HIGHLY SELECTIVE NUCLIDE REMOVAL FROM THE R-REACTOR DISASSEMBLY BASIN AT THE SRS

J. B. Pickett, W. E. Austin, H. H. Dukes
Facilities Decontamination and Decommissioning Program
Westinghouse Savannah River Co.
Aiken, SC 29808

ABSTRACT

This paper describes the results of a deployment of highly selective ion-exchange resin technologies for the *in-situ* removal of Cs-137 and Sr-90 from the Savannah River Site (SRS) R-Reactor Disassembly Basin. The deployment was supported by the DOE Office of Science and Technology's (OST, EM-50) National Engineering Technology Laboratory (NETL), as a part of an Accelerated Site Technology Deployment (ASTD) project. The Facilities Decontamination and Decommissioning (FDD) Program at the SRS conducted this deployment as a part of an overall program to deactivate three of the site's five reactor disassembly basins.

The R-Reactor was shutdown in 1964, and is currently maintained in a Surveillance and Maintenance (S&M) mode. The disassembly basin still contains the majority of the water left at shutdown, currently about 5,000,000 gallons. The ASTD deployment was designed to remove the majority of the Cs-137 and Sr-90, using highly nuclide specific ion-exchange resins. The use of highly specific resins would generate the least amount of secondary waste, by removing only the constituents of concern. The treatment was conducted *in-situ*, with the treated effluent discharged back into the basin. The goal was to treat one to two basin volumes of water, and to remove 67% to 73% of each of the radionuclides. At that point, the water could be treated one final time, which would meet the DOE release limits (and perhaps the EPA drinking water limits) and be released directly to a surface stream. Even if the water were not released, treatment of the basin water would reduce the impact to the surrounding groundwater, if the basin were to leak in the near future.

The deployments utilized two technologies for Cs-137 removal. One was a system from the 3M Co., St. Paul, MN (the Selective Separation Cartridge- SSC™) and a commercial water softening resin from Graver Technologies, Glasgow, DE. The 3M SSC™ system for Cs-137 removal treated over 6.8 million gallons of the basin water, or approximately 1.3 basin "turnovers" at 98 to 99% removal efficiency. The Selion CsTreat® system treated an additional 1.2 million gallons for Cs-137, at 97 to 99% removal efficiency. The Sr-90 deployment system treated over 5.6 million gallons at greater than 99.9% removal efficiency. Over 75% of both radionuclides were removed from the R-Disassembly basin water by the completion of the deployments.

INTRODUCTION

The 105-R Reactor Disassembly Basin is a reinforced concrete structure of blast-resistant design connected to the west side of the reactor building. The R-Reactor Disassembly Basin is the largest of the SRS production reactor basins, encompassing approximately 42,000 square feet, with a capacity of ~6.3 million gallons. The basin is constructed of reinforced concrete and is unlined, with depths varying from 17 to 30 feet. The exterior walls range from 2.5 to 4 feet thick, and the foundation is 7.5 feet thick. Reactor operations were initiated in 1953 and the reactor and disassembly basin were retired from service in 1964.

The disassembly basin has been emptied of all fuel (fissile) and target materials. Although no basin management is currently being performed, about 5 million gallons of water remains in the basin, about 6 feet below normal full. The water is stagnated as all deionizers, cooling systems, and filtration systems were phased out years ago. The basin has a 1/8 to 1/4 inch layer of sludge (mainly aluminum and iron oxide) over much of the basin floor and there are pieces of scrap aluminum and universal sleeve housings on the floor. The basin water contains approximately 750 curies of radioactivity, primarily tritium. The potential exists for leakage of the basin water to the surrounding groundwater. This would result in immediate groundwater contamination, since the water table is close to the same level as the water in the basin (~5 feet to 8 feet below ground surface). The basin water contains Cs-137 and Sr-90, at levels which would exceed EPA drinking water levels, if the basin water mixed with the groundwater.

In FY '99, the DOE Office of Science and Technology (OST, EM-50) approved a Deployment Plan for the water cleanup at the 105-R Disassembly Basin and provided funding amounting to $550,000 through FY 2001. FDD provided matching funding through EM-60 of $950,000 for these three years. The Deployment Plan, SR-09-DD-61, called for the use of a highly selective NUclide REmoval System (NURES) commercialized by Selion, OY, Finland. Graver Technologies Inc., of Glasgow DE, licensed the NURES technology from Selion, and provided the NURES selective resins and equipment to the SRS.

