removal efficiency, with K_ds in the order of 400 being routinely achieved for TcO_4^-;
- Sorption is best accomplished in the temperature range of 5°C to 40°C as the binding constant decreases with increased temperature;
- Processing rate is at 0.05 BV per min for >99% ^{99}Tc removal (as is washing and elution). Increasing this rate leads to early break through;
- The resin met the average >80% removal criteria for WTP LAW Vitrification feed;
- Elution requires approximately 10-15 BV at a flow rate of 0.1 BV per minute;

[11] SuperLig products are manufactured by IBC Advanced Technologies, Inc., of American Fork, Utah.

- There must be sufficient counter ions to the TcO_4^- anion (Na^+, K^+ or H^+) present in the solution;
- Early trials suggested that the initial performance degradation of the resin begin with exposure levels of $1x10^7$ Rads; Further trials indicated that the resin was resistant to significant damage at $1x10^8$ Rads, which is consistent with SuperLig 644 and polystyrene resins in general;
- Selectivity over hydroxide, chloride, fluoride, and bromide is nearly infinite. Selectivity over 2-3 M nitrate (NO_3^-) and (NO_2^-) nitrite is of multiple orders of magnitude, such that there is minimal effect on TcO_4^- binding up for Hanford's LAW;

3.2.7.1 Overview of Literature Reports for SuperLig® 639

a) BNF-003-98-0140, *Evaluation of SuperLig® 639 Ion Exchange Resin for the Removal of Rhenium from Hanford Envelope A Simulant*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

This report showed 90 to 150 BV to 50% breakthrough when the flow rate was in the correct range, demonstrating again the need for the correct flow rate. The elution is accomplished to 0.1 C/Co at 16 BV. The column bed design in this test had too much head space. The report included important statements such as "Tests highly successful in demonstrating effectiveness of this method for removing TcO4- from Hanford Tank Waste"; "No significant problems encountered which would prevent use of this resin as planned"; "No observations of cracking or swelling of the resin bed" are made.

b) BNF-003-98-0146, Rev. 1, *Small-Scale Ion Exchange Removal of Cesium and Technetium From Hanford Tank 241-AN-103*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000

Waste from tank AN-103 is designated as WTP envelop A feed. The Tc K_d reported was 471+/- 35 ml/g, λ_{50} was estimated at 221+/- 16 BV, and >97% removal of Tc was achieved. When the lead column breakthrough was 47% (270 BV) the corresponding lag column had 8% breakthrough – assumed to be due to resin floating in lag column.

c) BNF-003-98-0219, Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

This report concerns Envelope C feeds with very high organics and very low TcO_4^- percentages of the ^{99}Tc present. This report confirms that only the TcO_4^- will be removed as per the design of the ligand of the SuperLig 639 resin.

d) BNF-003-98-0230, *Intermediate-Scale Ion Exchange removal of Technetium from Savannah River Site Tank 44 F Supernate Solution*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

The solution tested was chosen to due to its similarity to Hanford LAW envelope A feed. This report is applicable to ^{99}Tc removal from Hanford's LAW. The results of this work are best summarized by Figure 3-20. Testing was performed using one column with the goal of determining 45% breakthrough, which required ~500 BV.

Figure 3-20. Batch Contact Data (BNF-003-98-230)

SuperLig® 639 K_d Measurements		
ICP-MS Analysis		
Resin Batch #981015DHC720011		
Sample #	SRS-1	SRS-1-D
ADS #	300132736	300132737
Solution Mass (g)	15.94	16.22
Resin Mass (g)	0.1217	0.1201
Solution Volume (mL)	13.28	13.52
Initial Tc Conc. (mg/L)	3.09	3.09
Final Tc Conc. (mg/L)	0.3274	0.32567
Kd (mL/g)	**932.8**	**967.5**
solution volume/exchanger mass	109.15	112.55
Shake Time (hrs)	**24.0**	
Temperature (C)	27-28	
Average Kd (mL/g)	**950.1**	
% Tc removal	89.4	89.5
average % Tc removal	89.4	
Feed		
Sample	SRS-1-FD	
ADS #	300132738	
Tc-99 mg/L	3.09	

e) BNFL-RPT-009, Rev 0, *Ion Exchange Distribution Coefficients for 137Cs and 99Tc removal from Hanford Tank Supernatants AW-101 (Envelope A) and AN-107 (Envelope C)*, Pacific Northwest Laboratory, Richland, Washington, 1999.

Results from a Tank AN-107 sample show that SuperLig 639 is not effective at capturing ^{99}Tc present in forms other than the TcO_4^- form (as stated by the supplier). The analysis stated that 75-78% of the Tc in the Tank AN-107 solution was not in the TcO_4^- form. The analysis also determined that approximately 2.9% of the ^{99}Tc in the Tank AW-101 sample was not in the TcO_4^- form. The reported K_d values from the Tank AW-101 sample were 450 – 500 ml/g.

Figure 3-21. ^{99}Tc K_ds for SuperLig® 639 for Tank AW-101 Waste (BNFL-RPT-009)

	SL-639 & AW-101									
Sample ID	W39	W39-R	W39-D	W39-D-R	W39-S1	W39-S1-R	W39-S1D	W39-S2	W39-S2-R	W39-S2D
Average Temperature [°C]	21	21	21	21	21	21	21	21	21	21
Mass of Exchanger [g]	0.0499	0.0499	0.0509	0.0509	0.0510	0.0510	0.0491	0.0502	0.0502	0.0504
Mass of AW-101 [g]	6.6903	6.6903	6.7034	6.7034	6.5986	6.5986	6.5231	6.5587	6.5587	6.6921
Avg. Density of AW-101 [g/mL]	1.3176	1.3176	1.3176	1.3176	1.3176	1.3176	1.3176	1.3176	1.3176	1.3176
Volume of AW-101 Taken [mL]	5.0776	5.0776	5.0876	5.0876	5.0080	5.0080	4.9507	4.9778	4.9778	5.0790
F-Factor	0.9855	0.9855	0.9855	0.9855	0.9855	0.9855	0.9855	0.9855	0.9855	0.9855
Init. ICP ^{99}Tc Conc. [ng/mL]	268.7	266.0	268.7	266.0	2070.0	2070.0	2070.0	7820.0	7820.0	7820.0
Initial Dilution Factor	20.0	20.5	20.0	20.5	20.0	20.0	20.0	20.0	20.0	20.0
Initial ^{99}Tc Conc. [ng/mL]	5373.3	5460.2	5373.3	5460.2	41400.0	41400.0	41400.0	156400.0	156400.0	156400.0
Initial ^{99}Tc Conc. [M]	5.43E-05	5.52E-05	5.43E-05	5.52E-05	4.18E-04	4.18E-04	4.18E-04	1.58E-03	1.58E-03	1.58E-03
Initial ^{99}Tc Conc. Ci/m^3 (uCi/mL)	9.13E-02	9.28E-02	9.13E-02	9.28E-02	7.04E-01	7.04E-01	7.04E-01	2.66	2.66	2.66
NO_3^- concentration, M	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Initial NO_3^-:^{99}Tc	3.67E+04	3.61E+04	3.67E+04	3.61E+04	4.76E+03	4.76E+03	4.76E+03	1.26E+03	1.26E+03	1.26E+03
Initial NO_3^-:TcO_4^-	3.78E+04									
Fin. ICP ^{99}Tc Conc. [ng/mL]	56.4	43.7	55.8	40.8	343.5	395.0	337.8	2039.5	1940.0	1669.0
Final Dilution Factor	20.0	20.6	20.0	20.7	20.0	20.3	20.0	20.0	20.8	20.0
Final ^{99}Tc Conc. [ng/mL]	1128	898	1116	846	6870	7999	6756	40790	40283	33380
Final ^{99}Tc Conc [M]	1.14E-05	9.07E-06	1.13E-05	8.55E-06	6.94E-05	8.08E-05	6.82E-05	4.12E-04	4.07E-04	3.37E-04
Final NO_3^-:^{99}Tc	1.75E+05	2.19E+05	1.77E+05	2.33E+05	2.87E+04	2.46E+04	2.92E+04	4.83E+03	4.89E+03	5.90E+03
Final ^{99}Tc Conc. Ci/m^3 (uCi/mL)	1.92E-02	1.53E-02	1.90E-02	1.44E-02	1.17E-01	1.36E-01	1.15E-01	6.93E-01	6.85E-01	5.67E-01
fraction Tc removed	0.79	0.84	0.79	0.85	0.83	0.81	0.84	0.74	0.74	0.79
^{99}Tc Kd [mL/g]	388.6	524.5	386.9	553.1	500.6	415.8	524.7	284.9	289.7	377.0
assumed nonpertechnetate fraction	0.029	0.029	0.029	0.029	3.74E-03	3.74E-03	3.74E-03	1.01E-03	1.01E-03	1.01E-03
Final TcO_4^- concentration, M	9.83E-06	7.48E-06	9.71E-06	6.96E-06	6.78E-05	7.92E-05	6.67E-05	4.10E-04	4.05E-04	3.36E-04
Final NO_3^-:TcO_4^-	2.02E+05	2.66E+05	2.05E+05	2.86E+05	2.93E+04	2.51E+04	2.98E+04	4.85E+03	4.91E+03	5.93E+03
TcO_4^- Kd [mL/g]	450.4	635.8	449.2	679.3	512.1	424.0	537.0	286.0	290.9	378.8

f) BNFL-RPT-016 Rev 0., *Small Column Testing of SuperLig® 639 for Removing ^{99}Tc From Hanford Tank Waste Envelope A (Tank 241-AW-101)*, Battelle, Pacific Northwest Division, Richland, Washington, 2000.

Testing reported 97% of the ^{99}Tc is removed, with the other 3% of ^{99}Tc being at lower oxidation states (note that this is in contradiction with the 15-20% non-pertechnetate form observed in AW-101 samples used for work in PNNL-11398). The 50% breakthrough point was reached at 213 BV on the lead column, and 260 BV for 60% breakthrough. The lag column performed well as a polishing column. The ^{99}Tc concentration in the product was 5.1 µCi/liter, less than 20% of the 26.8 µCi/liter allowable (this included the 3% non- TcO_4^- form). The maximum DF for TcO_4^- only is reported as 433. The eluent used for this work was not the WTP planned eluent -- this work used 0.5 M HNO_3 and led to a long, drawn out elution. The column design was also poor with undesired head space leading to large volumes of working solutions to clean the column of Al, Na, K, etc. from the feed. Despite the less than optimum configuration and procedure, data ^{99}Tc is effectively removed from the Envelope A tank waste.

g) BNFL-RPT-022, Rev. 0, *Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank Waste Envelop C (Tank 241-AN-107)*, Battelle, Pacific Northwest Division, Richland, Washington, 2000.

The report states that 65% to 87% of TcO_4^- is removed by tracking the $^{95m}TcO_4^-$ tracer, however review of total ^{99}Tc removed showed only 11% to 22% removal; indicating that envelope C wastes (containing CC) exhibit poor ^{99}Tc removal using sorption media.

h) BNFL-RPT-0028 Rev 0, *Analysis of Spent Ion Exchange Media: SuperLig® 639 and SuperLig® 644*, Battelle, Pacific Northwest Division, Richland, Washington, 2000

The report identifies residual amounts of components on resins after loading and elution tests to support disposition of the spent resin. The SuperLig 639 had two elements above the minimum reportable quantities, ^{99}Tc and K, despite the fact that the elution was only run at 50 °C with a feed that had significant K present. These conditions led to the elution being reported as less than optimal.

i) SRTC-BNFL-013 Rev 0, *Evaluation of the Radiation Stability of SuperLig® 639*, Westinghouse Savannah River Company, Aiken, South Carolina, 1997.

Testing performed exposed SuperLig 639 to a cobalt 60 (^{60}Co) gamma source for evaluation of loss in effectiveness. The data reported in this report are more than an order of magnitude better than previously reported. According to this report, no degradation occurs until the SuperLig® 639 sees 1 x 10^8 Rads; 50% degradation occurs at 1 x 10^8 Rads; and 90% at 1 x 10^9 Rads. Based on this data alone, these results would give a significantly longer life than even that BNFL which was proposing. If ^{137}Cs where not to be removed prior to ^{99}Tc removal SuperLig 639 degradation would be similar to that of SuperLig® 644; since ^{99}Tc removal will be post ^{137}Cs removal, degradation of the resin due to radiation is improbable.

j) WSRC-MS-2000-00499, *Comprehensive Scale Testing of the Ion Exchange Removal of Cesium and Technetium from Hanford Tank Wastes*, CH2MHill Hanford Group, Richland, Washington, 2000.

Lab and pilot scale removal of ^{99}Tc or rhenium (Re) (as ^{99}Tc simulant) from Tank AN-103 waste and a Tank AN-105 simulant was performed. Flow rate is shown to be important to proper removal. When the flow rates exceed 7 column volumes (CV) per hour (exceeding the optimal 0.1 CV/minute), breakthrough occurs early. However, when the flow rates are in the correct range, loading volumes to 50% breakthrough are in the 100s of BV. The report also states that the results (under the proper flow rates) met all conditions required at Hanford. In addition, the report states that the NO_3^- to TcO_4^- ratio is higher than that expected at Hanford, and that these results may not apply to even higher NO_3^- to TcO_4^- ratios. The one negative is that this test was done prior to increasing the density of the SuperLig 639 so that it would not float. Therefore, it is mentioned that floating of the resin may affected the sharpness of the curve. Also, the early ^{99}Tc polishing was not quite as high as in the batch equilibrium tests.

k) WSRC-MS-2001-00573, *SuperLig® 639 Equilibrium Sorption data for Technetium from Hanford Tank Waste Supernates*, Westinghouse Savannah River Company, Aiken, South Carolina, 2001.

