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SITE Technology Capsule
Filter Flow Technology, Inc., Colloid Polishing Filter Method

Abstract

The Filter Flow Technology, Inc. (FFT), Colloid Polishing Filter Method (CPFM) was demonstrated at the U.S. Department of Energy's (DOE) Rocky Flats Plant (RFP) as part of the U.S. Environmental Protection Agency's (EPA) Superfund Innovative Technology Evaluation (SITE) program. The CPFM system Is designed to remove ionic, colloidal, and complexed radionuclides and heavy metals from water. Pollutants are removed from water predominantly via sorption or chemical complexing. The purpose of the demonstration was to evaluate the ability of the CPFM system to remove low levels of uranium pnd gross alpha contamlnatton from RFP groundwater.

During the demonstration, average uranium and gross alpha concentrations in influent water were 98 micrograms per liter ug/L) and 91 picoCuries per liter (pCi/L), respectively. Analytical results showed that radionucllde levels decreased by about 75% following treatment with the CPFM system. At maximum removal efficiency, the CPFM system was capable of achieving Colorado Water Quality Control Commission (CWQCC) standards for water to be discharged from RFP.

As part of the SITE program, the CPFM technology was also evaluated based on nine criteria used for decision making In the Superfund feasibility study process. The results of this evaluation indicate that the CPFM system can provide short- and long-term protection of human health and the environment by removlng radionuclide contamination from water and concentrating It in spent filter packs.

Introduction

In 1980, the U.S. Congress passed the Comprehenslve Environmental Response, Compensatlon, and Liability Act (CERCLA), also known as Superfund. CERCLA committed resources to protecting human health and the environment from uncontrolled hazardous wastes sites. CERCLA was amended by the Superfund Amendments and Reauthorization Act (SARA) in 1986 – amendments that emphaslzed the achievement of long-term effectiveness and permanence of remedies at Superfund sltes. SARA mandated permanent solutions and alternative treatment technologies or resource recovery technologies to clean up hazardous waste sites to the maximum extent possible.

State and federal agencies, as well as private parties, are now exploring a growing number of innovative technologies for treating hazardous wastes. Because the sites on the National Priorities List comprise a broad spectrum of physical, chemical, and environmental conditions requlrlng varying types of remediatton, EPA has focused on policy, technical, and informational issues related to exploring and applying new remediatton technologies applicable to multiple Superfund sites. One such Initiative is EPA's SITE program. It was established to accelerate development, demonstration, and use of innovatlve technologies for site cleanups. EPA SITE Technology Capsules summarize the latest information available on selected innovative treatment and site remediation technologies and related issues, These capsules are designed to help EPA remedial project managers, EPA on-scene coordinators, contractors, and other site cleanup man-

SITE
SUPERFUND INNOVATIVE
TECHNOLOGY EVALUATION

agers understand the types of data needed to effectively evaluate a technology's applicabilety for cleaning up Superfund sites.

Results from an evaluation of the CPFM system, based on the nine criteria used for decision making In the Superfund feasubility study process, are presented In Table 1. This table shows that the CPFM system provldes both long-term and short-term protectlon of the environment, reduces contaminant mobility and volume, and presents few rlsks to the community or the environment.

This Capsule provides information on the FFT CPFM system, a technology developed to remove low levels of radlonuclldes and heavy metal pollutants from groundwater, wastewater, and soil washlng wastewater. The CPFM system was evaluated under EPA's SITE program in September 1993 at RFP in Golden, Colorado where groundwater is contaminated with radlonuclldes. Information In this Capsule emphasizes specific site characterlstlcs and results of the SITE field demonstration at RFP. Thls Capsule presents the following Information:

- Technology description
- Technology applicability
- Technology limitations
- Process residuals
- Site requirements
- Performance data
- Technology status
- Sources of further information

Technology Description

The FFT CPFM system uses a proprietary compound (Filter Flow 1000) that consists of inorganic, oxide-based granules. Filter Flow 1000 is formulated to remove radionuclides and heavy metals from water through a combination of sorption, chemical complexlng, and flltration. FFT states that sorption on the Filter Flow 1000 accounts for the majority of the removal action.

Filter Flow 1000 is contained In specialty designed collold filter packs within a colloid fllter press unit. The colloid filter press unit Is approximately 7 ft hlgh and 3 ft sq. The four filter plates of the collold filter press unit support three colloid filter packs. The filter plates are 26 In. sq, 2 in. thick and constructed of very strong plastic. One colloid filter pack Is located between each set of plates within the collold filter press unit. Each filter pack Is constructed of a durable, fibrous, polymer material that contains a premeasured amount of the complexing agent Filter Flow 1000. Once the filter packs have been placed between the filter plates, hydraulic pressure Is applied to the plates. Pressure seal O-rings contained In the plates form a water tight seal between the plates, holding water within the unit. The plates are also designed to evenly disperse water across the filter media.

