NEW TREATMENT FACILITY FOR LOW LEVEL PROCESS EFFLUENTS

AT THE SAVANNAH RIVER SITE

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ABSTRACT

A new facility, the F/H Effluent Treatment Facility (F/H ETF) is under construction at the Savannah River site. It will decontaminate process effluents containing low levels of radionuclides and hazardous chemicals prior to discharge to a surface stream. These effluents, which are currently discharged to seepage basins, originate in the chemical separations and high level radioactive waste processing areas, known as F-Area and H-Area. The new facility will allow closure of the basins in order to meet the provisions of the Resource Conservation and Recovery Act by November 1988. A high degree of reliability is expected from this design as a result of extensive process development work that has been conducted at the Savannah River Laboratory. This work has included both bench scale testing of individual unit operations and pilot scale testing of an integrated facility, 150-285 L/min (40-75 gpm), that contains the major operations.

INTRODUCTION

F/H ETF has been designed for an average processing rate of 625 L/min (165 gpm) and a maximum rate of 890 L/min (235 gpm). It consists of several holding basins and a water treatment building. The latter will house all unit operations associated with decontamination of the process effluents as shown in Fig. 1. Decontamination will be achieved by a sequence consisting of pretreatment, submicron filtration, organic compounds removal, reverse osmosis (RO), and ion exchange. The decontaminated effluent will be monitored and discharged to a creek on the site that flows to the Savannah River. Waste streams generated by these operations will be concentrated in an evaporator. The resulting concentrate will be mixed with other higher reactivity wastes and solidified in a grout matrix.

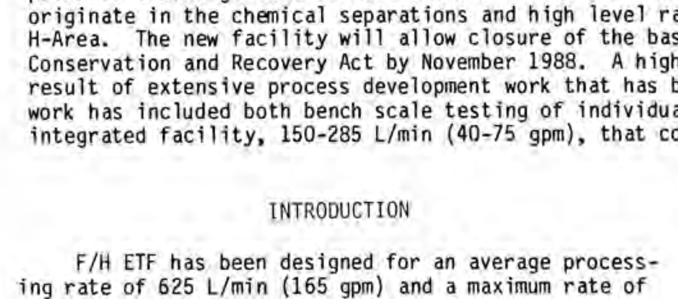

Fig. 1. Treatment Facility Process Flow Diagram.

The feed to the treatment operation is composed primarily of evaporator condensates. This stream will contain primarily $NaNO_3$ (2000 mg/L average), μCi/L quantities of radionuclides, and mg/L quantities of heavy metals. Under accident conditions, non-contact cooling water or storm water runoff can also be processed. Average expected feed compositions and associated discharge criteria to a surface stream are shown in Table I. Achievement of these criteria determined process selection. Table II shows maximum annual radionuclide discharges to the seepage basins currently allowed by administrative guidelines. The process selected will not remove tritium, which is present in μCi/L concentrations in the feed.

TABLE I

Chemical Composition of F/H ETF Feed and Test Solutions, mg/L

Species	Routine Effluents	Cooling Water	Storm Water	Simulant	Discharge Criteria
Na	558	11.0	4.0	406	
Ca	8.8	2.0	6.0	4.3	
Fe	2.7	0.6	20.	2.7	
Zn	1.1				1.48
NH_4^+	16.4			19.6	20.0
Ba	0.02			0.03	
K	0.77	1.0	1.0	0.2	
Al	1.5			1.5	
Mn	0.18	0.01	0.06	0.3	
Mg	0.4	0.4	0.6	0.44	
NO_3^-	1015			1237	
HCO_3^-, CO_3^{2-}	106	37.0	20.0	63.0	
NO_2^-	1.7			1.5	
Cl	1.2	0.5		1.4	
SO_4^{2-}	4.4	14.4	9.0	9.3	
F^-	1.1	1.0	1.0	0.8	
Si	6.9	3.4	10.7	6.3	
P	1.7			1.5	
Cr	0.031			0.025	1.71
Cu	0.14			0.14	1.46
Hg	0.053			0.053	0.045
Pb	0.15			0.15	0.29