Pertechnetate % removals calculated for the initial contacts were approximately 87, 91, and 89 % for the AN-103, AZ-102, and AN-102 samples, respectively. For the AN-102 sample, the % removal for total technetium for the initial contact was <30%, due to the fact that ~60% of the 99Tc was not TcO4-. The lower loadings observed for the AZ-102 sample indicates that resin performance varies directly with the ionic strength of the solution (AZ-102 had a roughly half the amount of Na in solution; resin performance increases with increasing ionic strength of the solution). The Kd values for Hanford tank wastes AN-103, AZ-102, and AN-102 were 530, 886, and 287 mL/g, respectively

Table 3-8. Concentrations of Selected Analytes in the Hanford Tank Waste Supernates (WSRC-MS-2001-00573)

Sample	Equilibrium TcO_4^- (M)	TcO_4^- K_d (mL/g)	TcO_4^- loading (mmol/g)
Tank AN-103			
Spike	4.24 E-05	452	1.92 E-02
Initial contact	3.93 E-06	530	2.06 E-03
1st Recontact	4.86 E-07	714	3.46 E-04
2nd Recontact	8.95 E-08	459	4.08 E-05
Tank AZ-102			
Initial contact	1.43 E-05	886	1.27 E-02
1st Recontact	1.21 E-06	982	1.17 E-03
2nd Recontact	1.62 E-07	548	7.98 E-05
3rd Recontact	1.72 E-08	1109	1.11 E-05
Tank AN-102			
Spike	6.39 E-05	288	1.83 E-02
Initial contact	5.14 E-06	281	1.43 E-03
1st Recontact	1.21 E-06	332*	4.03 E-04
2nd Recontact	2.00 E-06	NA	NA

* Value calculated from a single batch contact experiment rather than the average of duplicate experimental results. NA = not applicable; K_d and loading values were not calculated for this experiment because the data indicated that no technetium was adsorbed to the resin.

l) WSRC-MS-2001-00760, *Technetium Removal from Hanford and Savannah River Site Actual Tank Waste Supernates with SuperLig 639 Resin,* Westinghouse Savannah River Co., Aiken, South Carolina, 2001.

^{99}Tc was removed prior to removal of ^{137}Cs with SuperLig 644. The AN-103 sample, lead/lag column configuration, had ^{99}Tc removal of 92.6% (DF of 13.5). Analysis showed that SuperLig 639 extracts ^{99}Tc as an ion pair (KTcO4 or NaTcO4). Several issues where observed that resulted in data scatter, beads floating and column diameter less than optimal (due to amount of solution available for elution).

Comparison of the breakthrough data for a Savannah River sample from tank 44F verses the AN-103 sample (containing comparable sodium and pertechnetate concentrations) showed that SuperLig 639 had twice the capacity for Tank 44F solution, see table XXX. Either tank 44F's elevated OH- level and/or low nitrate concentration in this sample resulted in significantly enhanced pertechnetate removal.

Table 3-9. Hanford AN-103 vs. Savannah River 44F (extracted from WSRC-MS-2001-00760)

Analyte	Tank 44F	Tank AN-103
Na^+	5.4 M	4.99 M
NO_3^-	0.495 M	0.998 M
OH^- (free)	4.5 M	1.87
^{99}Tc	3.13 E-5	3.07 E-5
~ 45% Breakthrough	580 BV	270 BV

m) WSRC-MS-2003-00789, *Multiple Ion Exchange Column Tests for Technetium Removal from Hanford Tank Waste Supernate (U)*, Westinghouse Savannah River Company, Aiken South Carolina, 2003.

This report presents the results of ^{99}Tc removal from Tank AW-101 waste through five cycles of loading. The average ^{99}Tc loading for the cycles was 250 BV at 10% breakthrough. Removal of ^{99}Tc was greater than 99.4%, and 99% of the ^{99}Tc loaded on the resin was elutable with less than 15 BV of de-ionized water at 65 °C.

n) WSRC-MS-2003-00792, *Column Performance Testing of SuperLig® 639 Resin with Simulated Hanford Waste Supernates: Identification of the Primary Sorbing Species and Detailed Characterization of Their Desorption Profiles, Savannah River Technology Center*, Westinghouse Savannah River Company, Aiken, South Carolina, 2003.

Envelope A and B simulants show Re loaded well with over 200 BV to 50% breakthrough. The envelope C (containing organics) simulant resulted in lower ^{99}Tc oxidation states and subsequently poorer resin loading. Elution with hot water worked well with removal of potassium nitrate (KNO_3) harder than sodium nitrate ($NaNO_3$); also potassium perrhenate ($KReO_4$) eluted later than sodium perrhenate ($NaReO_4$). The manufacturer, IBC Advances Technologies, Inc., has stated that potassium (K) salts bind more strongly and require elution

with higher temperature water. The presence of K led to more Re (^{99}Tc) binding and not less. The data on the elution in this paper shows why elution with hot water is necessary. It is not a selectivity problem, rather a stronger equilibrium constant involved -- when K is present the $KTcO_4$ simply becomes the strongest binder. Roughly the same selectivity for $KTcO_4$ over KNO_3 exists as for $NaTcO_4$ over $NaNO_3$, etc.

o) WSRC-TR-2000-00302, *Summary of Testing of SuperLig® 639 at the TFL Ion Exchange Facility*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

This was pilot scale testing, designed to reach λ_{50} at 100 BV. The lead column removed 72% of the perrhenate, 24% was removed from the lag column. The simulant was at 18°C, modeling AN-105 waste. Data was obtained was used to assess the VERSEion exchange computer model which was to be used for design and optimization of WTP Tc removal facility. All runs exceeded 100 BV to 50% breakthrough, and DF was as high as 300.

p) WSRC-TR-2000-00303, Rev 0, *Demonstration of an Ion Exchange Resin Addition/Removal System with SuperLig® 659*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

This report focuses on testing the design of the ^{99}Tc removal media slurry system for the WTP. It utilizes SuperLig 659 in lieu of SuperLig 639 due to resin availability. The report is not directly applicable to efficiency of SuperLig 639 for ^{99}Tc removal, but would aid in the development of a removal system.

q) WSRC-TR-2000-00305, *Preliminary Ion Exchange Modeling for Removal of Technetium from Hanford Waste Using SuperLig® 639 Resin*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

Very comprehensive report for ion exchange as it would be implemented by WTP. The report is a represents a status on regarding the modeling of technetium removal using SuperLig 639. Twenty bench-scale column tests and approximately 88 batch equilibrium experiments are addressed. Data was also used to quantify the offset between Re and Tc.

r) WSRC-TR-2000-00419, Rev 0, *Small-Scale Ion Exchange Removal of Cesium and Technetium form Envelope B Hanford Tank 241-AZ-102*, Westinghouse Savannah River Company, Aiken, South Carolina, 2001.

Testing resulted in 170 BV on the lead column with a breakthrough of 9.8%. Breakthrough of 50% was projected to occur at 450 BV. Removal rate was 99.97% with a polishing column at over 127 BV. Elution was performed with water at room temperature elution, leading to higher than normal elution volumes.

s) WSRC-TR-2000-00420, *Intermediate-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

This report is about Envelope C feeds containing high organics and very low TcO_4^- percentages of the ^{99}Tc present. It confirms that only the TcO_4^- will be removed as per the design of the ligand of the SuperLig 639 resin.

t) WSRC-TR-2000-00424, Rev 0, *Tank 241-AZ-102 SuperLig® 639 Technetium Ion Exchange Eluate Evaporation Study*, Westinghouse Savannah River Company Aiken, South Carolina, 2000.

This report deals with the eluent from the SuperLig 639 after the separation. It shows that with eluent containing only water plus dilute NaOH (from the wash) and a little $NaNO_3$, the ^{99}Tc volatilizing in an evaporator is not an issue. This problem is mentioned specifically with other competing technologies that have to use at least some NO_3^- in the elution. This result is a specific example of an advantage to the SuperLig 639 beyond its performance in ^{99}Tc removal itself.

u) WSRC-2002-TR-00495, Rev 0, *Evaluating the Effects of Tri-Butyl Phosphate (TBP) and Normal Paraffin Hydrocarbon (NPH) in Simulated Low-Activity Waste Solution on Ion Exchange*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, 2002.

The solution was a WTP Envelope B AZ-101 filtrate simulant which had been used in ultrafiltration work using Re as a surrogate for ^{99}Tc. Two variations on the simulant were used: Simulant 0 - was the baseline filtrate, and Simulant H - was spiked with organics resulting in 2500µg/ml tri-butyl phosphate (TBP) and 2500µg/mL of normal paraffin hydrocarbon (NPH). No statistical difference in the performance of SuperLig 639 to remove ^{99}Tc was observed between the simulants - either batch contact λ values or column loading λ values. This work shows that the presents of organics by itself is not an indicator of ^{99}Tc (pertechnetate) removal effectiveness.

WSRC-TR-2003-00098, Rev 1, *Multiple Ion Exchange Column Runs for Cesium and Technetium Removal from AW-101 Waste Sample (U)*, Savannah River National Laboratory, Westinghouse Savannah River Company, Aiken, South Carolina, 2004. Approximately 250 BV of AW-101 of solution was processed at < 10 % breakthrough of ^{99}Tc. The percent of ^{99}Tc (pertechnetate) removal was > 99.94% (DF of about 1700) for each of the five cycles. Approximately 99% of the ^{99}Tc was eluted from resin in < 15 BV using de-ionized water at 65 °C.

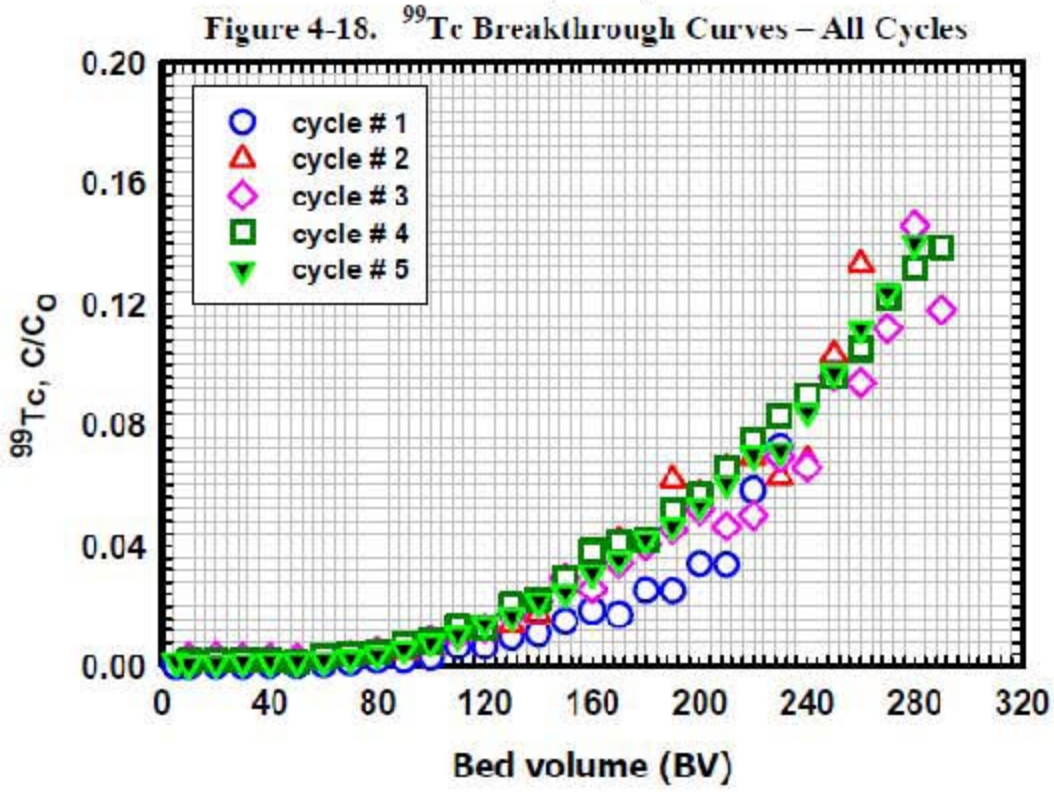
Figure 3-22. Equilibrium Distribution Coefficient Table for Tc Removal (WSRC-TR-2003-00098, Rev 1)

Table 4-2. K_ds for Technetium in AW-101 Actual Waste Sample

AW-101 Actual Waste Sample ID	phase ratio, mL/g	$[^{99}Tc]_0$ (µCi/mL)	$[^{99}Tc]_0$ (µCi/mL)	K_d (mL/g)	avg. K_d (mL/g)	% RSD
NH39-AW101-Kd-1	96	4725	492	839	na	na
NH39-AW101-Kd-1D	90	4725	508	766	802	6.4
NH39-AW101-Kd-2	9.5	4725	190	231	na	na
NH39-AW101-Kd-2D	9.5	4725	181	245	238	4.1

na = not applicable

Figure 3-23. Breakthrough Curves for SuperLig 639 on AW-101 Waste (WSRC-TR-2003-00098, Rev 1)



v) WTP-RPT-024, Rev 0 (PNWD-3239), *Radiation Stability Testing of SuperLig®639 and SuperLig®644 Resins*, Battelle, Pacific Northwest Division, Richland, Washington, 2003.