Figure 1 is a process flow diagram of the CPFM system used for the SITE technology demonstration at RFP. The following maln components comprise the CPFM system: an Influent mixing tank, a miniclarifier with a small sludge filter press, a bag filter, coiioid filter press units, and an effluent pH adjustment tank.

The CPFM process involves the foilowlng basic steps: (1) contaminated water Is pumped to an Influent mixing tank for chemical preconditioning (pH adJustment or sodium sulflde addition), if necessary, to induce formation of colloidal forms of pollutants. (2) suspended solids are then removed by an Incline plate mlniclarlfler, (3) overflow water from the miniclarifier is pumped through a microfiltration bag filter where particles greater than 10 microns In diameter are removed, (4) water passlng through the bag filter is pumped to the collold fllter press units where heavy metals and radlonuclldes are removed by the sorptlon, chemical complexlng, and filtration effects of Filter Flow 1000, (5) treated water exiting the collold fllters Is pH adjusted prior to discharge. Followlng treatment, sludge In the miniclarifier is dewatered in the small sludge fllter press using compressed air. The filter packs are also dewatered using compressed air to form a cake containing 60 to 70% solids. These two solid wastes are combined for dlsposal.

During the demonstration at RFP, the CPFM system treated contaminated groundwater collected by an intercepter trench system constructed downgradient of the RFP solar evaporation ponds. Contaminated water from the intercepter trench is pumped to three open-top, 500,000 gal storage tanks (the Interim measure/interim remedial action (IM/IRA) tanks), one of which stored Influent for the CPFM system. Influent pH adjustment was not required because the Influent was within the optimum pH range (8 to 9) for the CPFM system. The pH of the effluent water was monitored in the final pH adjustment tank and treated with hydrochloric acid to reduce the pH to its original level before discharge to a second IM/IRA tank.

Technology Applicability

The CPFM technology is designed to remove nontritium radionuclides and heavy metals from water to parts per million (ppm) or parts per billion (ppb) levels. The CPFM technology can be used as a stand alone unlt to treat low-total suspended solids (TSS) water or In a treatment train, downstream from other technologies such as soil washlng, or conventional wastewater treatment using flocculation and solids removal. According to the developer, potential applications also include remediation of contaminated liquid wastes from industrial operations, oil-drilling production water contaminated with naturally occurring radioactive materials (NORM), uranium mine groundwater, and transuranic and low-level radioactive wastes from nuclear-related facilities with contaminated water. FFT states that the CPFM system Is designed to treat a wide range of inorganic metallic pollutants in water including colloidal, complexed, and ionic forms. In general, low levels of radionuciides and heavy metals are the most suitable for treatment by the CPFM system.

Under the SITE program, in addition to the full-scale demonstration at RFP, the CPFM system has been tested at a bench-scale level. The study used RFP intercepter trench water that contained uranium-238 at approximately 35 pCI/L. and was spiked with up to 30 pCi/L of plutonium-239, americium-241, and radium-226. The results from this study indicated removal efficiencies of greater than 99% for uranium, plutonium, and americium with no chemical pretreatment. Removal efficiency for

Table 1. Criteria Evaluation for the CPFM Technology

Overall Protection of Human Health and the Environment	Compliance with Federal ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost[a]	Community Acceptance	State Acceptance
Provides both short- and long-term protection by eliminating exposure to contaminants in groundwater.	Requires compliance with RCRA treatment, storage, and land disposal regulations (of a hazardous waste).	Effectively removes and stabilizes contamination.	Significantly reduces toxicity, mobility, and volume of contaminants through treatment.	Presents few short-term risks to workers and community.	Involves few administrative difficulties.	$15 per 1000 gal to $0.50 per 1000 gal	Minimal short-term risks presented to the community make this technology favorable to the public.	If remediation is conducted as part of RCRA corrective actions, state regulatory agencies may require permits.
Prevents off-site migration through sorption on filter packs.	Wastewater discharges require compliance with clean Water Act regulations.	Involves well-demonstrated technique for removal of contaminants.		Some personal protective equipment required to be worn by operators.	Involves few utility requirements including water, electricity, and compressed air.			
		Involves some residuals treatment (filter cake, wastewater) or disposal (PPE).		The system can relatively rapidly reduce large volumes of contaminated water to clean water and filter cake.	Once on site, the treatment system can be operational within 1 week			

Notes:

[a]Actual cost of a remediation technology is highly specific and dependent upon the original and target cleanup level, contaminant concentrations, groundwater characteristics, and volume of water. Cost data presented in this table are for treating groundwater at 100 gpm for 1year.