In FY 2000, FDD also partnered with 3M, St. Paul, MN to deploy a similar highly selective material for Cs-137 at the R-Disassembly Basin. This technology is called the Selective Separation Cartridge (SSC™) technology. The 3M system was developed under a DOE Technical Task Plan FT-06-C-261, overseen by DOE's National Energy Technology Laboratory, Morgantown, WV, who provided the funding for the construction of the 3M system. FDD funded the 3M system deployment costs at the disassembly basin. Neither the Selion, nor the 3M, ion-exchange technologies had been previously deployed at a Department of Energy site. The 3M Cs removal system had been tested at the R-Disassembly Basin in 1998 at 5 GPM for a short period of time (2 weeks).

The SRS Technical Task Plan (TTP) goals for the removal of Cs and Sr are summarized in Table I. The treatment goals during the recycle treatment were selected to minimize the amount of water that had to be initially treated, but which would then allow one last "pass-through" prior to direct release. At 90% removal efficiency, the treated water would meet the DOE release guidelines, and if the ion-exchange removal efficiency exceeded 99%, the treated effluent would meet the EPA guidelines.

Table I: TTP Treatment Goals for the In-Situ R-Basin Deployments

	Initial Radionuclide Concentration, pCi/L	Deployment Goal During Recycle, pCi/L	DOE 5400.5 Release Guide, pCi/L	EPA Primary Drinking Water Limit, pCi/L
Cs-137	92,800	25,000 (73%)	3,000	200
Sr-90	23,400	10,000 (67%)	1,000	8

INNOVATIVE ION EXCHANGE TECHNOLOGIES

Both the 3M and Selion Cs-137 removal technologies are based on a sodium or potassium cobalti-hexacyanoferrate compound, which is extremely selective for Cs-137. The selectivity coefficients (Kd's) for various Cs-137 removal ion-exchange materials are given in Table II:

Table II: CsTreat® Selectivity Coefficients for Cs vs. Na for Various Media

Media	Na Concentration (moles/L)	Cs Selectivity Coefficient K_d
Strong Acid Resin	N/A	<10
Cs Selective (SRL R-F)	6.0	11,400
Zeolite	0.1	450
Crystalline silicotitanate (CST)	5.7	18,000
CsTreat® (hexacyanoferrate)	5.0	1,500,000

Cs-137 Removal System Descriptions

- **Selion CsTreat®**

The Selion CsTreat® technology is based on a deep bed ion-exchange technique, using very finely divided hexacyannoferrate, with a very high surface area. The bed is operated in a down–flow mode, with preferred flow rates in the range of 10 to 20 bed volumes per hour (BV/hr). At that flow rate, the CsTreat®'s anticipated removal efficiency is greater than 99.9% (a DF; Decontamination Factor of >1,000). The system for the R- Disassembly basin was initially designed to treat 50 gallons/min (3000 gallons/hr, or 400 cu. ft/hr). At 20 bed volumes per hour, his would have required 20 cubic feet of resin. This proved to be too expensive for the available ASTD deployment funding, since the CsTreat® costs ~$16,000 per cu. ft. In order to meet the deployment goals, the target flow rate was reduced to 15 to 20 gpm (~160 cu. ft/hr), and the flow rate was increased to 50 BV/hour. This allowed the use of only ~3 cu. ft of CsTreat®, at a cost of ~$48,000.

- **3M Selective Separation Cartridge® (SSC™)**

Since the original deployment goal of 50 gpm could not be accomplished with the down-sized Selion system, FDD partnered with the 3M Co., St. Paul, MN to deploy 3M's highly selective Cs-removal system. The 3M system could be operated at 15-20 gpm - which in parallel with the Selion system - would provide the overall treatment rate needed to process the basin water in a timely period. The 3M cartridge membrane is trademarked Selective Separation Cartridge® (SSC™) The high surface area sorbent particles, in this case cobalti-hexacyanoferrate, are loaded or enmeshed onto a web or membrane, which is then fabricated into a spiral-wound, cartridge-filter. The R-basin deployment used 22 cylindrical cartridges, 2.3" in diameter by 21" in length, at a total cost of $60,000. The 3M cartridge technology can provide higher flow rates than a standard packed bed system, and channeling is not a concern for the cartridge technology.