No change in the SL-639 Tc batch-equilibrium coefficient was observed until it was exposed to doses of greater than 10^7 R, and the changes were relatively minor even up to 10^8 R. This result is similar to that reported in the previous radiolysis study by Oji (SRTC-BNFL-013). Concentrations of benzene, toluene and xylene VOCs positively identified in the gases generated from the SL-639 resin increased with increasing temperature but there was no trend with dose. On the basis of the results from this report, the resin would only begin to show signs of deterioration in performance after 10,700 or 8,770 cycles processing envelope A or B LAW, respectively.

w) WTP-RPT-030, *Rev 0, Small Column Testing of SuperLig® 639 for Removing ^{99}Tc from Hanford Tank Waste Envelope A (Tank 241-AP-101)*, Battelle, Pacific Northwest Division, Richland, Washington, 2002.

Tank 241-AP-101 dilute feed is treated to remove ^{99}Tc on lead/trail system. 220 BV are treated with 50.1 µCi/liter reduced to 0.477 µCi/liter, which is over 99% removal. At end of 220 BV 5.2% breakthrough of lead column and 0.5% breakthrough of lag column. An initial DF of 230 was reported. Analysis of the eluant shows that after 17 BV of flushing a C/C_o of 0.01 was achieved. Testing was considered a complete success.

x) WTP-RPT-031, Rev 1, *Small Column Testing of SuperLig 639 for Removing ^{99}Tc from Hanford Tank Waste 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids (Envelope D) Wash and Permeate Solutions*, Battelle, Pacific Northwest Division, Richland, Washington, 2004.

This report is about Envelope C feeds with very high organics and low TcO_4^- percentages of the ^{99}Tc present. It confirms that only the TcO_4^- will be removed as per the design of the ligand of the SuperLig 639 resin.

y) WTP-RPT-047, Rev 0, *Chemical Degradation of SuperLig® 639 Ion Exchange Resin*, Battelle, Pacific Northwest Division, Richland, Washington, 2003.

Work performed included 26 cycles of operation of a single SuperLig 639 column with a variety of ^{99}Tc, NO_3^- and NO_2^- concentrations. The bed performance was hampered due to channeling for some of cycles. For this reason, not all test objectives could be met. However, data and conclusions reported show that there is no degradation by radiation or chemical attack over the 26 cycles (a result also shown by microscopic review of the resin) and no change in breakthrough curves or elution curves over the 26 cycles (other than issues with channeling). Breakthrough of 20-30% was seen at >200 BV in all cases where channeling was not significant. In elutions where channeling was avoided, 0.01 C/Co was obtained in 10 to 18 BV elution. The spent resin after 26 cycles had 0.69 µg/g ^{99}Tc or 5.86 mCi/m^3, which was reported as well below Hanford Site Solid Waste Acceptance. No toxicity issues were found in the spent resin. Nitrate and nitrite were found to compete with ^{99}Tc for resin sites.

z) WTP-RPT-058, Rev 1, *Small Column Testing of SuperLig® 639 for Removing ^{99}Tc from Hanford Tank Waste Envlope B (Tank 241-AZ-101)*, Battelle Pacific Northwest Division, Richland, Washington, 2004.

This report shows Envelope B ^{99}Tc removal from Tank AZ-101 waste. The results show the K_ds holding or increasing for increasing nitrate to TcO_4^- ratio, demonstrating the good selectivity of the resin. The 50% breakthrough point was 300+ BV, and the trail column maintained 0.1% or less C/Co for 300 BV. A 0.1 M NaOH solution was used to prepare the column for feed solution. It worked but was found to be low in total Na and hydroxide content for best performance. A 65 °C de-ionized water elution was used, and the ratio of TcO_4^- remaining on the resin was at 0.1 C/C_o at 9 BV elution and 0.01 C/Co at 16 BV despite the influent having a low C_o value. Performance of work was described as "progressed without difficulties".

4 CONCLUSION

A literature search has been performed for work regarding the removal of ^{99}Tc from Hanford's LAW using sorption media. Past work and SMEs were used to narrow the list to a manageable number for more thorough review. For final comparison the sorption media have been split into two logical classifications -- elutable and non-elutable. Sorption media have been evaluated based on technical development, with criteria for a 10 being 100% confidence of the media and system achieving all technical performance requirements upon implementation. Safety, environmental and economic aspects of the media have not been included. Work performed and documented in the references focus on technical feasibility. Both economics and safety will ultimately play a large role in the selection of the process and sorption media to be implemented.

The goal for the team was to rank the sorption media on the same scales, and then split them into two groups. The lower scores for non-elutable sorption media largely reflect the fact that the WTP path to ^{99}Tc removal required the use of elutable sorption media. Therefore, far more data exists for deployment of elutable sorption media than for non-elutable sorption media with Hanford LAW feed. Except for perhaps the case of SuperLig 639, the scores are best used as a rough guide to those sorption media that will likely perform well based on knowledge gathered to date, and not as a tool to select a final resin for implementation.

Rough rankings of elutable sorption media are outlined in 4-1. Due to previous work supporting the implementation of SuperLig 639 at WTP, it would be the clear sorption media of choice. Given that the system will not be implemented for some time, further investigation of ABEC 2000 may show it to be an equal competitor to SuperLig 639. Both SuperLig 639 and ABEC 2000 are elutable with water, making them more flexible for process flowsheet development and offering more favorable safety and environmental impacts.

Rough rankings of non-elutable sorption media are outlined in 4-2. The economic impacts of non-elutable resins may be the main driver in final selection of sorption media. However at this stage very little is known about disposal and process requirements and sorption media costs. Therefore, differentiating based on economics is omitted from this ranking. It is thought that TAM may be more environmentally safe due to its inorganic composition, resulting in less potential generation of off-gas and the likelihood of meeting long term disposal requirements. The latter result will be dependent on the disposal criteria of the repository. The real issue with all non-elutable sorption media is the lack of testing on Hanford's LAW feed. Until the ability of non-elutable resins to selectively remove and hold ^{99}Tc from a high ionic strength (>5 M Na), high pH ($\geq$ 12) solution is verified, the technical scores for these media will remain below those of elutable resins, where more development has been performed.

Table 4-1. Elutable Sorption Media

RESIN	TECHNICAL RANK (1 – 10)	COMMENTS
ABEC®-2000	7	Expected to be less expensive than SuperLig® 639, but less capacity per load cycle, these two factors balance; Elutable with water, which is good for processing (allows evaporation to concentrate); ^{99}Tc capacity less than SuperLig® 639), not much test data
DOWEX 1-X8 RESIN PROPERTIES	6	Elution with either 4M HNO_3 or ethylene diamine solution impacts cost and safety; Good ^{99}Tc removal, but nitrate addition to process via 4 M HNO_3 elution adds processing issues
Reillex HPQ	6	Elutable with 8M HNO_3 or ethylene diamine solution impacts both economics and safety viability
SuperLig 639	9	Extensive testing with Hanford DST wastes; expensive resin but can be reused for many cycles with reasonably high capacity per cycle; water elution does not add chemicals to process; extensive testing performed on Hanford's LAW

Table 4-2. Non-Elutable Sorption Media

RESIN	TECHNICAL RANK (1 – 10)	COMMENTS
Purolite A520E	5	Some testing has been performed on high pH tank waste.
Purolite A530E	4	Data shows it is very good at tying up ^{99}Tc. Recommended operating pH is below LAW pH
Reillex HPQ	6	Assumes that the harsh elution environments required allow the sorption media to perform as a non-elutable.
TAM – SnII Apatite Microspheres	5	Data shows it is very good at locking up ^{99}Tc. Nearly all data is from the vendor. Work has been performed regarding waste form performance. Tc(VII) reduced to Tc(IV)

5 REFERENCES

24590-PTF-RPT-RT-02-001, Rev 0, *WTP PTF Alternative Resin Selection*, Bechtel National, Inc., Richland, Washington, 2002.

24590-WTP-ICD-MG-01-019, Rev. 4, *ICD 19 – Interface Control Document for Waste Feed*, Bechtel National, Inc., Richland, Washington, 2008.

24590-WTP-RPT-PT-02-005, Rev 1, *Flowsheet Bases, Assumptions, and Requirements*, Bechtel National, Inc., Richland, Washington, 2002.

24590-WTP-RPT-PT-02-005, Rev 5, *Flowsheet Bases, Assumptions, and Requirements*, Bechtel National, Inc., Richland, Washington, 2009.

Atlas of Eh-pH Diagrams, Intercomparison of Thermodynamic Databases, Geological Survey of Japan Open File Report No. 419, National Institute of Advanced Industrial Science and Technology, Research Center for Deep Geological Environments, Naoto TAKENO, May, 2005.

BNF-003-98-0140, *Evaluation of SuperLig® 639 Ion Exchange Resin for the Removal of Rhenium from Hanford Envelope A Simulant*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

BNF-003-98-0146, Rev. 1, *Small-Scale Ion Exchange Removal of Cesium and Technetium From Hanford Tank 241-AN-103*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

BNF-003-98-0219, *Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

BNF-003-98-0230, *Intermediate-Scale Ion Exchange removal of Technetium from Savannah River Site Tank 44 F Supernate Solution*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

BNFL-RPT-009, Rev 0, *Ion Exchange Distribution Coefficients for 137Cs and 99Tc removal from Hanford Tank Supernatants AW-101 (Envelope A) and AN-107 (Envelope C)*, Pacific Northwest Laboratory, Richland, Washington, 1999.

BNFL-RPT-016 Rev 0., *Small Column Testing of SuperLig® 639 for Removing ^{99}Tc From Hanford Tank Waste Envelope A (Tank 241-AW-101)*, Battelle, Pacific Northwest Division, Richland, Washington, 2000.

BNFL-RPT-022, Rev. 0, *Small Column Testing of Superlig 639 for Removing ^{99}Tc from Hanford Tank Waste Envelop C (Tank 241-AN-107)*, Battelle, Pacific Northwest Division, Richland, Washington, 2000.

BNFL-RPT-028 Rev 0, *Analysis of Spent Ion Exchange Media: SuperLig®639 and SuperLig® 644*, Battelle, Pacific Northwest Division, Richland, Washington, 2000.

CONF-9505101--1, *Batch Test Equilibration Studies Examining the Removal of Cs, Sr, and Tc from Supernatants from ORNL Underground Tanks by Selected Ion Exchangers*, Oak Ridge National Lab, Tennessee, 1995.

CONF-970148--3, *Comprehensive Supernate Treatment*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1996.

DE-AC21-97MC33137--43, Separation, Concentration, and Immobilization of Technetium and Iodine from Alkaline Supernate Waste, Eichrom Industries, Inc, Darien, Illinois, 1998.

DOE Manual 435.1-1, *Radioactive Waste Management Manual*, United States Department of Energy, 1999.

Environmental Science & Technology, 34, 1075-1080, *Development of Novel Bifunctional Anion-Exchange Resins with Improved Selectivity for Pertechnetate sorption from Contaminated Groundwater*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, and University of Tennessee, Knoxville, Tennessee, 2000.

Environmental Science & Technology, 34, 3761-3766, *Development of Bifunctional Anion-Exchange Resins with Improved Selectivity and Sorptive Kinetics for Pertechnetate: Batch-Equilibrium Experiments*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, and University of Tennessee, Knoxville, Tennessee, 2000.

Industrial & Engineering Chemistry Research, 38, 1683-1689, *Flowsheet Feasibility Studies Using ABEC Resins for Removal of Pertechnetate from Nuclear Wastes*, Eichrom Industries, Inc., Darien, Illinois, University of Alabama, Tuscaloosa, Alabama, and Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1999.

K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*, ORNL Chemical Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1995

LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

LA-12863, Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF), Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.

MSE-174, *Development and Testing of a Portable Treatment Unit for Technetium-99 (Tc-99) in Groundwater at 200ZP-1 Operable Unit*, MSE Technology Applications, Inc., Butte, Montana, 2008.

ORNL/TM-13593, *A Field Trial of Novel Bifunctional Resins for Removing Pertechetate (TcO_4^-) from Contaminated Groundwater,* Oak Ridge National Laboratory, Lockheed Martin Energy research Corporation, Oak Ridge, Tennessee, 1998.

ORP-11242, Rev. 5, *River Protection Project System Plan*, Washington River Protection Solutions, Richland, Washington, 2010.

PNL-10750, *Efficient Separations and Processing Crosscutting Program: Develop and Test Sorbents*, Pacific Northwest Laboratory, Richland, Washington, 1995.

PNNL-11386, *Technetium in Alkaline, High-Salt, Radioactive Tank Waste Supernate: Preliminary Characterization and Removal*, Pacific Northwest National Laboratory, Richland, Washington, November 1997.

PNNL-11398, *Technetium Removal Column Flow Testing with Alkaline, High Salt, Radioactive Tank Waste*, Pacific Northwest National Laboratory, Richland, Washington, November 1997.

PNNL-14208, *Selection and Testing of "Getters" for Adsorption of Iodine-129 and Technetium-99: A Review*, Pacific Northwest National Laboratory, Richland, WA, 2003.

PNNL-19681, *Tc-99 Ion Exchange Resin Testing, Pacific Northwest Laboratory*, Pacific Northwest National Laboratory, Richland, Washington, 2010.

RPP-RPT-23199, Rev 0, *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins,* CH2M Hill Hanford Company, Richland, Washington, 2004.

RPP-RPT-34697, Rev 0, *Electrochemical Corrosion Report for Tanks 241-AW-103, 241-AZ-102, 241-AN-106, 241-AN-107, 241-AY-101, and 241-AY-102*, CH2M HILL Hanford Group, Inc., Richland, Washington, 2007.

RPP-RPT-38319, Rev 0, *Electrochemical Corrosion Tests for Tank 241-AP-105 Supernate Using Grab Samples 5AP-07-01, %AP-07-02A, 5AP-07-03A, and 5AP-07-04A*, CH2MHILL Hanford Group, Inc., Richland, Washington, 2008.