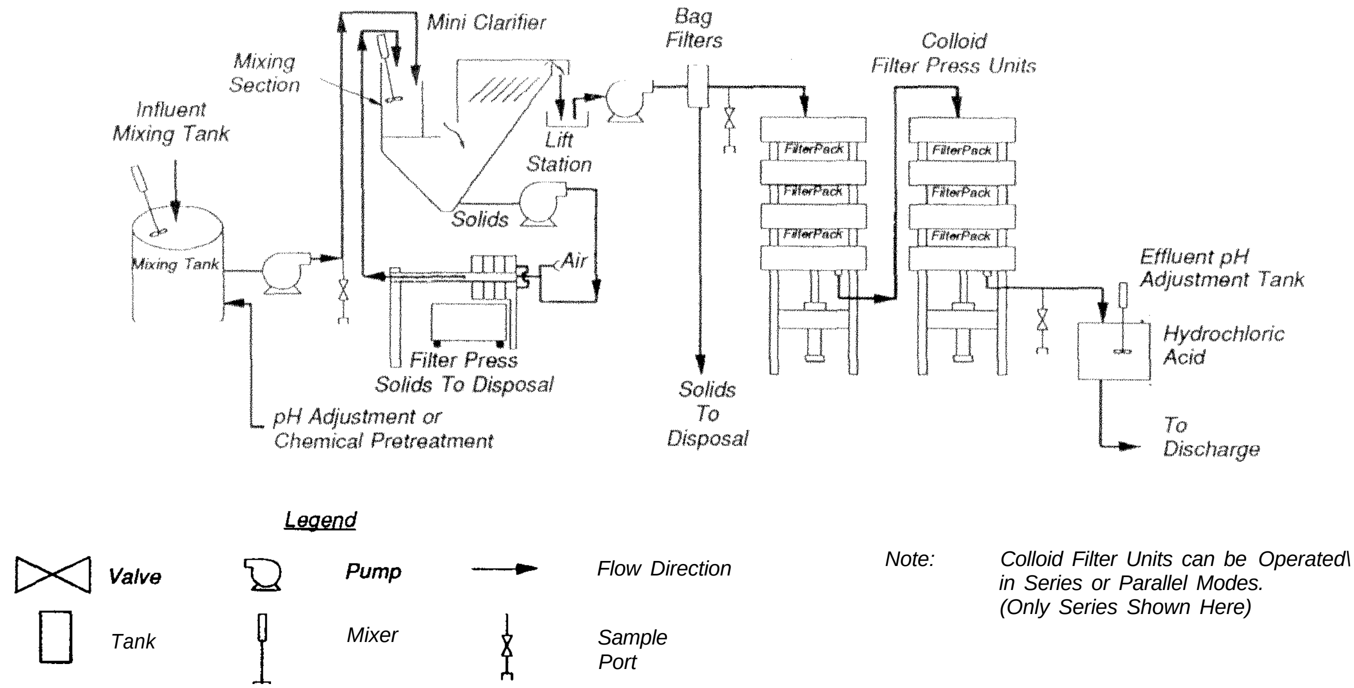

Figure 1. CPFM Treatment System.

gross alpha was 86%. These test runs showed only 43% removal efficiency for radium.

Technology Limitations

In general, the CPFM technology is designed to remove trace to moderate levels (less than 1,000 ppm) of non-trltlum radlonuclides and heavy metal pollutants present in water. The CPFM technology will not remove tritium because of Its chemical characterestics. Tritium In water Is Incorporated in water molecules and is therefore not retained by Filter Flow 1000. Only tritium associated with TSS will be removed by the bag fllter upstream of the colloid fllter units. Although future testing of this technology may show differently, preliminary results and theoretical Investlgatlons do not Indicate potential tritium removal.

Because high organic compound concentrations may Interfere wlth the chemical and physical reactions occurring between Filter Flow 1000 and charged radlonuclide and heavy metal pollutants, water with hlgh organic compound concentrations Is not treated as effectively by the CPFM technology.

Process Residuals

The CPFM process generates two waste streams: treated effluent and filter cake. Demonstration analytical results for composite samples shown In Table 2 indicate that effluent from runs 1 and 4 were near CWQCC discharge standards for uranium and gross alpha.

The filter cake generated durlng the demonstration was tested for hazardous waste and radiation characterlstics and is being stored at RFP pendlng dlsposal at an EPA- and DOE-approved facility. The EPA palnt filter liquids test, performed at the time of waste packaging, Indicated that the wastes do not contain free liquids. The toxicity characteristic leaching procedure was also performed on the filter cake solids. Table 3 shows that composlted filter cake sollds from the demonstration did not contain leachable radionuclldes, or leachable metals at levels above EPA standards (40 CFR Part 268). In addition. Table 4 Indicates that uranium and gross alpha activities were very low for filter cake solids from each run.