The deployment of two different ion-exchange systems in parallel, allowed a unique head-to-head comparison of both Cs-137 removal approaches. The colbalti-hexacyanoferrate forms an insoluble precipitate with cesium, therefore it was not intended to be regenerated; rather both the 3M and Selion materials will be disposed as low level radioactive waste (LLRW).

Sr-90 Removal System Descriptions

- **Selion SrTreat®**

The Selion ion-exchange system for Sr-90 is based on a sodium titanium oxide, again with a very small particle size and high surface area. Prior to the system deployment, Selion determined in tests (with simulated R-basin water), that two of the major cations present in the basin water, Ca (at 13 mg/L), and Mg (at 0.5 mg/L) would interfere strongly with strontium-90 removal. Therefore, it was decided to "pre-treat" the basin water with a conventional water softening resin, "GRAVEX® GX–080." This resin is a sulfonated styrene and divinylbenzene strong acid exchange resin, produced by Graver Technologies, DE. The plan was to use the Gravex® water softening resin to remove the majority of the Ca and Mg in the water, prior to a final treatment with the SrTreat®. However, there was insufficient time to utilize the SrTreat® at the end the Ca/Mg pretreatment, so the SrTreat® was not deployed. Twelve 100-gallon tanks containing the water softening GRAVEX® GX–080 resin were not regenerated; they were disposed as LLRW.

- **3M Strontium Removal (SSC®) Cartridge System**

The 3M strontium selective removal system was based on a sulfonated divinylbenzene compound, similar to Graver's water softening resin. As with the SrTreat®, calcium and magnesium also compete strongly with Sr-90 removal for the 3M material. Two sets (22 cartridges per set) of the 3M Sr-90 removal cartridges were tested in the R-Basin in June 2000, at 20 gallons per minute. Initial Sr-90 removal during the first 5,000 gallons treated was greater than 99% (DF >100). After this point, Ca and Mg started to saturate the available exchange sites, and 50% breakthrough for Sr-90 occurred at ~12,000 gallons on both sets of filters. The concentration of Ca was ~13 mg/L, while the concentration of natural strontium was 0.15 mg/L in the basin water, a factor of about 100. The 3M cartridges did not demonstrate a high enough selectivity for strontium vs. Ca/Mg for the R-Basin deployment, so no further testing was conducted with the 3M SSC® Sr-90 cartridge removal system.

SYSTEM OPERATION AND PERFORMANCE

General Operations

Both of the cesium and strontium systems were operated in a "recycle" mode, i.e.; treated water was discharged back into the basin. The discharge locations were re-positioned such that untreated water was "swept-back" toward the intake from the farthest distance in the basin. If the treated water did not mix with the untreated water, all of the water could be treated in one pass, i.e.; this would be similar to "plug flow". If the treated water mixed uniformly with the untreated water, then the whole basin system would be similar to a "continuously stirred tank reactor" (CSTR). By placing the discharge of the treated water at the farthest basin walls, with the water intake near the center of the basin, untreated water was "swept back" to the intake. This resulted in less mixing and in a treatment rate greater than that of a CSTR. This allowed the TTP treatment goals (Table I) to be met without treating as many basin turnovers as were anticipated based on complete mixing. The final results are shown in Table III.

Table III: Cs and Sr Removal vs. Continuously Stirred Tank Reactor Predicted Rate

	Gallons Treated	Basin Volumes	% Removal if CSTR rate	Actual % removal Final pCi/L / initial pCi/L
Cs-137	8,000,000	1.60	78%	89% ~10,000/ 92,800
Sr-90	5,627,000	1.12	64%	74%; ~6000/ 23,4000

Although a recycle mode is somewhat inefficient vs. a once through operational mode, the minimal operational oversight can make it very cost effective. If the treated water had been directly released as it was treated, large storage tanks would have had to be procured and installed. To ensure that the treatment goals were met, the treated effluent would have had to be analyzed before release, and the treatment discharge transferred to another, empty tank while the initial tank was discharged. This type of wastewater treatment requires significant capital investment and operational oversight. Treating the basin water by the recycle mode allowed the lowest possible *in-situ* treatment costs. Utilizing the discharge re-positioning technique allowed the goal to be attained with as few basin turnovers as possible.