RPP-RPT-39195, Rev. 1, *Assessment of Technetium Leachability in Cement-Stabilized Basin 43 Groundwater Brine*, Washington River Protection Solutions, Richland, Washington, 2009.

RR196, *New Technologies for Metal Ion Separations: Aqueous Biphasic Extraction Chromatography (ABEC). Part I. Uptake of Pertechnetate*, Department of Chemistry, Northern Illinois University, DeKalb, Illinois, Argonne National Laboratory, Argonne, Illinois, 1996.

SGW-46453, Rev 0, *Testing Guidelines for Technetium99 Adsorption on Activated Carbon*, CH2MHILL Plateau Remediation Company, Richland, Washington, 2010.

SRTC-BNFL-013 Rev 0, *Evaluation of the Radiation Stability of SuperLig® 639*, Westinghouse Savannah River Company, Aiken, South Carolina, 1997.

SFV-2000, *FeedVectorWTP Realignment AOff BEL Gen-6.l-8.40-2010-O-07-at- 15-14-1ll.xlsx.*, Washington River Protection Solutions, Richland, Washington, 2010.

SVF-2023, *Immobilization System Hazard Category Source Term for Pre-Conceptual Candidate Technologies*, Washington River Protection Solutions, Richland, Washington, 2011.

WHC-SD-WM-TI-699, Rev. 1, *Technical Basis for Classification of Low-Activity Waste Fraction from Hanford Site Tanks*, Westinghouse Hanford Company, Richland, Washington, 1996.

WHC-SD-WM-TI-718, *Technetium Removal: Preliminary Flowsheet Options*, Westinghouse Hanford Company, Richland, Washington, 1995.

WSRC-MS-2000-00499, *Comprehensive Scale Testing of the Ion Exchange Removal of Cesium and Technetium from Hanford Tank Wastes*, CH2MHill Hanford Group, Richland, Washington, 2000.

WSRC-MS-2001-00573, *SuperLig® 639 Equilibrium Sorption data for Technetium from Hanford Tank Waste Supernates*, Westinghouse Savannah River Company, Aiken, South Carolina, 2001.

WSRC-MS-2001-00760, *Technetium Removal from Hanford and Savannah River Site Actual Tank Waste Supernates with SuperLig 639 Resin*, Westinghouse Savannah River Co., Aiken, South Carolina, 2001.

WSRC-MS-2003-00789, *Multiple Ion Exchange Column Tests for Technetium Removal from Hanford Tank Waste Supernate (U)*, Westinghouse Savannah River Company, Aiken South Carolina, 2003.

WSRC-MS-2003-00792, *Column Performance Testing of SuperLig® 639 Resin with Simulated Hanford Waste Supernates: Identification of the Primary Sorbing Species and Detailed Characterization of Their Desorption Profiles*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, 2003.

WSRC-MS-98-00601, *Pretreatment/Radionuclide Separations of Cs/Tc from Supernates*, Westinghouse Savannah River Company, Aiken, South Carolina, 1998.

WSRC-TR-2000-00302, *Summary of Testing of SuperLig® 639 at the TFL Ion Exchange Facility*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

WSRC-TR-2000-00303, Rev 0, *Demonstration of an Ion Exchange Resin Addition/Removal System with SuperLig® 659*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

WSRC-TR-2000-00305, *Preliminary Ion Exchange Modeling for Removal of Technetium from Hanford Waste Using SuperLig® 639 Resin*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

WSRC-TR-2000-00419, Rev 0, *Small-Scale Ion Exchange removal of Cesium and Technetium form Envelope B Hanford Tank 241-AZ-102*, Westinghouse Savannah River Company, Aiken, South Carolina, 2001.

WSRC-TR-2000-00420, *Intermediate-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

WSRC-TR-2000-00424, Rev 0, *Tank 241-AZ-102 SuperLig® 639 Technetium Ion Exchange Eluate Evaporation Study*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.

WSRC-TR-2002-00495, Rev 0, *Evaluating the Effects of Tri-Butyl Phosphate (TBP) and Normal Paraffin Hydrocarbon (NPH) in Simulated Low-Activity Waste Solution on Ion Exchange*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, 2002.

WSRC-TR-2003-00098, Rev 1, *Multiple Ion Exchange Column Runs for Cesium and Technetium Removal from AW-101 Waste Sample (U)*, Savannah River National Laboratory, Westinghouse Savannah River Company, Aiken, South Carolina, 2004.

WSRC-TR-99-00317, *Qualification of Reillex™ HPQ Anion Exchange Resin for Use in SRS* Processes, William J, Crooks III, et. Al., Westinghouse Savannah River Company , Aiken, SC, 2000.

WTP-RPT-024, Rev 0, *Radiation Stability Testing of SuperLig®639 and SuperLig®644 Resins*, Battelle, Pacific Northwest Division, Richland, Washington, 2003.

WTP-RPT-030, Rev 0, *Small Column Testing of SuperLig® 639 for Removing ^{99}Tc from Hanford Tank Waste Envelope A (Tank 241-AP-101)*, Battelle, Pacific Northwest Division, Richland, Washington, 2002.

WTP-RPT-031, Rev 1, *Small Column Testing of SuperLig 639 for Removing 99Tc from Hanford Tank Waste 241-AN-102 Supernate (Envelope C) Mixed with Tank 241-C-104 Solids (Envelope D) Wash and Permeate Solutions*, Battelle, Pacific Northwest Division, Richland, Washington, 2004.

WTP-RPT-047, Rev 0, *Chemical Degradation of SuperLig® 639 Ion Exchange Resin*, Battelle, Pacific Northwest Division, Richland, Washington, 2003.

WTP-RPT-058, Rev 1, *Small Column Testing of SuperLig® 639 for Removing 99Tc from Hanford Tank Waste Envelope B (Tank 241-AZ-101)*, Battelle, Pacific Northwest Division, Richland, Washington, 2004.

6 GLOSSARY OF TERMS

ACIDITY: An expression of the concentration of hydrogen ions present in a solution.

ABSORPTION: The incorporation of a substance in one state into another of a different state (e.g., liquids being absorbed by a solid or gases being absorbed by a liquid).

ADSORBENT: A synthetic resin possessing the ability to attract and hold charged particles.

ADSORPTION: The attachment of charged particles to the chemically active groups on the surface and in the pores of an ion exchanger.

ALKALINITY: An expression of the total basic anions (hydroxyl groups) present in a solution. It also represents, particularly in water analysis, the bicarbonate, carbonate and occasionally the borate, silicate and phosphate salts which will react with water to produce the hydroxyl groups.

ANION: A negatively charged ion.

ANION INTERCHANGE: The displacement of one negatively charged particle by another on an anion exchange material

ASH: The residual mineral content of resin after incineration at 800° C.

ATTRITION: The rubbing of one particle against another in a resin bed; frictional wear that will affect the size of resin particles.

BACKWASH: The upward flow of water through a resin bed (i.e., in at the bottom of the exchange unit, out at the top) to clean and reclassify the bed after exhaustion.

BASE: The hydroxyl form of a cation or a compound that can neutralize an acid.

BASE-EXCHANGE: The property of the trading of cations shown by certain insoluble naturally occurring materials (zeolites) and developed to a high degree of specificity and efficiency in synthetic resin adsorbents.

BATCH OPERATION: The utilization of ion exchange resins to treat a solution in a container wherein the removal of ions is accomplished by agitation of the solution and subsequent decanting of the treated liquid.

BED: The ion exchange resin contained in a column.

BED DEPTH: The height of the resinous material in the column after the exchanger has been properly conditioned for effective operation.

BED EXPANSION: The effect produced during backwashing: The resin particles become separated and rise in the column. The expansion of the bed due to the increase in the space between resin particles may be controlled by regulating backwash flow.

BREAKTHROUGH: The first appearance in the solution flowing from an ion exchange unit of unadsorbed ions similar to those which are depleting the activity of the resin bed. Breakthrough is an indication that regeneration of the resin is necessary.

BRINE: A salt solution, generally sodium chloride, in a saturated solution.

CAPACITY: The ability of an ion exchange material to absorb ions; usually expressed in kilograins per cubic foot or milliequivalents per milliliter.

CATION: A positively charged ion.

CHANNELING: Cleavage and furrowing of the bed due to faulty operational procedures, in which the solution being treated follows the path of least resistance, runs through these furrows, and fails to contact active groups in other parts of the bed.

CHEMICAL STABILITY: Resistance to chemical change that ion exchange resins must possess despite contact with aggressive solutions.

COLLOIDAL: Composed of extremely small size particles that are not removed by normal filtration.

COLOR-THROW: Discoloration of the liquid passing through an ion exchange material; the flushing from the resin interstices of traces of colored organic reaction intermediates.

COLUMN OPERATION: Conventional utilization of ion exchange resins in columns through which pass, either up-flow or down-flow, the solution to be treated.

CROSSLINKAGE: The degree of binding of a monomer or set of monomers to form an insoluble tri-dimensional resin matrix.

CYCLE: A complete course of ion exchange operation. For instance, a complete cycle of cation exchange would involve exhaustion of regenerated bed, backwash, regeneration and rinse to remove excess regenerant.

DEIONIZATION: A more general term than deashing, deionization includes the removal of all charged constituents or ionizable salts (both inorganic and organic) from solution.

DENSITY: The weight of a given volume of exchange material, backwashed and in place in the column.

DIFFUSION: The diffusion of ions through the ion exchange resin beads.

DISSOCIATE: The process of ionization of an electrolyte or a salt upon being dissolved in water, forming ions of cation and anion.

DOWN-FLOW: Conventional direction of solutions to be processed in ion exchange column operation, i.e., in at the top, out at the bottom of the column.

DRY SOLIDS: The matter, usually expressed in weight percent, remaining after liquid removal.

EFFICIENCY: The effectiveness of the operational performance of an ion exchanger. Efficiency in the adsorption of ions is expressed as the quantity of regenerant required to remove a specified unit weight of adsorbed material.

EFFLUENT: The solution that emerges from an ion exchange column.

ELECTROLYTE: A chemical compound that dissociates or ionizes in water to produce a solution the will conduct an electric current -- an acid, base or salt.

ELUTION: The stripping of adsorbed ions from an ion exchange material by the use of solutions containing other ions in relatively high concentrations.

EQUIVALENT WEIGHT: The molecular weight of any element or radical expressed as grams, pounds, etc., divided by the valence.

EXCHANGE SITES: The reactive groups on an ion exchange resin.

EXHAUSTION: The state in which the resin is no longer capable of useful ion exchange; the depletion of the exchanger's supply of available ions. The exhaustion point is determined arbitrarily in terms of: (a) a value in parts per million of ions in the effluent solution; and/or (b) the reduction in quality of the effluent water determined by a conductivity bridge which measures the electrical resistance of the water.

FLOW RATE: The volume of solution passing through a given quantity of resin within a given time. It is usually expressed in terms of gallons per minute per cubic foot of resin, as milliliters per minute per milliliter of resin or as gallons per square foot of resin per minute.

FREEBOARD: The space provided above the resin bed in an ion exchange column to allow for expansion of the bed during backwashing.

GEL: Ion exchange resins that are made up of firm gel structure in a solid bead form allowing for the diffusion of ions through the gel.

HEADLOSS: The reduction in liquid pressure associated with the passage of a solution through a bed of exchange material; a measure of the resistance of a resin bed to the flow of the liquid passing through it.

HYDRAULIC CLASSIFICATION: The rearrangement of resin particles in an ion exchange unit. As the backwash water flows up through the resin bed, the particles become mobile. The larger particles settle and the smaller particles rise to the top of the bed.

HYDROXYL: The term used to describe the anionic radical (OH-), which is responsible for the alkalinity of a solution.

INFLUENT: The solution that enters an ion exchange unit.

ION: Any particle of less than colloidal size possessing either a positive or a negative electric charge.

IONIZATION: The dissociation of molecules into charged particles.

LEAKAGE: The phenomenon in which some of the influent ions are not adsorbed or exchanged and appear in the effluent when a solution is passed through an under- regenerated exchange resin bed.

MACROPOROUS: Resins that have a rigid polymer porous network in which there exists a true pore structure even after drying. The pores are larger than atomic distances and are not part of the gel structure.

MONOMER: A single reactive molecule capable of combining with another different monomer to form a polymer.

pH: The measurement of the acidity of a solution where 1 is very acidic, 7 is neutral and 14 is very basic.

PHYSICAL STABILITY: The quality that an ion exchange resin must possess to resist changes that might be caused by attrition, high temperatures and other physical conditions.

POROSITY: An expression of the degree of permeability in ion exchange resins to liquids and large organic molecules. Gel resins, even when referred to as highly porous, have a negligible porosity in comparison to the macropores inherent in the macroporous resins.

POSITIVE CHARGE: The electrical potential acquired by an atom that has lost one or more electrons; a characteristic of a cation.

QUATERNARY AMMONIUM: A specific basic group [-N(CH3)3+] on which depends the exchange activity of certain anion exchange resins.

RAW WATER: Untreated water from wells or from surface sources.

REGENERANT: The solution used to restore the activity of an ion exchanger. Acids are employed to restore a cation exchanger to its hydrogen form, while brine solutions may be used to convert the cation exchanger to the sodium form. The anion exchanger may be rejuvenated by treatment with an alkaline solution.

REGENERATION: Restoration of the activity of an ion exchanger by replacing the ions adsorbed from the treated solution by ions that were adsorbed initially on the resin.

RESIN: An insoluble matrix (or support structure) normally in the form of small (1–2 mm diameter) beads, fabricated from an organic polymer substrate. The material has highly developed structure of pores on the surface, which are sites with easily trapped and released ions.

