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WHC-SA-2406-FP

Source Term Development for the 300 Area Treated Effluent Disposal Facility

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Date Published
April 1994

To Be Presented at
1994 Safety Analysis Workshop
Albuquerque, New Mexico
June 8-10, 1994

Prepared for the U.S. Department of Energy
Office of Environmental Restoration and
Waste Management

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Hanford Operations and Engineering Contractor for the
U.S. Department of Energy under Contract DE-AC06-87RL10930

SOURCE TERM DEVELOPMENT FOR THE 300 AREA TREATED EFFLUENT DISPOSAL FACILITY

1.0 INTRODUCTION

A novel method for developing a source term for radiation and hazardous material content of sludge processing equipment and barrels in a new waste water treatment facility is presented in this paper.

The 300 Area Treated Effluent Disposal Facility (TEDF), located in the 300 Area of the Hanford Site near Richland, Washington, will treat process sewer waste water from the 300 Area and discharge a permittable effluent flow into the Columbia River. When completed and operating, the 300 Area TEDF effluent water flow will meet or exceed water quality standards for the 300 Area process sewer effluents. A process information and hazards analysis document needed a process flowsheet detailing the concentrations of radionuclides, inorganics, and organics throughout the process, including the sludge effluent flow.

A hazards analysis for a processing facility usually includes a flowsheet showing the process, materials, heat balances, and instrumentation for that facility. The flowsheet estimates stream flow quantities, activities, compositions, and properties. For the 300 Area TEDF, it was necessary to prepare the flowsheet with all of the information so that radiation doses to workers could be estimated.

Previous flowsheets did not provide the concentrations of radionuclide, inorganic, and organic components for each flow. The novel method used to develop the 300 Area TEDF flowsheet included generating recycle factors. To prepare each component in the flowsheet, precipitation, destruction, and two recycle factors were developed. The factors were entered into a spreadsheet and provided a method of estimating the steady-state concentrations of all of the components in the facility.

After the facility begins to operate, data from process samples can be used to provide better estimates of the factors, the factors can be entered into the flowsheet, and the flowsheet will calculate new steady-state concentrations for the components. Radiation doses to facility operating personnel during initial operations will provide additional data to refine the earlier dose estimates.

This report describes how the factors were developed, explains how they were used in developing the flowsheet, and presents the results of using these values to estimate radiation doses for personnel working in the facility. The report concludes with a discussion of the effect of estimates of radioactive and hazardous material concentrations on shielding design and the need for containment features for equipment in the facility.