Drummed personal protective equipment (PPE) was screened for radioactivity and disposed of In accordance with state and federal requirements. Wash water from decontamination was collected and placed In a 1,000 gal storage tank prlor to acceptance by a wastewater disposal facility at RFP.

Site Requirements

All process equipment Is mounted and operated on the bed of a trailer. Access roads are needed for equlpment transport. A paved or well graded gravel area of approximately 450 sq ft Is also needed to accommodate the CPFM unit. support equipment, and facilities. In addition, berms are needed for spill containment. Once onsite, the unit can be operational within a week if all the necessary facilities utilities, equipment, and supplies are available.

Utility requirements for the CPFM system are water, electricity, compressed alr, and a telephone. Clean process water is required for system operatlon and decon tamination of equipment and personnel. Flre hydrant water was provlded by the site operator for the demonstration. The CPFM system used for the demonstration

Table 2. Analytical Results from the CPFM SiTE Demonstration

Parameter	Run Number	Influent Composite/ Duplicate	Influent Grab/ Duplicate	Intermediate Composite/ Duplicate	Intermediate Grab/ Duplicate	Effluent Composite/ Duplicate	Effluent Grab/ Duplicate	CWQCC* Standards
Uranium (µg/L)	1	102/104	102	60/60	62	9.5/9.6	3.4	7
Gross Alpha (pCi/L)		98/99	94	40	77	13	9.4	7
Uranium (µg/L)	2	89/94	102	92	98/94	38/38	43	7
Gross Alpha (pCi/L)		88/62	110	84	68/110	53/47	24	7
Uranium (µg/L)	3	102	96/96	94	94/92	23/25	7.9/8.3	7
Gross Alpha (pCi/L)		110	100/110	36	110/57	27	0/25	7
Uranium (µg/L)	4	98	104	64	55	5.1	19	7
Gross Alpha (pCi/L)		65	100	71	50	3.7	11	7

* Colorado Water Quality Control Commmission

Table 3. Analytical Results for TCLP Extract Solutions

Parameter	Run 5 Pack 1	Run 5 Pack 2	Regulatory Level (mg/L)
Uranium (µg/L)	1.0U	1.0U	–
Gross Alpha (pCi/L)	82U	290U	–
Arsenic (µg/L)	380u	380U	6.0
Barium (µg/L)	2,640	4,780	100.0
Cadmium (g/L)	50U	50U	1.0
Chromium (g/L)	40U	40U	5.0
Lead (µg/L)	290U	29OU	5.0
Mercury (µg/L)	10U	10U	0.2
Selenium (µg/L)	10U	10U	7.0
Silver (µg/L)	40U	40U	5.0

U = undetected at this value

Table 4. Analytical Result for Filter Pack Solids

Parameter	Run 1	Run 2	Run 3	Run 4 Pack 1	Run 5 Pack 2	Run 5
Uranium (µg/g)	2 1	2.1	3.4	2.6	4.7	5.7
Gross Alpha (pCi/g)	13U	12	15	8. 1	11	12U

U = undetected at this value

requires 120-volt, 30-amperes electrical service and a minimum of 100 psi compressed air supply for the process equipment and field laboratory equipment. For the demonstratton, gas powered generators and an air compressor were used. Telephone service is required mainly for ordering equlpment. scheduling deliverles, and communicating emergencies. A cellular telephone was used during the demonstration.

Additional equipment and suppl1es included a 1,000-gal water storage tank for decontamination rinse water, equlpment for filter cake disposal, lncluding 55-gal drums and a forklift with operator, sampling equipment and containers, and health- and safety-related gear.

After treatment Is completed, the treatment system can be demobilized within 1 week. Thls activity includes equlpment decontamination and utilities dlsconnection. Demobilization following the demonstration took approximately 1 week.

Performance Data

The CPFM technology was developed to treat water contaminated with radlonucl1des and heavy metals. Water from the RFP IM/IRA storage tanks was selected as a source of contaminated water for the demonstration because the principal contaminants in groundwater at RFP were expected to be uranium, radium, plutonium, and americium. Following the bench scale testing, the contamination in RFP water was determined to be dominantly uranlum and gross alpha. Therefore, these contaninants were considered the critical parameters and radlum, plutonium, and amerlclum were considered secondary parameters.