RINSE: The operation that follows regeneration; a flushing out of excess regenerant solution.

SALT SPLITTING: The conversion of salts to their corresponding acids or bases by passage through ion exchange resins containing strongly acidic or strongly basic functional groups.

SELECTIVITY: The difference in attraction of one ion over another by an ion exchange resin.

SORPTION: Refers to the action of absorption or adsorption. Absorption is the incorporation of a substance in one state into another of a different state (e.g., liquids being absorbed by a solid or gases being absorbed by a liquid). Adsorption is the physical adherence or bonding of ions and molecules onto the surface of another phase (e.g., reagents adsorbed to solid catalyst surface).

SWELLING: The expansion of an ion exchange bed that occurs when the reactive groups on the resin are converted into certain forms.

THROUGHPUT: The amount of solution treated prior to the exhaustion of the ion exchange resin.

UP-FLOW: The operation of an ion exchange unit in which solutions are passed in at the bottom and out at the top of the container.

VALANCE: A measurement of the number of atoms or ions of hydrogen it takes to combine with, or be replaced by, an element or radical. In short, it is the number of positive or negative charges of an ion.

VOID VOLUME: The space between particles of ion exchange resins in a settled bed, also called interstitial volume.

WEAK ELECTROLYTE: The equivalent of weakly acidic or weakly basic resins not capable of splitting neutral salts.

ZEOLITE: A mineral composed of hydrated silicates of aluminum and sodium or calcium. The term has been used, sometimes improperly, to describe softening done by synthetic ion exchange resins.

APPENDIX A SORPTION MEDIA REFERENCE MATRIX

Table A-6-1. Sorption Media References by Feed Solution

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
Duolite™[12] CS-100	Not Selected for Review (SME)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
ABEC 2000	Selected for Review	RR 196 *New Technologies for Metal Ion Separations: Aqueous Biphasic Extraction Chromatography (ABEC). Part I. Uptake of Pertechnetate*		X			X	
		DE-AC21-97MC33137 *Separation, Concentration, and Immobilization of Technetium and Iodine from Alkaline Supernate Waste*	X	X		X	X	These waste streams include actual Hanford tank waste from tank AW-101, (a cesium decontaminated double shell slurry feed composite), three different Hanford tank waste simulants, actual waste samples from ORNL Melton Valley Storage Tanks W-29 and W-3, and waste simulant solutions from two British Nuclear Fuel (BNFL) locations—Capenhurst and Sellafield—in the United Kingdom.
Aliquat (tricaprylmethylammonium chloride)™[13]	Not Selected for Review (WTP Screening)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
		LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*		X				
		LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCAW)*		X				
		PNL-10750 *Efficient Separations and Processing Crosscutting Program: Develop and Test Sorbents*					X	
Amberlite™[14] IRA-400	Not Selected for Review (SEM)	CONF-9505101--1 *Batch Test Equilibration Studies Examining the Removal of Cs, Sr, and Tc from Supernatants from ORNL Underground Tanks by Selected Ion Exchangers*				X		

[12] Duolite materials are trademarked products of Rohm and Haas Corporation, of West Philadelphia, Pennsylvania.

[13] Original product registrant was General Mills, of Minneapolis, Minnesota. Current registrant is Cognis IP Management GmbH Corporation of Duesseldorf, Germany.

[14] Amberlite products are trademarked by Rohm & Haas Corporation, of West Philadelphia, Pennsylvania.

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
Amberlite IRA-904	Not Selected for Review (SME)	CONF-9505101--1 *Batch Test Equilibration Studies Examining the Removal of Cs, Sr, and Tc from Supernatants from ORNL Underground Tanks by Selected Ion Exchangers*				X		
Amberlite XE-238	Not Selected for Review (WTP Screening)							
Azaphosphane-based resins	Not Selected for Review (WTP Screening)							
Bio-Rad™[15] AG 1-x8	Not Selected for Review (SME)	K/TCD-1141 *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*						Simulated Oak Ridge National Lab Newly Generaged Liquid Low-Level Waste
Bio-Rad MSZ-1	Not Selected for Review (WTP Screening)							
BiQuat[16] RO-02-119	Not Selected for Review (WTP Screening)							
BiQuat VP-02-217	Not Selected for Review (WTP Screening)							

[15] Bio-Rad products are trademarked by Bio-Rad Laboratories of Hercules, California.

[16] BiQuat materials are formulated by Oak Ridge National Laboratory in conjunction with the University of Tennessee.

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
Boehmite, Synthetic aluminum oxyhydroxide gel	Not Selected for Review (WTP Screening)							
ABEC 5000	Selected for Review	PNNL-13386 *Technetium in Alkaline, High-Salt, Radioactive Tank Waste Supernate: Preliminary Characterization and Removal*	X					DSSF and 3 CC wastes (AN-107, SY-101, ANS SY-103)
		RR 196, *New Technologies for Metal Ion Separations: Aqueous Biphasic Extraction Chromatography (ABEC). Part I. Uptake of Pertechnetate*	X				X	
		DE-AC21-97MC33137, *Separation, Concentration, and Immobilization of Technetium and Iodine from Alkaline Supernate Waste*	X	X		X	X	These waste streams include actual Hanford tank waste from tank AW-101, (a cesium decontaminated double shell slurry feed composite), three different Hanford tank waste simulants, actual waste samples from ORNL Melton Valley Storage Tanks W-29 and W-3, and waste simulant solutions from two British Nuclear Fuel (BNFL) locations—Capenhurst and Sellafield—in the United Kingdom.
		PNNL-11398, *Technetium Removal Column Flow Testing with Alkaline, High Salt, Radioactive Tank Waste*	X					DSSF/ AW-101
		WSRC-MS-98-00601, *Pretreatment/Radionuclide Separations of Cs/Tc from Supernates*				X		ORNL wastes
		CONF-970148—3, *Comprehensive Supernate Treatment*					X	MVST W-29 supernate depleted in cesium and strontium and spiked with pertechnetate.
Activated Carbon	Not Selected for Review (WTP Screening)	SGW-46453, Testing Guidelines for Technetium99 Adsorption on Activated Carbon					X	
Cross-linked Polyvinyl Pyridine	Not Selected for Review (WTP Screening)							

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
Crypt-DER[17]	Not Selected for Review (WTP Screening)							
Dowex 1X8	Selected for Review	K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*				X		Simulated Oak Ridge National Lab Newly Generaged Liquid Low-Level Waste
Dowex 2X8	Not Selected for Review (WTP Screening)	K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*				X		Simulated Oak Ridge National Lab Newly Generaged Liquid Low-Level Waste
Forager™[18] Sponge	Not Selected for Review (WTP Screening)							
IONSIV™[19] IE-910	Not Selected for Review (SME)							
Iron Sulfide	Not Selected for Review (WTP Screening)							
LANL[20] – TiO2/carbon beads	Not Selected for Review (WTP Screening)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				

[17] No trademarks or proprietary information located.

[18] Forager sponges and other Forager products are manufactured by Dynaphore, Inc., of Richmond, Virginia.

[19] ION-SIV products are trademarked by the Union Carbide Corporation, of New York, New York.

[20] Formulated at the Los Alamos National Laboratory.

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
Purolite A-520E	Selected for Review	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
		LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.		X				
		LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA)*, Los Alamos National Laboratory, Los Alamos, New Mexico, 1994.		X				
		ORNL/TM-13593, *A Field Trial of Novel Bifunctinal Resins for Removing Pertechnetate (TcO4-) from Contaminated Groundwater*					X	
Purolite A-530E	Selected for Review	RPP-RPT-39195 Rev. 1					X	Brine solution of 25 wt% mimicking the anticipated Basin 43 waste from the ETF
		RPP-RPT-23199, Rev 0 *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins*					X	ETF Basin 44 Reverse Osmosis (RO) reject stream
		MSE-174, *Development and Testing of a Portable Treatment Unit for Technetium-99 (Tc-99) in Groundwater at 200ZP-1 Operable Unit*					X	Column and batch testing at the Mike Mansfield Advanced Technology Center (MMATC) using the perrhenate ion as a surrogate for technetium-99
		PNNL-19681, *Tc-99 Ion Exchange Resin Testing*					X	Groundwater from well 299-W15-765
		LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
		Environmental Science & Technology, 2000, 34, 1075-1080, Development of Novel Bifunctional Anion-Exchange Resins with Improved Selectivity for Pertechnetate sorption from Contaminated Groundwater					X	
Purolite A-532E	Selected for Review	RPP-RPT-39195 Rev. 1					X	Brine solution of 25 wt% mimicking the anticipated Basin 43 waste from the ETF

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
Reillex – HPQ	Selected for Review	K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*				X		Simulated Oak Ridge National Lab Newly Generaged Liquid Low-Level Waste
		RPP-RPT-23199, Rev 0 *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins*					X	ETF Basin 44 Reverse Osmosis (RO) reject stream
		PNNL-11386, *Technetium in Alkaline, High-Salt, Radioactive Tank Waste Supernate: Preliminary Characterization and Removal*	X					DSSF and 3 CC wastes (AN-107, SY-101, ANS SY-103)
		PNNL-11398 *Technetium Removal Column Flow Testing with Alkaline, High Salt, Radioactive Tank Waste*	X					DSSF/ AW-101
		CONF-9505101--1, *Batch Test Equilibration Studies Examining the Removal of Cs, Sr, and Tc from Supernatants from ORNL Underground Tanks by Selected Ion Exchangers*				X		
		LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
		LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*		X				
		LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA),*		X				
		WSRC-MS-98-00601, *Pretreatment/Radionuclide Separations of Cs/Tc from Supernates*	X					
		WHC-SD-WM-TI-718, *Technetium Removal: Preliminary Flowsheet Options*	X					
		CONF-970148—3, *Comprehensive Supernate Treatment*					X	MVST W-29 supernate depleted in cesium and strontium and spiked with pertechnetate.
		WHC-SD-WM-TI-699, Rev. 1, *Technical Basis for Classification of Low-Activity Waste Fraction from Hanford Site Tanks*		X				DSSF simulants
		Environmental Science & Technology, 2000, 34, 3761-3766, Development of Bifunctional Anion-Exchange Resins with Improved Selectivity and Sorptive Kinetics for Pertechnetate:					X	

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
		Batch-Equilibrium Experiments						
Reillex 402	Not Selected for Review (WTP Screening)	CONF-9505101--1, *Batch Test Equilibration Studies Examining the Removal of Cs, Sr, and Tc from Supernatants from ORNL Underground Tanks by Selected Ion Exchangers*				X		
Reillex HP	Not Selected for Review (WTP Screening)	K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*				X		Simulated Oak Ridge National Lab Newly Generaged Liquid Low-Level Waste
Sn^{++} apatite	Selected for Review	Vendor Questionnaire			?			"WTP Recycle surrogate and AN-104 Surrogate"
		RPP-RPT-39195 Rev. 1, *Assessment of Technetium Leachability in Cement-Stabilized Basin 43 Groundwater Brine*					X	Simulant Basin 43 waste with concentrated brine consisting of approximately 25 weight percent salts.
		PNNL-14208, *Selection and Testing of "Getters" for Adsorption of Iodine-129 and Technetium-99: A Review*					X	Groundwater matrix and concentrated sodium salt solution.
Sr-SPEC™[21]	Not Selected for Review (WTP Screening)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
Steel Wool	Not Selected for Review (SME)	K/TCD-1141, *Removal of Technetium-99 from Simulated Oak Ridge National Laboratory Newly-Generated Liquid Low-Level Waste*					X	Simulated Oak Ridge National Lab Newly Generaged Liquid Low-Level Waste
SuperLig 639	Selected for Review	Science and Technology, 40: 1, 383 — 394, 2005, '*Column Performance Testing of SuperLig® 639 Resin with Simulated Hanford Waste Supernates: Identification of the Primary Sorbing Species and Detailed Characterization of Their Desorption Profiles*', Separation			X			
		PNWD-3004, BNFL-RPT-016, *Rev 0 Small Column Testing of SuperLig 639 for Removing Tc-99 from Hanford Tank Waste Envelope A (241-AW-101)*	X					

[21] Sr-SPEC is a trademarked product of Eichrom Industries of Darien, Illinois.