TABLE II

Administrative Guidelines for Radionuclide Discharges

to Seepage Basins, Ci/yr

Nuclide	Cr-51	Co-58	Co-60	Zn-65	Sr-89	Zr-95	Nb-95	Ru-103	Ru-106	
Limit	7.5	1.0	1.0	0.8	0.5	9.0	7.5	3.5	17.5	
Nuclide	Sb-124	I-131	Cs-134	Cs-137	Ce-141	Ce-144	Pm-147	H-3	alpha	other β-γ
Limit	0.2	1.2	1.8	13.0	0.5	3.6	1.5	30000	0.7	1.3

Pretreatment will consist of a pH adjustment step, to enhance removal during filtration, and chlorination to prevent biological fouling of the RO membranes. Submicron filtration will be achieved by inertial filters using ceramic elements. Removal of organic compounds that can foul RO membranes will be achieved by the use of carbon impregnated resin cartridge filters or similar technology. Reverse osmosis will be carried out in staged units using high salt injection membranes designed to achieve salt rejections >90% at water recoveries >90%. During routine operation, ion exchange columns containing sulfide and sulfonic acid functionalized resins will operate in series to remove heavy metals and cationic radionuclides. Provisions have been made for the future installation of anion exchange columns should process changes dictate their use.

Bench work has been used to determine the optimum pH for filtration, the behavior of various radionuclides across each operation (including uptake by components such as RO membranes), and the decontamination achieved for hazardous metals in each step. The pilot facility, which uses nonradioactive simulants, has provided data on both the short and long term behavior of the integrated process. It will be used to train operating personnel prior to startup of the F/H ETF. These data have shown that the F/H ETF liquid effluent will be able to consistently meet NPDES[a] discharge criteria proposed by the South Carolina Department of Health and Environmental Control. Data on grouts used to solidify expected waste concentrate compositions show that they will provide adequate groundwater protection.

PROCESS DEVELOPMENT

Process selection was dictated by the dual necessities of achieving high decontamination factors and minimizing secondary liquid waste generation, (1). In addition, the facility will be closely coupled with production operations thus requiring high utility. Reverse osmosis, well-known but only recently applied to waste treatment, was selected as the best available technology to meet these goals. Discussions with RO users consistently revealed the need for appropriate pretreatment in order to ensure optimum performance. Much effort was given to finding pretreatment/filtration schemes that would remove potential RO foulants. In order to ensure adequate decontamination during expected excursions of hazardous metals and radionuclides in the feed, an ion exchange polishing step was included downstream of RO.

Pretreatment/Filtration

To meet the goal of minimum secondary waste volume, the RO system will be operated at >90% water recovery and >90% salt rejection. This goal is readily met at high utility if chlorination, pH adjustment, and submicron filtration precede RO. Sodium hypochlorite will be used to prevent biological growth. ETF feed streams contain iron and aluminum, both potential foulants. Adjustment to pH 7 will precipitate these elements, permitting removal by filtration. In addition, filtration will provide some decontamination for radionuclides present as particulates.

The F/H ETF will require a filtrate containing <0.4 mg/L total suspended solids, TSS, which corresponds to a silt density index, SDI, <1.0 for this stream. SDI is a relative measure of colloidal fouling tendency used by RO manufacturers.

Three types of filters which meet these stringent criteria have been extensively studied:

- inertial crossflow filters with ceramic[b] or stainless steel elements[c], <0.2 μm pore size
- tubular precoat filters[d] using diatomaceous earth, powdered ion exchange resins, or activated charcoal on sintered stainless steel
- ultrafilters with dynamically formed inorganic membranes or sintered stainless steel[e]

A single element or small unit of each was used to test actual plant streams to establish decontamination factors for radionuclides and hazardous metals. Large scale systems capable of 50-150 L/min have been used to establish filter performance and foulant removal using a process simulant (Table I). The SRP Facility will use three Norton CERAFLO, 3-stage, 380 L/min units in parallel.