Cs-137 Radiation Shielding

Although the total amount of Cs-137 in the R-basin water is not very great (~1.7 Curies), concentrating ½ of the Cs onto either the 3M cartridges or CsTreat® material would have resulted in a significant radiation dose rate, ~3.5 Rad/hr at the surface of the containment tanks. Therefore, a one-inch thick lead shield was constructed and placed around the 3M Cs-137 removal tank. The Selion CsTreat® container tank is shielded in a similar technique, except that 2½ feet of water is was used, rather than lead. The water shielding approach was much more convenient, in that the CsTreat could be easily rolled into the basin without the water shielding. Basin water was then pumped into the outer, shielding tank. For the 3M system, the lead plating had to be pre-installed, which made moving the final, very heavy, cart quite difficult.

Graver/Selion, CsTreat® Operations

The Graver/Selion CsTreat® deployment consisted of a 35 gpm centrifugal pump, with 2 parallel 25-micron bag filters following the pump. A tank with 200 gallons of activated carbon followed, to remove oil or grease – which could adversely affect the CsTreat® material. Following the activated carbon was 2 sets of 5-micron followed in-turn by 1-micron pre-filters, in parallel – to remove solid particulates, which would plug the fine particle size CsTreat® resin. The Cs-Treat® material itself was inside a 25-gallon stainless steel tank, which was enclosed in a 200-gallon plastic tank (with water shielding to reduce the gamma dose rate). A photograph of the system inside the R-disassembly basin is given in Fig. 1.

Initial start-up of the CsTreat® system in the R-basin occurred 7/28/00. First, the activated carbon tank was flushed, to remove fines, until the discharge was clear. Initial start-up of the CsTreat® media encountered a very high-pressure drop across the CsTreat®; 84-88 psi at a flow rate of 12.7 gpm. This was a much higher pressure than desired. Although the entire system had been hydrostatically tested to 150 psi, we did not want to operate much above 60 to 65 psi to minimize leaks or spills. Consultation with Selion, OY suggested that the CsTreat® media might have significant fines which were causing the high delta P (pressure drop), and that back-flushing might solve the problem. This proved to be the case; after back-flushing 3 times, the delta P dropped to 30 psi at 14.6 gpm. Each successive back-flush generated copious amounts of the brownish-black CsTreat®, so the back flush was allowed to run until the effluent was clear. There was some concern that back-flushing the CsTreat® media into the basin water would result in some of the small particles being swept back to the 25-micron inlet filters, and causing higher than desired radiation dose rates on the unshielded pre-filters. This did not prove to be a significant problem, as the surface/contact dose rate on the 25-micron pre-filters never exceeded 25 mrem/hr.

Fig. 1; Graver/Selion System in R-Basin: Activated Carbon Tank to the Right, with the 1 and 5 Micron Filters in the Center, and the CsTreat® Inside the Shielding Tank to the Left

After the initial start-up, the system started operating continuously on 8/16/01. The pressure drop across the CsTreat® was acceptable at 30 psi, at 17.5 gpm. The 1 micron pre-filters started with a delta P of 4-5 psi, but their delta P increased to 37 psi after ~200,000 gallons had been treated, by 8/28/01. At that point the delta P across the 1-micron filters leveled out, and then started to diminish. It was not recognized until 4 weeks later that the 1-micron pre-filters had "broken-through" and were allowing particulates to plug the CsTreat® media – until a total of 785,000 gallons had been treated. By that time (9/28/01), the delta P across the CsTreat® had increased to 36 psi, at a reduced flow rate of 13 gpm. We then started replacing the 1-micron filters on a 10-day frequency, about every 100,000 gallons of water treated. However, the delta P across the CsTreat® continued to increase until it reached 57 psi at only 10 gpm. Including the pressure drop across the 1-micron filters, the total system was operating at a delta P of 75-85 psi, and we had a small leak at one of the quick-disconnect couplings.

We considered back-flushing the CsTreat® to reduce the pressure drop and increase flow rate, but the 1-micron filter replacement rate was too high to be supported. Therefore, at 1,189,000 gallons treated, on 11/30/00, the Graver/Selion CsTreat® system was shutdown.