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
		PNWD-3028, BNFL-RPT-022 Rev. 0, *Small Column Testing of Superlig 639 for Removing Tc99 from Hanford Tank Waste Envelope C (Tank 241-AN-107)*	X					
		WSRC-MS-2000-00499, *Comprehensive Scale Testing of the Ion Exchange Removal of Cesium and Technetium from Hanford Tank Wastes*	X		X			AN-103 salt solution and AN-105 simulant spiked with rhenium
		WSRC-TR-2000-00420, *Superlig 639 Intermediate - Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank AN-102*	X					Envelope C salt solution from Hanford Tank 241-AN-102
		WSRC-MS-2003-00792, *Column Performance Testing of SuperLig 639 resin with simulated Hanford waste supernates: identification of the primary sorbing species and detailed characterization of their desportion profiles*			X			
		WSRC-TR-2000-00419, *Small-Scale Ion Exchange Removal of Cesium and Technetium from Envelope B Hanford Tank 241-AZ-102*	X					Envelope B salt solution from Hanford Tank AZ-102
		WSRC-MS-2001-00760, *Technetium Removal from Hanford and Savannah River Site Actual Tank Waste Supernates with SuperLig 639 Resin*, Westinghouse Savannah River Co., Aiken, South Carolina, 2001.	X					AN-103
		WSRC-TR-2000-00302, BNF-003-98-0153, *Summary of Testing of SuperLig® 639 at the TFL Ion Exchange Facility*, Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.			X			
		WSRC-MS-2001-00573, *SuperLig® 639 Equilibrium Sorption data for Technetium from Hanford Tank Waste Supernates*, Westinghouse Savannah River Company, Aiken, South Carolina, 2001.	X					AN-103, AZ-102, and AN-102
		WSRC-TR-2000-00303, Rev 0, *Demonstration of an Ion Exchange Resin Addition/Removal System with SuperLig® 659*, Westinghouse Savannah River Company, Aiken, South Carolina, 2000.					X	Demonstration of slurry transport of resin media; SuperLig 659 was used in place of SuperLig 639.
		WSRC-TR-2000-00305, *Preliminary Ion Exchange Modeling for Removal of Technetium from Hanford Waste Using SuperLig® 639 Resin*						

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
		WSRC-TR-2002-00495, Rev 0, *Evaluating the Effects of Tri-Butyl Phosphate (TBP) and Normal Paraffin Hydrocarbon (NPH) in Simulated Low-Activity Waste Solution on Ion Exchange*			X			Testing the influence of two organics, TBP and NPH, on SuperLig 639 performance.
		WTP-RPT-024, Rev 0, PNWD-3239, Rev 0, *Radiation Stability Testing of SuperLig®639 and SuperLig®644 Resins*						
		BNF-003-98-0219, *Small-Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-102*	X					
		PNWD-3251, *WTP-RPT-026 Equilibrium Batch Contact Testing of SuperLig 639*					X	
		PNWD-3222, WTP-RPT-030 Rev 0, *Small Column Testing of SuperLig 639 for Removing Tc99 from Hanford Tank Waste Envelope A (Tank 241-AP-101)*	X					
		PNWD-3252, WTP-RPT-031, *Small Column Testing of Superlig 639 for Removing Tc99 from Hanford Tank Waste 241-AN-102 Supernate (Envelope C) mixed with Tank 241-C-104 Solids (Envelope D) Wash and Permeate Solutions*	X					
		PNWD-3345, WTP-RPT-047, *Chemical Degradation of Superlig 639 Ion Exchange Resin*		X				Simulated LAW based on AN-105
		PNWD-3281, WTP-RPT-058, *Small Column Testing of Superlig 639 for Removing Tc99 from Hanford Tank Waste Envelope B (Tank 241-AZ-101)*	X					
		PNWD-3037, BNFL-RPT-028 Rev. 0, *Analysis of Spent Ion Exchange Media: SuperLig 639 and SuperLig 644*	X					samples from Tanks 241-AW- 101 and 24 l-AN-l 07
		BNF-003-98-0230, *Intermediate-Scale Ion Exchange Removal of Technetium from Savannah River Site Tank 44 F Supernate Solution*				X		
		BNF_003-98-0140, *Evaluation of SuperLig 639 Ion Exchange Resin for the Removal of Rhenium from Hanford Envelope A Simulant*			X			
		SRTC-BNFL-013, *Evaluation of Radiation Stability of SuperLig 639*			X			

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
		WSRC-TR-2000-00424, ART-RPP-2000-00024 *Tank 241-AZ-102 Superlig 639 Technetium Ion Exchange Eluate Evaporation Study*	X					
		WSRC-TR-2003-00098, Rev 1, (SRT-RPP-2003-00026, Rev 1), *Multiple Ion Exchange Column Runs for Cesium and Technetium Removal from AW-101 Waste Sample (U)*	X					
		PNWD-2467, BNFL-RPT-009, *Ion Exchange Distribution Coefficients for Cs137 and Tc99 removal from Hanford Tank Supernatants AW-101 (Envelope A) and AN-107 (Envelope C)*	X	X				
		WSRC-MS-2003-00789, *Multiple Ion Exchange Column Tests for Technetium Removal from Hanford Tank Waste Supernate*	X					AW-101 sample
		BNFL-RPT-022, Rev. 0, *Small Column Testing of Superlig 639 for Removing 99Tc from Hanford Tank Waste Envelop C (Tank 241-AN-107)*	X					
		BNF-003-98-0146, Rev. 1, *Small Scale Ion Exchange Removal of Cesium and Technetium from Hanford Tank 241-AN-103*	X					
Sybron™[22] Ionac SR-3	Not Selected for Review (WTP Screening)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
		LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*		X				
		LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA),*		X				
Sybron Ionac SR-6	Not Selected for Review (WTP Screening)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*		X				
		LA-12863, *Distributions of 15 Elements on 58 Absorbers from Simulated Hanford Double-shell Slurry Feed (DSSF)*		X				

[22] Sybron materials are trademarked products of Sybron International Corporation of Milwaukee, Wisconsin.

Ion Exchange / Sorbent Media	Disposition	References	Hanford Tank Waste	Hanford Tank waste simulant spiked with Tc	Hanford tank waste simulant with Re (as a surrogate for Tc)	DOE Radioactive tank waste from another site	Other	Comments
		LA-12889, *Distributions of 12 Elements on 64 Absorbers from Simulated Hanford Neutralized Current Acid Waste (NCWA)*,		X				
Sybron Ionic SR-7	Not Selected for Review (SME)	RPP-RPT-23199, Rev 0 *The Removal of Technetium-99 from the Effluent Treatment Facility Basin 44 Waste Using Purolite A-530E, Reillex HPQ, and Sybron IONAC SR-7 Ion Exchange Resins*					X	ETF Basin 44 Reverse Osmosis (RO) reject stream
TEVA[23]	Not Selected for Review (WTP Screening)							
TRU-SPEC[24]	Not Selected for Review (WTP Screening)	LA-12654, Rev., *Distributions of 14 Elements on 63 Absorbers from Three Simulant Solutions (Acid-Dissolved Sludge, Acidified Supernate, and Alkaline Supernate) for Hanford HLW Tank 102-SY*						
Zero-valence Iron filings/beads	Not Selected for Review (WTP Screening)							

[23] No trademarked or proprietary information located.

[24] No trademarked or proprietary information located.

APPENDIX B VENDOR INFORMATION

Figure B-1. ABEC™ 2000 Page 1

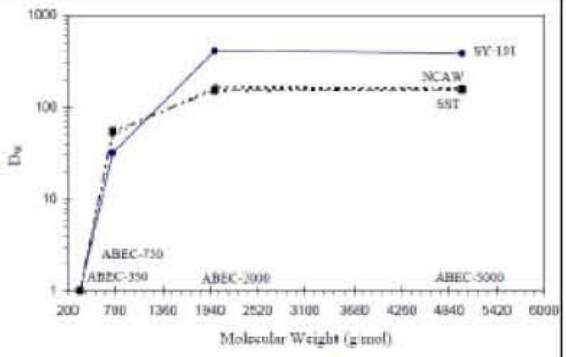
Influent		
pH Range	≥12	
Viscosity of Feed	1-20 cP	
Specific Gravity	1 to 1.46	
Resin Type		
Inorganic	Y or NOT Orgainic	
Organic	YES or N – Organic	
If Known for Pertechnetate (TcO_4^-) Removal		
Kd [Tc]	Vendor	Depends on other analyte concentrations but improves with higher concentration of anions
	WTP Resin Screening Presentation	Kd: 141-160 ml/g λ50: 40-60BV at 10BV/hr
	DE-AC21-97MC33137—43	
	RR-196	Highest Dw of 410 was obtained for ABEC 2000 for testing of Hanford waste with SY-101 waste.
Selectivity to Tc	The resin has good selectivity for Tc(VII) but will co-extract I and Re(VII)	
Poisons	Reducing agents capable of reducing Tc(VII) will reduce the Tc(IV) which will not be retained by the resin	
Equivalents/L	0.8 moles / L	
Resin Properties		
Preparation Procedure	ABEC® resin should be preconditioned with a basic solution of similar molarity prior to loading waste solutions	
Radiological Stability and/or Gas Generation	There is potential for CO_2 evolution from radiolysis of the resin	
Bed Volumes per Hour Operation	Estimate 45 – 60 bed volumes per hour.	
Particle Size	Recommend 30-60 mesh bead size	

Figure B-2. ABEC™ 2000 Page 2

Elutable	YES or N
Eluant	Water, dilute saline or dilute acid
Storage, Shelf Life	Anticipate greater than 2 years of shelf life under environmentally controlled conditions.
Handling Specifications	Resin will shrink and swell up to 30% depending on ionic strength of solutions passed through the resin bed.
Loading Cycles	Estimate 20 loading cycles for the resin but actual results will depending on the effects of radiolytic damage to the resin.
Resin Density (weight per unit volume)	0.8 g/mL in H_2O and 1.1 g/mL in 6M KOH
pH operating range	pH 6 to 14+
Temperature operating range	10°C – 50°C
Cost per Pound (or ft^3)	See attached quotation
Ability to supply amounts of ≥ 2000 lbs	Will require scale up development but is technological possible.

Vendor:_Eichrom Technologies LLC, Lisle, IL__Resin: _ABEC®-2000_____

Contact Name/Phone/Email:_Terence O'Brien, 630-963-0320, tobrien@eichrom.com _____

Figure B-3. DOWEX® 1-X8, Aldrich® Page 1 of 3

Ion Exchange Resins: Classification and Properties

Ion exchange resins are highly ionic, covalently cross-linked, insoluble polyelectrolytes supplied as beads. The beads have either a dense internal structure with no discrete pores (gel resins, also called microporous resins) or a porous, multichannelled structure (macroporous or macroreticular resins). They are commonly prepared from styrene and various levels of the cross-linking agent divinyl benzene, which controls the porosity of the particles. Porous beads can be made also by adding homopolystrene, which is soluble in the monomer mixture, and leaching it out later with, toluene, for instance. The PS-DVB precursor beads are post-functionalized to yield the finished resin. Acrylic based, ion exchange resins are also available (see Table I).

These ionic polymers contain two types of ions, those which are bound within the structure and the oppositely charged counter ions which are free. The property of ion exchange is a consequence of *Donnan exclusion* – when the resin is immersed in a medium in which it is insoluble, the counter ions are mobile and can be exchanged for other counter ions from the surrounding medium; ions of the same type of charge as the bound ions do not have free movement into and out of the polymer. Ion exchange resins have been classified based on the charge on the exchangeable counterion (cation exchanger or anion exchanger) and the ionic strength of the bound ion (strong exchanger or weak exchanger). Thus, there are four primary types of ion exchange resins:

1. Strong cation exchange resins, containing sulfonic acid groups or the corresponding salts.
2. Weak cation exchange resins, containing carboxylic acid groups or the corresponding salts.
3. Strong anion exchange resins, containing quarternary ammonium groups. Of these, there are two types: Type I resins contain trialkyl ammonium chloride or hydroxide and Type II resins contain dialkyl 2-hydroxyethyl ammonium chloride or hydroxide.
4. Weak anion exchange resins, containing ammonium chloride or hydroxide.

Additional types of ion exchange resins include blends of cation and anion exchange resins, called *mixed bed resins*.

A resin which contains both an anion and a cation as bound ions is said to be *ampholytic*. Some ion exchange resins are prepared with *chelating* properties making them highly selective towards certain ions. In addition to their use in ion exchange, organic polymer supports, many of which are based on PS-DVB resins, are being used as *polymeric catalysts* in the expanding research area involving heterogenization of homogenous catalysts and as polymeric supports and reagents in combinatorial chemistry.

The internal structure of the resin beads, i.e., whether microporous (gel-type) or macroporous, is important in the selection of an ion exchanger. Macroporous resins, with their high effective surface area, facilitate the ion exchange process. Also, they give access to the exchange sites for larger ions, can be used with almost any solvent, irrespective of whether it is a good solvent for the uncrosslinked polymer, and take up the solvent with little or no change in volume. They make more rigid beads, facilitating ease of removal from the reaction system. In the case of the microporous resins, since they have no discrete pores, solute ions diffuse through the particle to interact with exchange sites. Despite diffusional limitations on reaction rates, these resins offer certain advantages: they are less fragile, requiring less care in handling, react faster in functionalization and applications reactions, and possess higher loading capacities.

In addition to being a function of bead morphology, the kinetics of the exchange depends on the particle size distribution of the resin. It is enhanced by a monodisperse resin, for example, see the Marathon® and Amberjet® resins in Table I; they permit faster elution and regeneration times with reduced back pressure.

To help you select an exchanger or combination of exchangers, Table I provides a compilation of ion exchange resins offered by Aldrich, classified by type, as defined above, along with characteristics of each resin such as particle size, functional group, ionic form (i.e., the counterion), exchange capacity, and operating conditions. For additional information on ion exchange resins from Aldrich, please request Aldrich Technical Bulletin AL-142. For additional information on polymeric supports, please refer to the *Applications* Section.