The CPFM technology was evaluated to determlne appropriateness for use in removing radionuclides from RFP water. The objectives for the project were to:

- Assess the technology's ability to remove uranlum and gross alpha contaminants to levels below CWQCC standards
- Document the operating conditions. and identify operational needs, such as utility and labor re qulrements, for the treatment system
- Estimate costs associated with the operation of the CPFM system
- Assess the technology's ability to remove other radlonuclldes (plutonium, americium. and radium)
- Evaluate the disposal options for prefiltered solids (miniclarlfler and bag filter solids) and spent filter packs from the collold filter unit

The demonstratlon was comprised of three tests. The flrst test conslsted of three replicate runs of 4 hr each, at operating parameters established by the developer. Three runs were conducted durlng this test In order to collect enough data to statistically evaluate the CPFM system's ability to meet CWQCC standards. For these runs, the collold fllter presses held three fllter packs each and water was routed through the packs In series. During these three runs, process parameters Including flow rate (5 gal/mln), and amount of filter bed material (30 kilograms of Filter Flow 1000) were held constant. For the second test, sodium sulfide was added to the influent water In the pretreatment tank to change the oxidation state of radionuclides In water. Thls test consisted of one run; using the same operating configuration and conditions as the flrst test. The purpose of this test was to determine whether pretreatment could be used to improve CPFM performance that may be requlred to attaln CWQCC standards. The thlrd test was a 15-hr run. Thls test used only a single pack In each collold filter press. Thls run was designed to determine the time of breakthrough and the amount of contamination each filter pack Is capable of treating. This Information was then used in evaluating the operational costs of the CPFM system.

Durlng the demonstration. samples were collected of the untreated water (Influent), pretreated water after passing through the miniclarifier and bag filter (intermediate), and treated water that had passed through the filter packs (effluent). Filter cake was also analyzed. Samples were analyzed to determlne the technology's effectiveness and evaluate disposal options for filter cake,

Analytical results for uranium and gross alpha from runs 1 through 4 are presented in Table 2. Runs 1 through 4 were designed to collect sufficient data to do a statistical evaluation of CPFM system capabilities. Therefore, composite, grab, and replicate samples were collected and analyzed.

Assessment of data quality for the critical parameters uranlum and gross alpha included evaluation of laboratory method blanks, matrix spike and matrix spike duplicate recoveries. and analytical/field duplicates. No laboratory contamination was indicated by method blank data. Uranium matrix spike recoveries were all within the acceptable range of 80 to 120%. However, 3 out of 20 matrix spike recoveries for gross alpha were outside of these control limits. Duplicate uranlum analyses were all well within + 20%. Samples and duplicates yield an r^2 value from linear regression of 0.99, indicating that uranium analyses had good precision. However, 12 out of 20 duplicate gross alpha analyses exceeded $\pm$ 20%. Samples and duplicates yield an r^2 value fromlinear regression of 0.15, Indlcatlng poor precision of gross qlpha data. Therefore, only uranlum analyses are considered reliable for assessing the performance of the CPFM system and gross alpha data should be Interpreted with caution.

Flgures 2 and 3 show graphically the removal of radionuclldes in runs 1 through 4. Figures 4 and 5 show gross alpha and uranlum concentrations, respectively, for sampling durlng the breakthrough assessment of run 5. Where possible, only composite data were used to construct these flgures (where replicate composites exist, an average value was used). Composlte gross alpha and uranium concentrations for influent for runs 1 through 3. varied from 62 to 110 pCI/L for gross alpha and 89 to 104 µg/L for uranlum. Analytical results for composite samples of intermediate waters from these three runs show a range of 36 to 84 pCI/L for gross alpha and a range of 60 to 94 µg/L for uranlum. Analytical results for composite effluent water from runs 1 through 3 show gross alpha values that range from a low of 13 pCi/L for run 1 to a hlgh of 53 pCi/L for run 2. Similarly analytical results for uranlum ranged from a low of 9.5 µg/L for run 1 to a hlgh of 38 µg/L for run 2.

Removal efficiencies for runs 1 through 4 were calculated using composite data and are shown in Table 5. (Where replicate composites exist, an average value was used.) Overall removal efficiencies for uranium during runs 1 through 3 ranged from a low of 58.4% to a high of 90.6%. Overall removal efficiencies for gross alpha for runs 1 through 3 ranged between 33.3% and 86.8%. Overall removal efficiencies for uranium and gross alpha for run 4 were slightly better than the best of the initial 3 runs (run 1) with 94.8% and 94.3% removal, respectively. It should be noted that only in run 4 were the CWQCC standards for composite sampling met. Though removal Is largely attributable to the colloid filter pack, significant removal of uranium occurred in runs 1 and 4 prior to the colloid filter unit. Slgniflcant pre-colloid filter removal of gross alpha is also Indicated for runs 1 and 3.

Analytical results for plutonium and amerlclum showed that these elements were at or near method detection limits. Therefore, the ability of the CPFM system to remove them from RFP groundwater could not be properly evaluated. Results for radium analyses indicated that the CPFM system did not remove radlum from RFP groundwater.