3M SSC Cs-137 Operations

The SSC™ system for the selective removal of Cs-137 was started up 6/21/00. The system had a 65 gpm centrifugal pump. It had one 2-micron pre-filter, followed by a set of nine 0.2-micron pre-filters, prior to the 22 SSC™ cartridges. Initially, the system was run only during the day, with operational personnel present. By 6/26/00 sufficient confidence had been gained that 24 hr/day, 7 days/week operation was initiated. After that time, the oversight was conducted usually on Monday mornings and Thursday afternoons. From 6/26/00 to 9/13/01, the system was "down" only for change-out of the 3M™ 2-micron and 0.2-micron pre-filters. The initial 8 weeks of operation were considered a "demonstration" of the new technology. The demonstration was completed 8/17/00, with 1.1 million gallons treated. The 3M system continued to be operated, so that the total treatment rate of both the 3M SSC™ system and the Graver/Selion CsTreat® system (when it started later, in July, '00) would be 40 to 50 gpm.

As with the Graver/Selion CsTreat® system the 3M pre-filters had to be periodically removed and replaced. At the start of treatment the 2-micron filters were removed after reaching a delta P of 30 to 40 psi, which occurred after 300,000 to 400,000 gallons treated. The replacement frequency averaged once/month during the first 4 months of operation. After that time, the volume treated increased to 800,000 to 1,200,000 gallons of water treated between filter changes, with a reduced change-out frequency of 3 to 4 months. The set of 0.2-micron pre-filters had to be replaced twice. The improved change-out rate as the treatment progressed is attributed to the removal of suspended and/or dissolved iron and aluminum oxides/hydroxides, such that the filter life was increased. This data is given in Table IV. A photograph of the 3M system in the R-disassembly basin is shown below.

Fig. 2 – 3M Cs-137 Removal System in the R-Reactor Disassembly Basin. The 4-foot tall, 6-inch diameter, 2-micron pre-filter is to the right and a small tank with nine 0.2-micron prefilters is in the center. The 22 SSC™ Cs-137 removal filters are inside a stainless steel tank to the left, which was covered with ~1 inch of lead shielding to reduce the gamma dose.

After 10 months of 3M operations, and 3 months of Graver/Selion operations for Cs-137 removal, a total metals analysis was conducted on a basin water sample (at the Graver/Selion intake). The concentrations of aluminum, iron, copper, manganese, and nickel were each reduced by approximately 90% vs. the pre-treatment concentrations in 1997 (see Table IV). Since these heavy metals can form slightly insoluble hydroxides/oxides, their removal is attributed to the 3M 2-and 0.2-micron pre-filters and the Graver 1-micron pre-filters. Although none of the filters themselves were chemically analyzed, the reddish/brown visual appearance is consistent with metallic hydroxide removal. The combination of the 3M 2- and 0.2-micron filters lasted longer than the Graver 5- and 1-micron array, and the 3M prefilters allowed very low solids to impact the 3M SSC™ cartridges. The SSC™ cartridges evidenced almost no pressure drop increase during the entire 6.8 million gallons treated (zero to ~2 psi delta P).

Table IV. Metal Concentrations, mg/L

	Composite Sample, 1997	Inlet Sample 4/19/01	Graver, Lead Tank 4/30/01	Graver, Lead Tank 5/7/01
Gallons Treated	Zero (Ref. 1)	5,765,000 Total	160,000 Through Sr	315,000 Through Sr
Al	0.103	<0.015	<0.015	
B	0.029	0.012	0.008	
Ba	0.005	0.005	<0.003	
Ca	12.2	11.98	0.126	6.77
Cd	<0.001	<0.002	<0.002	
Co	0.007	0.006	<0.003	
Cr	0.002	<0.009	<0.009	
Cu	0.084	<0.003	<0.003	
Fe	0.116	0.008	0.091	
Li	-	0.024	0.026	
Mg	0.49	0.45	0.016	0.99
Mn	0.027	<0.001	<0.001	
Mo	0.001	<0.003	<0.003	
Na	16.5	17.7	25	
Ni	0.059	<0.009	<0.009	
Pb	<1.0	<0.046	<0.046	
Si	1.32	1.19	1.17	
Sn	<1.0	0.029	0.023	
Sr	0.150	0.164	<0.001	<0.001
Ti	0.001	<0.003	<0.001	
V	0.033	<0.003	<0.003	
Zn	0.015	0.009	0.091	