Table I: Classification and Properties of Numerous Ion Exchange Resins offered by Aldrich

Cat. No.	Exchanger	% cross-linking	Matrix[1]	Mesh/ Bead size	Ionic Form	% Moisture	Max.Op. Temp. °C	Total Exchange Capacity[2] meq/ml	meq/g	pH range
Strong Cation Exchangers on Polystyrene										
Amberlite®/Amberlyst®/Amberjet®	**(Sulfonic Acid)**									
21,653-4	IR-120 Plus(H)	8	G	16-50	H	45	120	1.9	4.4	0-14
22,435-9	IR-120 Plus	-	G	16-50	Na	45	120	1.9	4.4	0-14
27,427-5	IRP-69	-	-	25-150µm	Na	10	-	-	-	-
21,638-0	15	-	Mp	16-50	H	<1	120	2.8	4.7	0-14
43,673-9	1200(H)	-	G	20-35	H	52	120	1.8	4.7	0-14

Figure B-4. DOWEX® 1-X8, Aldrich® Page 2 of 3

Table I: Classification and Properties of Numerous Ion Exchange Resins offered by Aldrich (continued)

Cat. No.	Exchanger	% cross-linking	Matrix[1]	Mesh/ Bead size	Ionic Form	% Moisture	Max.Op. Temp. °C	Total Exchange Capacity[2] meq/ml	meq/g	pH range
Strong Cation Exchangers on Polystyrene (continued)										
Dowex® (Sulfonic Acid)										
21,744-1	50WX2-100	2	G	50-100	H	78	150	0.6	4.8	0-14
21,746-8	50WX2-200	2	G	100-200	H	78	150	0.6	4.8	0-14
21,747-6	50WX2-400	2	G	200-400	H	78	150	0.6	4.8	0-14
42,882-5	50WX4-50	4	G	20-50	H	68	150	1.1	4.8	0-14
42,868-3	50WX4-100	4	G	50-100	H	68	150	1.1	4.8	0-14
42,209-6	50WX4-200	4	G	100-200	H	68	150	1.1	4.8	0-14
42,867-1	50WX4-200R	4	G	100-200	H	68	150	1.1	4.8	0-14
21,748-4	50WX4-400	4	G	200-400	H	68	150	1.1	4.8	0-14
21,749-2	50WX8-100	8	G	50-100	H	53	150	1.7	4.8	0-14
21,750-6	50WX8-200	8	G	100-200	H	54	150	1.7	4.8	0-14
21,751-4	50WX8-400	8	G	200-400	H	54	150	1.7	4.8	0-14
42,872-8	HCR-S	8	G	20-50	H	53	150	1.8	4.8	0-14
42,870-1	HCR-W2	8	G	16-40	H	52	150	1.8	4.8	0-14
43,668-2	88	-	Mp	16-40	Na	45	150	1.8	1.8	0-14
43,661-5	650C	-	G	25-30	H	50	150	1.9	1.9	0-14
43,395-0	Marathon C	-	G	30-40	H	53	149	1.8	2.6	0-14
42,878-7	MSC-1	-	-	20-50	Na	47	150	1.7	4.5	0-14
Duolite® (Sulfonic Acid)										
43,669-0	C-26	-	Mp	520µm	Na	50	150	1.8	-	0-14
Weak Cation Exchangers on Polyacrylic										
Amberlite® (Carboxylic Acid)										
21,635-6	CG-50 Type I	4	Mp	100-200	H	5	120	3.5	10.0	5-14
42,883-3	IRC-50	4	Mp	16-50	H	48	120	3.5	10.0	5-14
21,657-7	IRC-50S	-	Mp	400µm	H	48	120	3.5	-	5-14
27,426-7	IRP-64	-	Mp	100-400	H	5	-	-	10.0	-
Dowex® (Carboxylic Acid)										
42,881-7	CCR-3	-	-	20-50	H	50	120	3.9	-	-
Strong Anion Exchangers on Polystyrene										
Amberlite® Strong Anion Exchangers, Type I (Trialkylbenzyl Ammonium)										
24,766-9	IRA-400(Cl)	8	G	16-50	Cl	45	77	1.4	3.8	0-14
21,644-5	IRA-743	-	G	450µm	OH	58	77	0.6	-	-
21,658-5	IRA-900	-	Mp	16-50	Cl	60	77	1.0	4.2	0-14
43,674-7	4200(Cl)	-	G	25-25	Cl	53	50	1.2	3.7	0-14
Dowex® Type I (Trimethylbenzyl Ammonium)										
21,737-9	1X2-100	2	G	50-100	Cl	70	66	0.7	3.5	0-14
21,738-7	1X2-200	2	G	100-200	Cl	75	66	0.6	3.5	0-14
21,739-5	1X2-400	2	G	200-400	Cl	75	66	0.6	3.5	0-14
42,861-2	1X4-50	4	G	20-50	Cl	50	66	1.0	3.5	0-14
42,858-2	1X4-100	4	G	50-100	Cl	50	66	1.0	3.5	0-14
42,859-0	1X4-200	4	G	100-200	Cl	59	66	1.0	3.5	0-14
42,860-4	1X4-400	4	G	200-400	Cl	59	66	1.0	3.5	0-14
21,740-9	1X8-50	8	G	20-50	Cl	46	66	1.2	3.5	0-14
21,741-7	1X8-100	8	G	50-100	Cl	46	66	1.2	3.5	0-14
21,742-5	1X8-200	8	G	100-200	Cl	46	66	1.2	3.5	0-14
21,743-3	1X8-400	8	G	200-400	Cl	46	66	1.2	3.5	0-14
42,876-0	MSA-1	-	Mp	20-50	Cl	60	66	1.0	4.0	0-14
43,665-8	21K	-	G	16-30	Cl	54	60	1.2	3.8	0-14
43,660-7	550A	-	G	25-35	OH	48	60	1.1	3.4	0-14
43,394-2	Marathon A	-	G	30-40	Cl	57	60	1.2	4.0	0-14
Amberlite®, Type II (Dimethyl-2-hydroxyethylbenzyl Ammonium)										
21,656-9	IRA-410	-	G	20-50	Cl	42	41-77	1.4	3.4	0-14
Dowex® Type II (Dimethyl-2-hydroxyethylbenzyl Ammonium)										
42,862-0	2X8-100	8	G	50-100	Cl	38	66	1.2	-	0-14
42,863-9	2X8-200	8	G	100-200	Cl	37	66	1.2	-	0-14
42,864-7	2X8-400	8	G	200-400	Cl	37	66	1.2	-	0-14
42,877-9	MSA-2	-	Mp	16-50	Cl	56	77	1.0	3.7	0-14
43,393-4	Marathon A2	-	G	30-40	Cl	42	35-80	3.2	3.2	0-14
43,662-3	22	-	Mp	20-40	Cl	54	46	1.2	-	-

Figure B-5. DOWEX® 1-X8, Aldrich® Page 3 of 3

Table I: Classification and Properties of Numerous Ion Exchange Resins offered by Aldrich (continued)

Cat. No.	Exchanger	% cross-linking	Matrix[1]	Mesh/ Bead size	Ionic Form	% Moisture	Max.Op. Temp. °C	Total Exchange Capacity[2] meq/ml	Total Exchange Capacity[2] meq/g	pH range
Weak Anion Exchangers on Polystyrene										
Amberlite® (Polyamine)										
47,663-3	IRA-67	-	G	16-50	FB	60	60	1.6	5.6	7-9
Dowex® (Polyamine)										
42,879-5	WGR-2	-	Mp	20-50	FB	55	93	1.9	6.1	0-7
43,667-4	66	-	Mp	16-50	FB	45	60	1.4	4.0	0-7
43,666-6	Marathon WBA	-	Mp	25-50	FB	54	60	1.25	4.2	0-7
Duolite® (Polyamine)										
43,670-4	A-7	-	Mp	16-50	FB	56	40	2.2	13.9	0-6
Mixed Bed Resins on Polystyrene										
Dowex® Mixed Bed Resins										
42,873-6	MR-3	-	G	20-50	H,OH	50	50	-	1.7	0-14
42,874-4	MR-3C	-	G	16-45	H,OH	50	50	-	1.7	0-14
42,869-8	11A8 Retardion	-	G	35-80	Na	45	70	Na	Na	0-14
Chelating Resins										
Amberlite® (Iminodiacetic Acid)										
21,645-3	IRC-718	-	Mp	16-50	Na	65	90	1.1	4.4	1.5-14
Polymeric Catalysts										
Amberlyst® Strong Acid (Sulfonic Acid)										
21,638-0	15 Dry	250	120	<1.5	45	0.30	1.8	4.7		
21,639-9	15 Wet	250	120							
43,671-2	36 Wet	200	140	55	35	0.30	1.9	5.4		
DOWEX® Strong Acid (Sulfonic Acid)										
44,648-3	DR-2030			3					2.6	
Amberlyst® Weak Base (Alkyl Amine)										
21,641-0	A-21 Wet	400	100	64	25	0.20	1.1	4.7		

[1] G = gel (or microporous); Mp = macroporous (or macroreticular)

[2] NA = not applicable

Amberjet, Amberlite, Amberlyst, and Duolite are registered trademarks of Rohm and Haas Co.
Dowex, Marathon, and Retardion are registered trademarks of Dow Chemical Co.

Figure B-6. DOWEX™ 1-X8 Cost from GFS Chemicals (supplier/non-bulk)

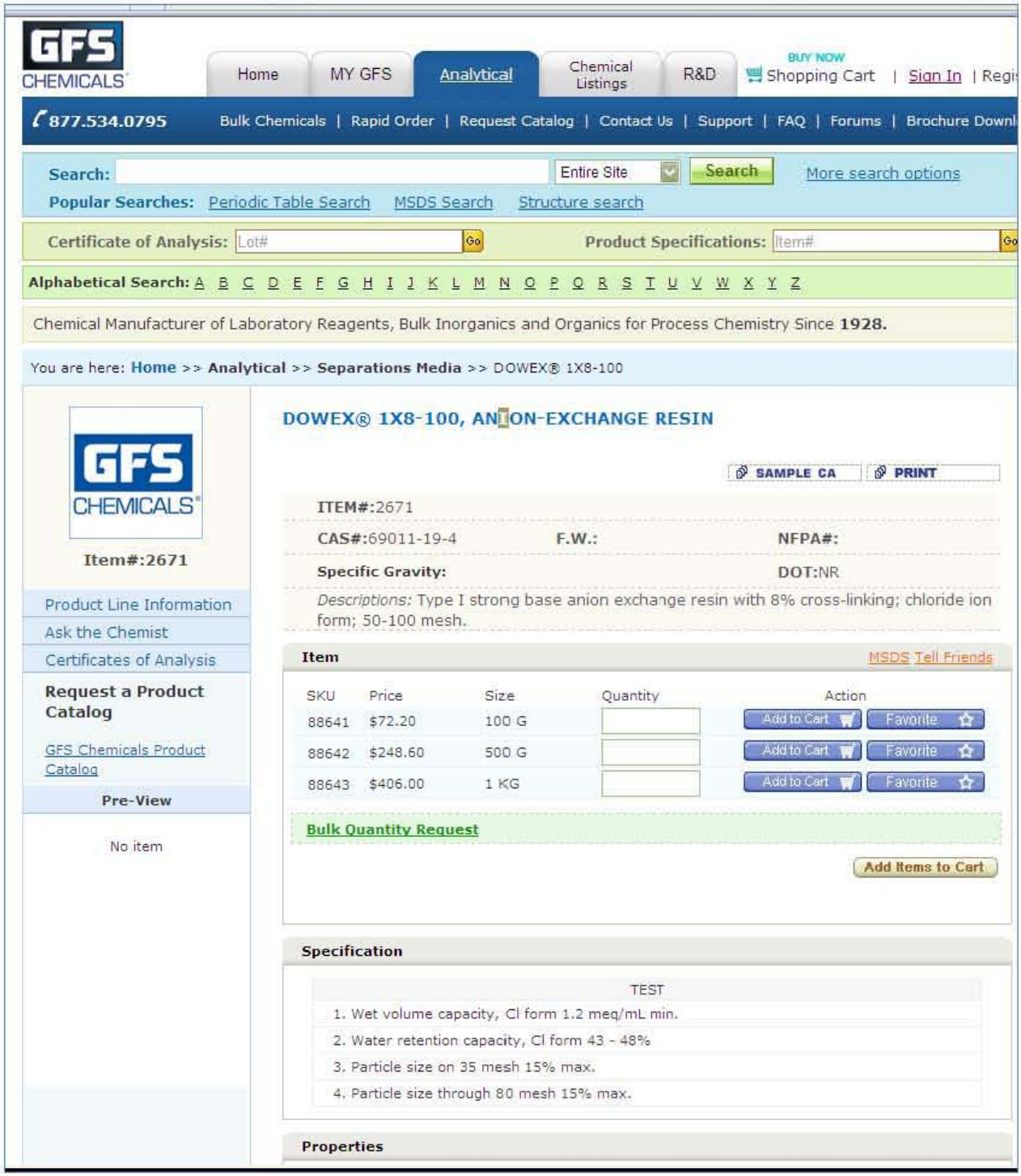


Figure B-7. DOWEX™ 1-X8 Supplier Information

DOWEX® Ion Exchange Resins

DOWEX® resins are made of spherical particles. The benefit for the user is a highly efficient exchange process, due to optimal flow-through kinetics because of the round (spherical) particles.
We offer a broad range of DOWEX® ion exchangers (anion and cation) featuring small particle sizes and narrow particle size distributions (50 - 100 mesh, 100 - 200 mesh, 200 - 400 mesh). In addition, analytical grade qualities of DOWEX® resins are available. These products are processed from original DOWEX® (»practical grades«) resins, following a proprietory procedure developed by us.

DOWEX® 1 - anion exchangers of type I, strongly basic:
A series of gel ion exchangers based on styrene-DVB-copolymerisates of type I. Refers to U.S. Food Additive Regulations, Ref. 1.21.1148

Supplied form of all DOWEX® anionic resins:
- pract. grade = Cl^- form
- analytical grade = Cl^- form

Maximum working temperature for all DOWEX® anion resins listed:
- 60 °C (140 °F) for Cl^- form
- 40 °C (104 °F) for OH^- form

For other counter ions please inquire for special bulk production.

DOWEX® 50 W - cation exchangers, strongly acidic:
Spherical beads, sulfonated polystyrene/ DVB matrix.
Supplied form of all DOWEX® 50 W resins:
- pract. = H^+ form
- analytical grade = Na^+ form

For other counter ions please inquire for special bulk production.

DOWEX® is a trademark of Dow Chemical Comp., Michigan, USA.

DOWEX® 1X2 (50-100 mesh) pract.