The results from run 5. the breakthrough run, are presented graphically In Figures 4 and 5. These result Indicate that using a single collold filter unit, breakthrough occurred prlor to the first sampling time at 120 mln or that the single pack was not capable of removing significant contamination. This result was not expected based on the information Initially provided by FFT. On average, only a slight reduction in the influent uranlum and gross alpha

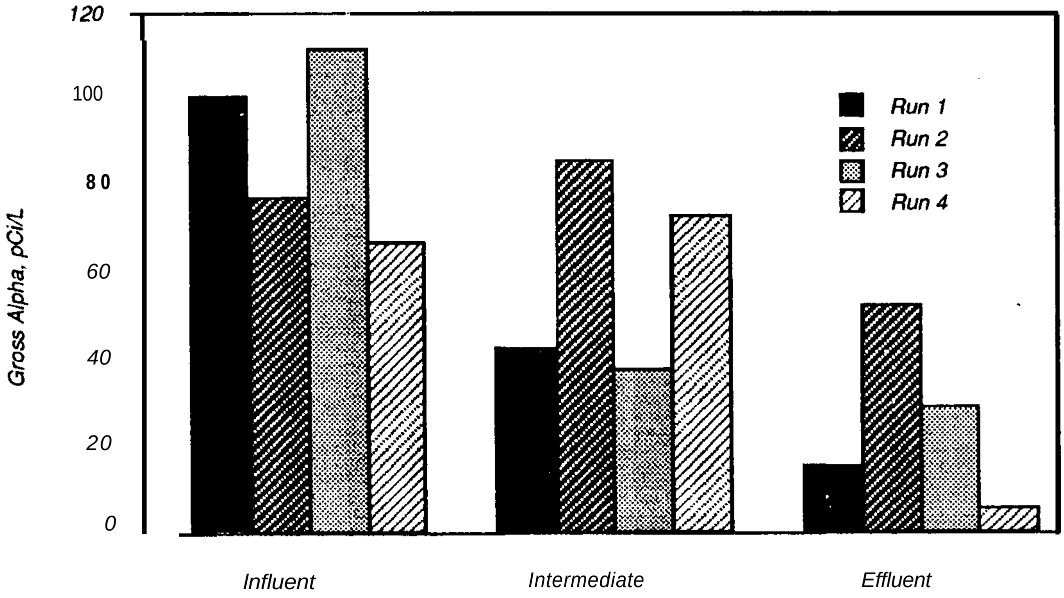

Figure 2. Gross alpha concentrations for runs 1 through 4.

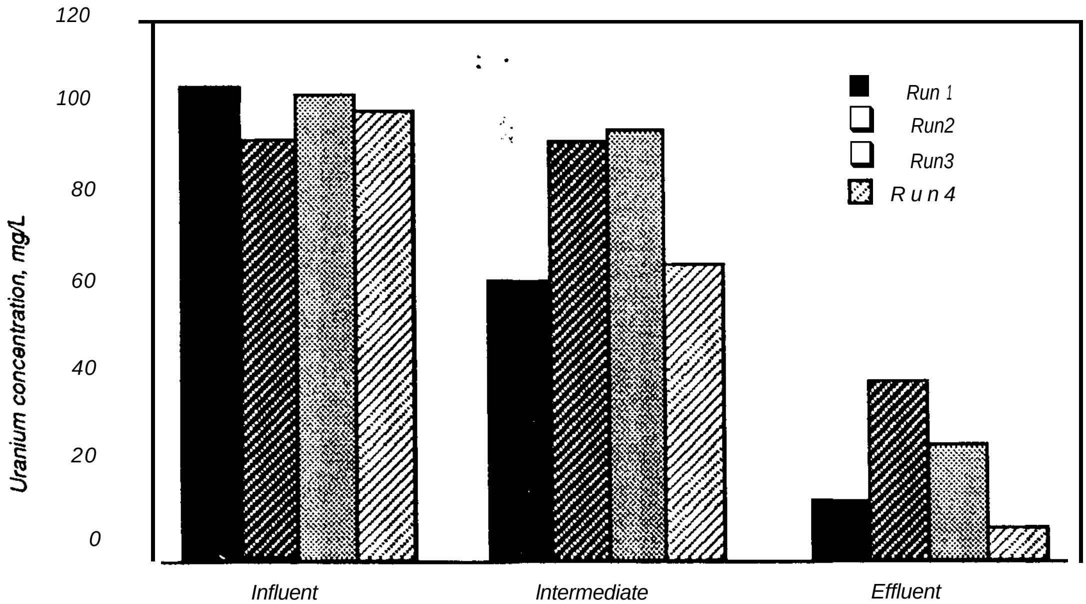

Figure 3. Uranium concentrations for runs 1 through 4.