Graver Sr-90 Operations

The Graver/Selion Sr-90 removal system was started-up 4/16/01. As discussed previously, the Selion SrTreat® could not be used initially, due to calcium and magnesium interference. Therefore, a series of 100 gallon tanks, containing the GRAVEX-080® water softening resin were used. The Cs-137 removal tank was bypassed, and four, 5-micron Graver/Selion pre-filters were used. Two 100-gallon Sr-90 removal tanks were used in series, a "Lead" and a "Lag" tank. The intent of the two tanks was to prevent any significant breakthrough of Sr-90 in the treated effluent. Graver estimated that it would take 3000 gallons of the water softening resin (30, 100 gallon tanks) to treat one basin turnover (~5,000,000 gallons) to remove sufficient Ca and Mg - to allow use of the SrTreat® material. As each lead tank reached its capacity for calcium, and strontium, it was removed and replaced with a fresh tank. The replacement was accomplished by rolling the mobile cart outside the basin through a nearby access door, and lifting the 100 gallon tank off of the cart with a lifting sling and overhead crane. The spent tank was placed into a LLRW disposal container, a new tank was placed onto the rolling cart, and the cart and tank pushed back into the basin area. All the lines between the various tanks and pre-filters were joined by "quick-disconnect" connectors, which facilitated removing and replacing the tanks. The GRAVEX-080® resin is in bead form, and is a much larger particle size than the CsTreat® material. The 1-micron prefilters did not need to be used, as the 5-micron pre-filters were adequate to protect the water softening resin. The pressure drop across both the lead and lag tanks combined never exceeded 28- 30 psi, at flow rates up to 30 to 32.5 gallons per minute. Even with a flow rate of 32.5 gpm (~47,000 gallons/day), a one basin volume turnover was not accomplished until 10/8/01, when 5,627,000 gallons had been treated. Since the funding for this deployment only included fiscal years '99, '00, and '01 – the SrTreat® material could not be deployed. However, the GRAVEX–080® resin removed Sr-90 much more effectively than anticipated, and the final % removal goals were attained.

RESULTS AND DISCUSSION

3M and Graver/Selion Cs-137 Removal

The results for the Cs-137 removal by both systems are given in Table V. The Cs-137 analyses were conducted by the Savannah River Technology Center, using 3M's Empore® disk technology. This technology allowed very low detection limits for both Cs-137 and Sr-90.

The 3M system always removed Cs-137 at >97%, usually >99%. The Selion CsTreat® % removal was similar, ranging from 97% to 99%. While the higher than desired bed volume per hour flow rate (~50 BV/hr) probably reduced CsTreat® removal efficiency, it was completely satisfactory for the recycle mode of operation.

After the 4/16/01 startup of the Graver Sr-90 removal system, samples were collected from the Sr-90 removal system and analyzed for Cs-137. The data indicated that the GRAVEX –080® resin initially absorbs Cs-137, up to a volume of ~100,000 gallons (5/14/01 data, Table V), and then starts to desorb and release the Cs-137 (6/25/01 data, Table V). This indicates that the sodium cation was initially replaced by cesium and calcium, but that the cesium was then replaced by strontium. This can be seen in the total metal concentration data in Table IV, where calcium is almost totally absorbed up-to 160,000 gallons, while at 315,000 gallons the Ca and Mg have started to "breakthrough". The natural strontium (and Sr-90) is still being removed at >99.9% removal, even after the calcium has broken through.

The desorption of Cs-137 was very desirable from an operational standpoint, since the Sr-90 removal tanks were not shielded, and a significant Cs-137 uptake would have resulted in undesired radiation exposure while removing the tanks.

The goal of <25,000 pCi/L of Cs-137 was attained by 3/26/01, after which no analysis was greater than 23,000 pCi/L Cs-137.