Low-levels (mg/L) of organic contaminants, primarily tributylphosphate and n-paraffins from solvent extraction processes, will be present in F/H ETF feed streams. Single element testing of the RO membranes indicates a potential for reversible fouling when these compounds are present. Further testing on a large, 3-stage pilot unit will confirm whether or not this fouling results in unacceptably high cleaning frequencies and waste volumes. If needed, activated carbon in cartridge or column form has been demonstrated to remove these contaminants and will be replaced just prior to RO. The use of macroporous resin beads is also being investigated (2).

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[a] National Pollutant Discharge Elimination System Permit

[b] Norton Co. CERAFLO Microfilters
[c] Mott Metallurgical Corp.
[d] Mott Metallurgical Corp., Inverted Pneumatic Hydropulse
[e] Carre Inc., distributed by Associated Technologies, Inc.

Reverse Osmosis

Reverse osmosis will achieve high salt removal through the use of spiral wound, thin film membranes such as Filmtech SW30HR. The F/H ETF will contain three 380 L/min, 3-stage systems in parallel. The first stage will contain 2 pressure vessels, each holding 6 membrane elements. The second and third stages consist of one pressure vessel each. To protect the membranes any residual chlorine will be destroyed by sodium bisulfite addition ahead of RO.

Most of the development work has used the Filmtech SW30 and SW30HR membranes due to their low ion exchange capacity at pH7. This is an attractive feature for radioactive applications since it minimizes both the amount of shielding required during operation and the activity retained on spent membranes to be discarded.

Again as in filtration, tests of single elements established radionuclide and hazardous metal decontamination factors using process water and the SW30 membrane, Table III. Staged RO performance has been demonstrated using the simulant on a 150 L/min ultrafiltration/RO system. This pilot scale system consists of a Carre ultrafilter (3) in series with a 3-stage, RO system that can be operated at 150 or 285 L/min. Table IV shows the performance obtained by the RO unit using filtered simulant at various total dissolved solids (TDS) concentrations. These were obtained during a continuous 5-week run at 83% water recovery at 26°C. The first two stages were operated at 300-360 psi, and the third at 520-700 psi. Filmtech SW30HR membranes were used.

TABLE III

Representative RO Decontamination Factors, 90% Water Recovery

Species	Ce-144	Sr-85	Cs-137	Cu	Hg	Pb	Zn	Cr
DF	>130	70	25	25	20	2	5	8

TABLE IV

RO Decontamination Factors

For Filtered Simulant of Varying TDS

Species	NO_3^-	Na^+	Cs^+	Sr^{2+}	Si	Ba^{2+}	Mg^{2+}	Ca^{2+}	Zn^{2+}
TDS									
700	74	40	214*	200			80	123	28*
1800	45	44		194	118		57	73	
2400	50	49	24	260	110	52	187	102	74
2800	45	58	34	764*	90	63	201	119	
4400	67	60	44	335	64		291	193	90
6200	43	39	27	207			150		85
7600	37	47	29	249			195		104

* Suspect values

Ion Exchange

The final decontamination step in the F/H ETF is intended to remove any residual amounts of cesium, strontium, and hazardous metals present in the RO permeate and the overheads from the waste concentration evaporators in the facility (4). In order to minimize regenerant waste volumes, two types of resins will be used. A thiol functionalized resin, Duolite GP-73, will remove cationic heavy metals very selectively, especially mercury. Then further treatment will take place using a conventional sulfonic acid cation exchange (CIX) resin to remove cesium and strontium.

The facility will contain two GT-73 columns in parallel and three CIX columns, two on-line in series and a third being regenerated. Because of their high selectivity and capacity, plans are to load the GT-73 columns and not regenerate. Mercury-loaded GT-73 meets EP toxicity test criteria.

Secondary Waste

Concentrate from filtration and reverse osmosis, ion exchange regenerant solution, and cleaning solutions from filtration and RO will be further concentrated in two recirculating evaporators. The evaporator bottoms will then be mixed with other wastes and solidified in low leachability grout.

CONCLUSIONS

The F/H Effluent Treatment Facility will allow closure of existing seepage basins and produce an effluent that meets all pertinent discharge criteria. Secondary liquid waste from this facility will be concentrated and solidified in grout. All solid wastes will be discarded in approved land disposal facilities on site.

ACKNOWLEDGEMENT

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