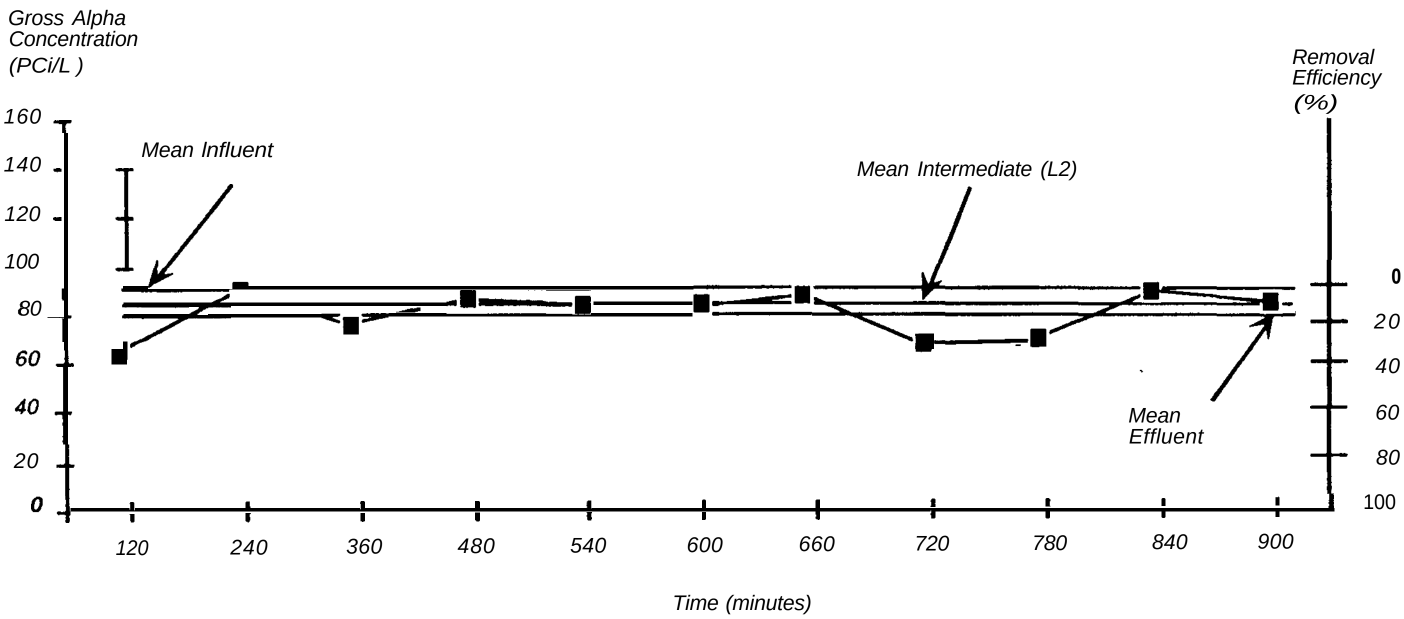

Figure 4. Gross alpha concentrations for run 5 effluent. So/id squares correspond to concentrations and removal efficiencies.