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	2 % DVB
Capacity	min. 0.7 eq/l
Loss on Drying	65 - 75 %

DOWEX® is a trademark of Dow Chemical Comp., Michigan, USA.

Cat.No.	Size
41010.01	100 g
41010.02	500 g

DOWEX® 1X2 (50-100 mesh) analytical grade

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	2 % DVB
Capacity	min. 0.7 eq/l
Loss on Drying	65 - 75 %

Cat.No.	Size
41011.01	100 g
41011.02	500 g

DOWEX® 1X2 (200-400 mesh) pract.

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	2 % DVB
Capacity	min. 0.6 eq/l
Loss on Drying	70 - 80 %

Cat.No.	Size
41030.01	100 g
41030.02	500 g

DOWEX® 1X2 (200-400 mesh) analytical grade

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	2 % DVB
Capacity	min. 0.6 eq/l
Loss on Drying	70 - 80 %

Cat.No.	Size
41031.01	100 g
41031.02	500 g

DOWEX® 1X8 (20-50 mesh) pract.

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	8 % DVB
Capacity	min. 1.3 eq/l
Loss on Drying	50 - 60 %

Cat.No.	Size
41080.03	100 g
41080.04	500 g

DOWEX® 1X8 (20-50 mesh) analytical grade

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	8 % DVB
Capacity	1.0 - 1.5 eq/l
Loss on Drying	50 - 60 %

Cat.No.	Size
41081.03	100 g
41081.04	500 g

DOWEX® 1X8 (50-100 mesh) pract.

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	8 % DVB
Capacity	min. 1.2 eq/l
Loss on Drying	43 - 47 %

Cat.No.	Size
41090.01	100 g
41090.02	500 g

DOWEX® 1X8 (50-100 mesh) analytical grade

HS 39140000

Anion exchanger of type I, strongly basic.

Cross Linkage	8 % DVB
Capacity	min. 1.2 eq/l
Loss on Drying	45 - 55 %

Cat.No.	Size
41091.01	100 g
41091.02	500 g

Figure B-8. Purolite™ A-520E

Vendor:____The Purolite Company_____

Contact Name/Phone/Email:___Steve Soldatek_____

Influent	
pH Range	≥12
Viscosity of Feed	1-20 cP
Resin Type	
Inorganic	No
Organic	YES - Purolite A520E
If Known for Pertechnetate (TcO_4^-) Removal	
Kd [Tc]	
Selectivity to Tc	
Poisons	Competing anions (SO4, Cl, HCO3, NO3, U)
Equivalents/L	0.9 eq/l min.
Resin Properties	
Preparation Procedure	Backwash to classify bed and then rinse
Radiological Stability and/or Gas Generation	
Bed Volumes per Hour Operation	Depends on concentration of competing anions
Particle Size	300 – 1200 micron diameter
Elutable	No
Eluant	No
Storage, Shelf Life	5 years
Handling Specifications	
Loading Cycles	Single use disposable resin
Resin Density (weight per unit volume)	675 705 g/l
pH operating range	0 - 14
Temperature operating range	5 – 60C
Cost per Pound (or ft^3)	
Ability to supply amounts of ≥ 2000 lbs	Yes

Figure B-9. Purolite™ A-530E

Vendor:____The Purolite Company_____

Contact Name/Phone/Email:___Steve Soldatek_____

Influent	
pH Range	≥12
Viscosity of Feed	1-20 cP
Resin Type	
Inorganic	No
Organic	YES - Purolite A530E
If Known for Pertechnetate (TcO_4^-) Removal	
Kd [Tc]	
Selectivity to Tc	
Poisons	Competing anions (SO4, Cl, HCO3, NO3, U)
Equivalents/L	0.6 eq/l min.
Resin Properties	
Preparation Procedure	Backwash to classify bed and then rinse
Radiological Stability and/or Gas Generation	
Bed Volumes per Hour Operation	Depends on concentration of competing anions
Particle Size	300 – 1200 micron diameter
Elutable	No
Eluant	No
Storage, Shelf Life	5 years
Handling Specifications	
Loading Cycles	Single use disposable resin
Resin Density (weight per unit volume)	670 g/l
pH operating range	0 - 14
Temperature operating range	5 – 60C
Cost per Pound (or ft^3)	
Ability to supply amounts of ≥ 2000 lbs	Yes

Figure B-10. Reillex™ HPQ (from Vertellus®)

TYPICAL PROPERTIES
REILLEX™ crosslinked poly-4-vinylpyridines

	Reillex™ 402	Reillex™ 425	Reillex™ HP	Reillex™ HPQ
Appearance	granular powder	spherical beads	spherical beads	spherical beads
Weak Base Capacity	8.0 eq/kg dry	6.0 eq/kg dry 1.7 eq/l wet	6.0 eq/kg dry 1.7 eq/l wet	N/A
Strong Base Capacity	none	none	none	4.0 eq/kg dry (min)
Water (%)	10% max.	~50%	~50%	~50%
DVB (%)	2	25	25	25
Particle Size (U.S. Mesh)	-60/+200	-18/+50	-30/+60	-30/+60
Bulk Density (Kgs/ft^3)	-	27.2	26.2	25.2
Average Pore Size (A)	none	450	600	600

Figure B-11. SuperLig® Vendor Information (page 1 of 3)

Date: Mon, 25 Apr 2011 13:01:27 -0600
From: rbruening@ibcmrt.com
To: slzatt@ibcmrt.com; Rebecca_A_Robbins@rl.gov
Subject: Tc and SuperLigR 639 Questions

Dear Rebecca

The following is an answer to your questions. Please note that IBC does not have a copy of the data reports for the SuperLigR 639 like we do for at least some of the SuperLigR 644 testing for Cs. Hence, much of the information we do not have the ability to send you the reports to give you back up graphs, etc. This information has been communicated to us largely by showing us data without giving us copies of reports, etc. Perhaps some of these reports are now public. We would be happy to comment on any of the reports you might have or could provide.

Past testing summary

SuperLigR 639 has been shown to have the ability to reduce the amount of Tc present as pertechnetate multiple orders of magnitude. Any Tc present in other oxidation states has not been removed. The tanks containing significant organics have shown levels of Tc up to 20% (and occasionally higher) that were not removable due to other oxidation states being present while most of the tanks have shown 99 to 99.9% Tc removal. BNFL concluded that all requirements (as they were present in their time) could be met by mixing the outputs of the organic and non-organic containing tanks to reach the necessary Tc decontamination factor. All separation methods studied for Tc removal had the same issue and so the superiority of the SuperLigR 639 was based on its superior removal of the pertechnetate in tanks with high nitrate/nitrite and its ability to be eluted with water (rather than with large excesses of nitrate, etc.).

SuperLigR 639 is a ligand covalently bound to polysytrene. Hence, its radiolytic stability is primarily the radiolytic stability of the polystyrene (as per all other polystyrene based resins) which is around 1 x 10 7 rads. This has required that SuperLigR 639 and all other polystyrene and other organic supported resins for Tc removal be used after the Cs has already been removed to allow for many cycles of operation to be obtained.
SuperLigR 639 had to be prepared in a maximized density state (issue for all polystyrene based resins) in order for the resin not to float in some of the highest density feed solutions (density of 1.25 to 1.27 g/ml). This has already been achieved and demonstrated in production of the SuperLigR 639 later batches after this requirement was communicated to IBC.

Tc removal from a variety of tanks including high and low nitrate/nitrite, high and low organic content, high and low K with Tc removal being very high for all pertechnetate in all cases and not removing the Tc present in other oxidation states has all been tested in columns of lab and pilot size. In all cases the Tc was eluted with deionized water. In cases where the high K was present the elution required 70 C water instead of room temperature water.

Resin Description

Organic polystyrene support (0.5 mm beads) with covalently bonded ligands present. This is an elutable resin that is eluted in room temperature water except when the pertechnetate binds significantly as the K or ammonium salt (higher binding constants in this case) where 70 C deionized water is required for elution. SuperLigR 639 had to be prepared in a maximized density state (issue for all polystyrene based resins) in order for the resin not to float in some of the highest density feed solutions (density of 1.25 to 1.27 g/ml).

Details of Eluent

This is an elutable resin that is eluted in room temperature water except when the pertechnetate binds significantly as the K or ammonium salt (higher binding constants in this case) where 70 C deionized water is required for elution. The eluent in total usually requires approximately 10-15 bed volumes at a flow rate of 0.1 bed volumes per minute. However, if desired the elution can be divided into two halves or three thirds with only the first outlet portion of the eluent sent to the Tc recovery section of the plant and the remaining tail of the elution recycled as the first part of the next elution.

Figure B-12. SuperLig® Vendor Information (page 2 of 3)

Resin shelf life
5-10 years

Resin storage requirement
Resin can be stored dry or in water.

Resin handability
Resin is readily handled similarly to standard IX resin as it has similar solid support and similar particle size. The difference is in the ligand present that has the high pertechnetate over other anion selectivity, but this does not affect the physical characteristics of the resin. SuperLigR 639 had to be prepared in a maximized density state (issue for all polystyrene based resins) in order for the resin not to float in some of the highest density feed solutions (density of 1.25 to 1.27 g/ml).

Resin preparation/conditioning requirement
Soak in water for 30 minutes or longer to wet and slurry pack into packed bed column. No other preparation/conditioning requirement to contend with. There is a slight shrink/swell of the material in going from neutral pH to basic pH and acidic pH.

Tc Loading
This varies with the level of Tc in the feed. Typical loading amounts are 70-200 Bed volumes and then the amount of Tc loaded depends on the Tc level in the feed. For higher Tc feed levels, higher Tc loadings (not higher Bed volumes) have been obtained. It would be wise to obtain some of the lab and pilot reports from the DOE complex to be able to have examples of specific loadings for specific feed types and concentrations that are not available directly to IBC.

Anticipated loading cycles before failure
Determined primarily by when 1 x 10 7 rads of exposure are reached. Assuming the Cs is removed first, this exposure is expected to take around 100-200 cycles to occur, but this will vary with the radiation level of the Tc and other radioactive elements present. Hence, you will want to check what the radioactivities of the different tank feeds are (with the Cs removed) to determine this for different tank feeds.

Selectivity with respect to competing anions
Virtually infinite selectivity over hydroxide, chloride, fluoride, and bromide. Selectivity over 2-3 M nitrate and nitrite of multiple orders of magnitude such that there is minimal effect on pertechnetate binding up to this range of nitrate/nitrite concentrations.

Resin poisons
No poisons found in tank feeds to this point in testing. Feed needs to be fully clarified prior to entry of resin column as solids can block physical access of pertechnetate to resin ligand sites. Note that this requirement is the case with any resin system and is not unique to SuperligR. Radioactivity stability to 1 x 10 7 rads.
Operating temperature range

Because the binding constants for the pertechnetate decrease with increasing temperature a temperature range of 5 C to 40 C is recommended. The elution, however, can either always be done at 70 C or done at 70 C with high K feeds.

Operating pH range
No limit in either acidic, neutral, or basic range. The Tc binds to a completely neutral ligand as a total salt. Hence, the requirement for Tc binding is sufficient Na+, K+, NH4+, or H+ being present.

Process rate
Loading, washing, and elution done at 0.1 Bed Volumes per hour.

Potential for gas generation (due to radiolysis)
Same as for other polystyrene based resins.

Figure B-13. SuperLig® Vendor Information (page 3 of 3)

Estimate of Tc remaining on spent resins
Less than 0.01% of Tc loaded on last loading cycle.

Suggestions for disposition of spent resins
Same methods applicable to other polystyrene based resins applicable to SuperLigR 639.

ROM cost/lb
Cost per lb is dependent on volume and commercial terms. SuperLigR 639 will, however, be economic based on all studies to date.

Development requirements
None that IBC is aware of.

Technology risks
None that IBC is aware of.

I hope that this information is helpful to you.
Regards,

Ron Bruening
IBC Advanced Technologies, Inc.
(801) 763-8400 (phone) (
801) 763-8491
(fax) http://www.ibcmrt.com

Figure B-14. TAM (Kurion, Inc)

Vendor:__Kurion, Inc._____

Contact Name/Phone/Email:__Dr. Mark S. Denton, 865-368-0979

Influent	
pH Range	≥12
Viscosity of Feed	1-20 cP
Resin Type	
Inorganic	Y or N
Organic	Y or N
If Known for Pertechnetate (TcO_4^-) Removal	
Kd [Tc] SnII Apatite Microspheres (TAM)	pH 8.6 WTP Recycle Surrogate: 6.19E+01 pH 13.2 At tank AN-104 Surrogate: 6.94E+02
Selectivity to Tc	Extremely specific at high salt molarity and high pH
Poisons	Neither salts nor chelants seem to have an affect
Equivalents/L	~ 2.25-2.50
Resin Properties	
Preparation Procedure	Sn II substitution for Ca in Hydroxy Apatite (CaPO4) Microsphere production. Glass substrate initiator.
Radiological Stability and/or Gas Generation	Extreme rad stability. No know gas generation.
Bed Volumes per Hour Operation	Depends on application.
Particle Size	20-50 mesh. ~ 300-850 micron
Elutable	Unknown at this time
Eluant	Ditto (the object is to trap Tc-99, not elute it)
Storage, Shelf Life	Indefinite
Handling Specifications	No special specs.
Loading Cycles	See above.
Resin Density (weight per unit volume)	~ 1.37 g/cc
pH operating range	6.5-14 (not for acidic conditions)
Temperature operating range	Made from glass microspheres at high temperatures. So none known.
Cost per Pound (or ft^3)	To be specified.
Ability to supply amounts of ≥ 2000 lbs	Depends on time frame specified.