Table V. Cs-137 Results, pCi/L

Date	3M, Gals Treated (1000)	3M in	3M out	% rem.'	Selion Gals Treated	Selion In	Selion Out	% Rem.'
6/22/00	22	78,195	<1392					
6/29/00	101	80,982	<1644	-				
7/13/00	493	66,933	120	99.8				
8/7/00	845	50,406	758	98.5	1	59,500	108	99.8
8/17/00	1,093	90,060	148	99.8	32	35,344	739	97.9
9/11/00*	1,435	29,230	802	97.3	465	32,730	875	97.3
11/2/00	1,869	64,810	118	99.8				
11/9/00*	2,058	51,213	177	99.7	1,158	55,628	648	98.8
11/21/00	2,302	69,932	235	99.7				
11/30/00	2,434	27,937	<413	>98.5				
3/26/01#	4,188	20,188	<334	>98.3	-			
4/19/01	4,575	22,992	<102	>99.5	-	21,334@		
5/14/01##	4,957	19,028	48	99.7	-	13,662	433	96.8
5/31/01	5,204	19,781	78	99.6				
6/25/01					-	13,032	15,246	-
7/2/01	5,750	16,320	<69	>99.6	-			
8/20/01	6,494	15,454	104	99.3	-			
9/13/01	6,813	12,391	123	99.0	-	8,501		

* Moved 3M discharge toward far southeast corner, then all the way to the corner; the intake concentration increased after each move, as untreated water "swept" back
# Moved 3M discharge to far southwest corner
Moved 3M discharge to far northwest corner
@ Graver Sr removal system operating; discharging to far northeast corner of the basin.
Note: the 5/14/01 analysis indicated Cs-137 removal, while the 6/25/01 analysis indicated Cs-137 stripping.

Graver/Selion Sr-90 Removal

The Sr-90 removal results are summarized in Table VI. The % removal for Sr-90 with both the lead and lag tank in series was never below 99.5%. The % removal for the lead tank for Sr-90 went as low as ~85 %, when the total volume of water was over 600,000 gallons. The Sr-90 removal far exceeded the expectation that only 150,000 gallons could be treated per tank, before Sr-90 breakthrough. At these volumes (500,000 to 600,000 gallons), the Ca and Mg were not removed at all, but Sr-90 was still be selectively removed. The GRAVEX-080® resin was found to be selective for Sr-90 in the presence of Ca and Mg 100 fold the concentration of natural strontium.

Table VI. Sr-90 Results, pCi/L

Date	Lead Gallons (1000)	Lag Gallons (1000)	Lead in	Lead out	% rem.'	Lag In	Lag Out	% Rem.'*
4/19/01	35	35	23,400	-	-	-	<10	<99.95
4/30/01	160	160	23,700	18	>99.9	18	<10	>99.95
5/7/01	315	315	21,600	194	>99.5			
5/21/01	275	590	20,600	27	>99.9	27	12.6	99.9
6/11/01	425	1,015	15,800	396	97.4	396	17.5	99.8
6/25/01	446	1,461	4,919	89	98.2	89	23	99.5
7/12/01	551	2,012	5,177	226	95.7	226	21	99.6
8/6/01	625	2,637	8,811	1,354	85.4	1,354	13	99.8
8/20/01	652	0	7,000	1,094	84.3			
8/30/01	488	488	6,608	51	99.2	51	23	99.6
9/10/01	532	1,020	5,602	26	99.5	26	12	99.8
1/8/01	1,318	2,338	3,974	2,416	38	2,416	12	99.7

* The % removal is for both the lead and lag tank combined.

SUMMARY

Both the 3M and Graver/Selion systems were highly effective at removing Cs-137. The Selion CsTreat® is more sensitive to particulate plugging than the 3M SSC cartridge technology. The 3M SSC® filter cartridges can be used at higher flow rates than the Selion CsTreat®, which is limited by the bed volumes/hr it can treat. The Selion system would work very well at high Cs-137 concentrations and low flows, while the 3M system will work more effectively at low Cs-137 concentrations and high flow rates.

The "Gravex 080®" resin was shown to be was very selective for Sr-90 in the presence of Ca and Mg. This allowed the resin tanks to continue to be utilized even after they were saturated with respect to Ca and Mg.

The *in-situ* approach demonstrated a new and innovative water treatment technology for these radionuclides. The selective and highly efficient ion exchange media removed Cs-137 from the R-Reactor Disassembly Basin water with drastically reduced radiological waste volumes. The innovative in-site technologies saved the DOE an estimated $4 to $5 million at the R-Disassembly Basin compared to conventional baseline technology (transport to and treatment at a centralized wastewater treatment facility).

References

1. J. B. PICKETT, "Analytical Results of the 1997 R-Reactor Disassembly Basin Sampling Program", FDD-ENG-98-0029, Westinghouse Savannah River Co., Aiken, SC 29808, 4/1/98.