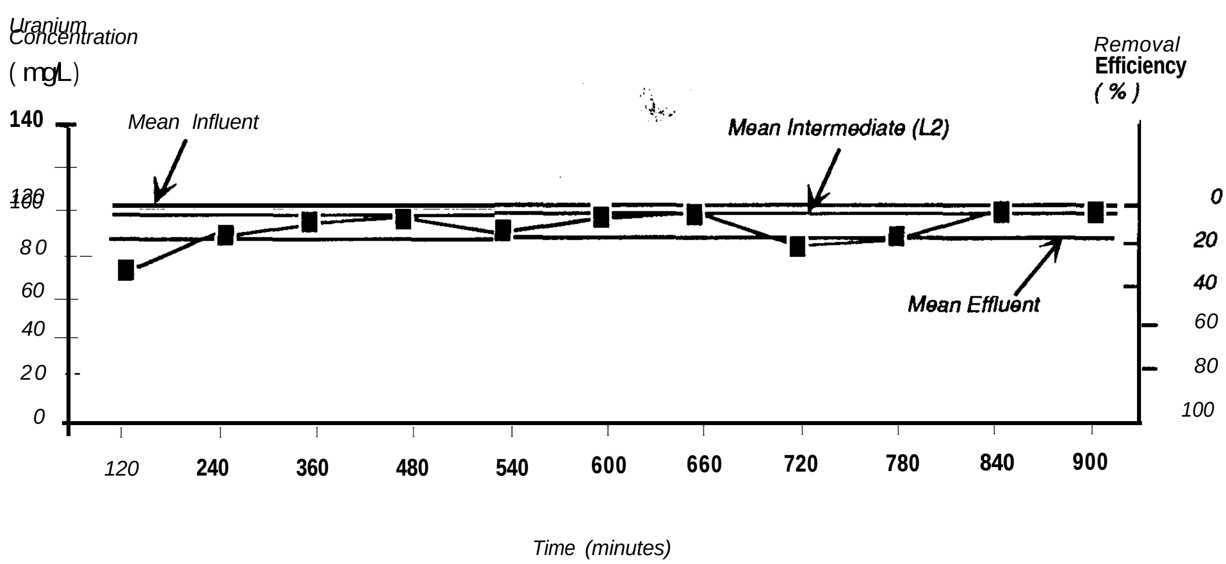

Figure 5. Uranium concentrations for run 5 effluent. Solid squares correspond to concentrations and removal efficiencies.

Table 5. Removal Efficiency Results for Runs 1 through 4 for the CPFM SITE Demonstration

Parameter	*Run Number*	*Influent*	*Intermediate*	*Effluent*	*CWQCC Standards*	*Mini-Clarifier and Bag Fitter Removal Efficiency*	*Colloid Filler Unit Removal Efficiency*	*Overall Removal Efficiency*
Uranium (µg/L)	1	*103*	*60*	*9.6*	*7*	*41.7*	*84.0*	*90.6*
Gross Alpha (pCi/L)		*98.5*	*40*	*13*	*7*	*59.4*	*67.5*	*86.8*
Uranium (µg/L)	*2*	*91.5*	*92*	*38*	*7*	*- 0.5*	*58.6*	*58.4*
Gross Alpha (pCi/L)		*75*	*84*	*50*	*7*	*-12.0*	*40.5*	*33.3*
Uranium (µg/L)	*3*	*102*	*94*	*24*	*7*	*7.8*	*74.5*	*76.5*
Gross Alpha (pCi/L)		*110*	*36*	*27*	*7*	*72.5*	*25.0*	*75.5*
Uranium (µg/L)	*4*	*96*	*64*	*5.1*	*7*	*34.7*	*92*	*94.8*
Gross Alpha (pCi/L)		*65*	*71*	*3.7*	*7*	*-9.2*	*94.8*	*94.3*

* *Overall removal efficiency* = $\frac{[Influent] - [Effluent]}{[Influent]} \times 100$

** *Colloid Filter Unit removal efficiency* = $\frac{[Intermediate] - [Effluent]}{[Intermediate]} \times 100$

Where: *[ ]* **equals** *the concentration of the* individual parameters

concentrations was observed In run 5. It should be noted that data for this run are erratic, thus indicating that performance of the system during discrete time intervals may be unpredictable. Single pack removal efficiencies are considerably less than the series of six packs used In runs 1 through 4. Reduction In removal efficiencies may be due to a variety of factors such as channeling through a single pack, or insufficient residence time within the pack. However, this demonstration was not designed to evaluate such factors.

Operatlng conditions documented during the demonstration Indicated that water treatment with a series of colloid filter packs was successful In removing uranlum and gross alpha contamination from RFP waters. The demonstration results also indicate that pretreatment of Influent water with sodlum sulfide improves CPFM system removal efficiencies.

Disposal options for the used filter pack are determined by Its radionuclide and leachable metal content. Table 4 shows that concentrations of uranium In the filter cake ranged from 2.1 to 5.7 µg/g and gross alpha concentrations ranged from not detectable to 15 picoCuries per gram (pCi/g). In addition, Table 3 shows TCLP test results Indicating that the filter cake does not contain extractable metals above regulatory limits.

Based on an economic analysts using a l-year treatment scenario at 100 gal/min for 24 hr/day, 7 days/wk, the treatment cost Is approximately $15/1000 gal. This cost Is reduced to $0.5O/l000 gal using a 5-yr treatment scenario. Costs can be expected to vary depending on contamination type, level, and volume of water treated.

Technology Status

Other sites are considering the CPFM system. Pilot-scale testing is underway at the Oak Ridge National Laboratory through a Joint venture with Martin Marietta and Dwight and Church. The pilot test will determine the CPFM process effectiveness In treating mlxed waste. In another pilot-scale test, funded by the Westinghouse Science and Technology Group, the process Is being applied In a treatment train to mlxed wastewater that has been pretreated to destroy organic compounds and remove suspended solids. The CPFM system Is also belng used to treat metal finishing wastes. FFT Is also building a CPFM system In Peru that will treat mine wastewater discharge that contains copper, zinc, lead, and arsenic. In all, a total of 15 commercial projects are planned or underway.

Sources of Further Information

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