2.0 METHODOLOGY

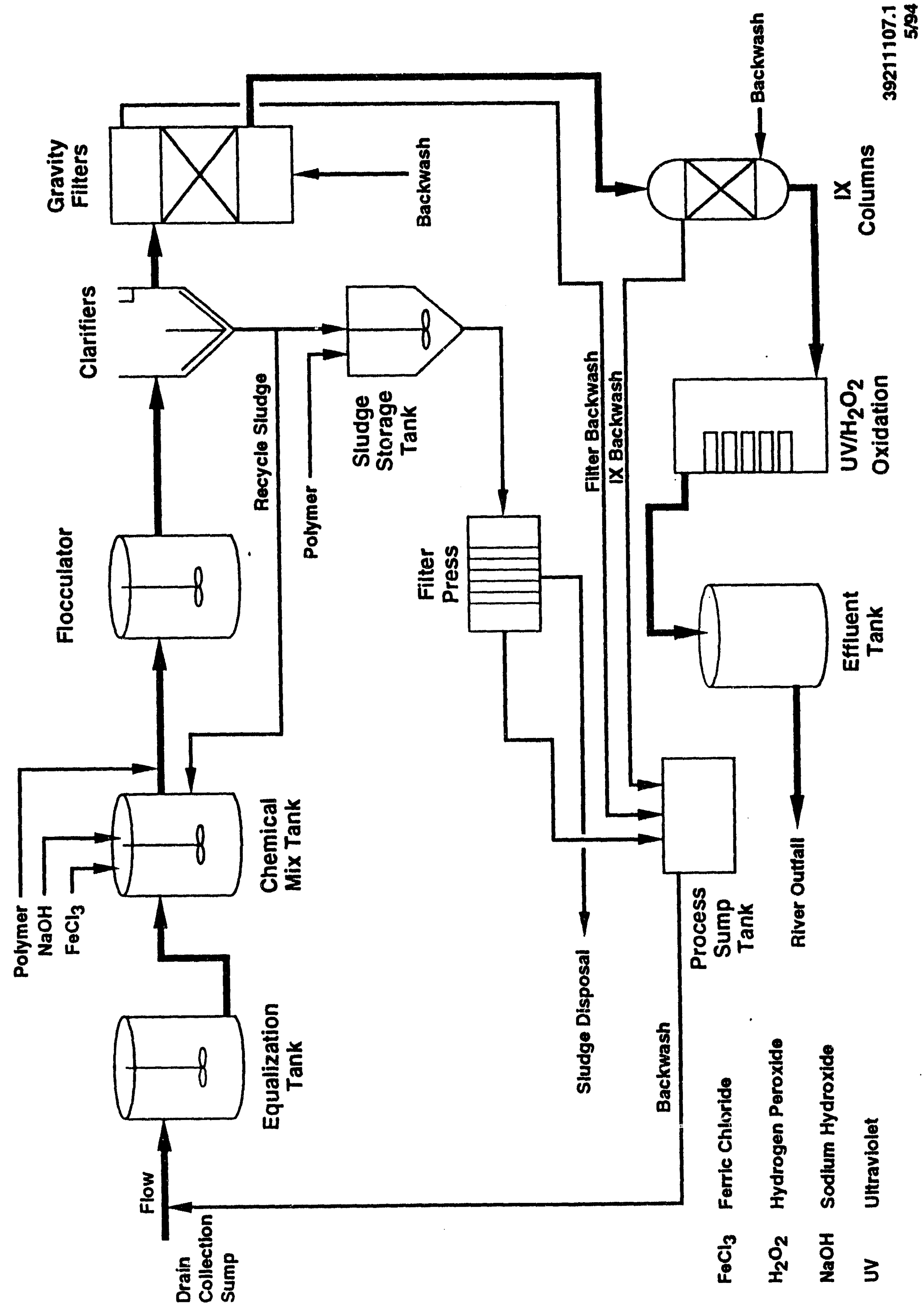
The 300 Area TEDF, to be operated by Westinghouse Hanford Company, will use best available technology to treat the process sewer waste water flow. Figure 1 shows a simplified schematic of the 300 Area TEDF process flow streams. The process will use iron-coprecipitation, filtration, ion exchange, ultraviolet-hydrogen peroxide (UV/H_2O_2) destruction, and sludge separation technology to further reduce low concentrations of heavy metals, suspended solids, organic compounds, and cyanide. The 300 Area TEDF building contains the main process components of the treatment system: tanks, pumps, ion exchange columns, a filter press, filter units, UV/H_2O_2 units, the control room, and the electrical distribution equipment. The clarifier tanks, chemical supply storage tanks, diversion tanks, equalization feed tank and sludge barrel storage pad are located outside of and adjacent to the 300 Area TEDF building.

Preparation of the 300 Area TEDF flowsheet included using a computer spreadsheet. During steady-state operation, the 300 Area TEDF flowsheet has four recycle flows (sludge, filter backwash, ion exchange backwash, and filter press filtrate) within the process. The recycle flows presented a challenge for the computer spreadsheet because the circular-reference-of-formulas ("circ") status indicator will be lighted during spreadsheet preparation if the calculations for two or more spreadsheet cells are dependant on each other. The requirement for noncircular-dependent equations was the driving force for developing "factors" to estimate concentrations of components in the recycle flows. The development of factors for the precipitation, filter, ion exchange, and UV/H_2O_2 processing operations provided the new approach for developing noncircular equations.

The precipitation factor is the fraction of the influent component that precipitates and exits with the effluent sludge flow. The UV/H_2O_2 factor is the fraction of the influent component destructed by the UV/H_2O_2 units. The filter and ion exchange factors estimate the fraction of the influent component captured by the respective filter units and ion exchange units and recycled during backwash operations of the filter and ion exchange units.

During steady-state operation, the 300 Area TEDF process continuously receives feed from the drain collection sump through the equalization feed tank, heavy metal components precipitate in the clarifiers, the filter units remove residual solids carryover from the clarifiers, the ion exchange columns remove mercury by adsorption on the ion specific resin, and the UV/H_2O_2 units destruct organic and cyanide compounds. Steady-state operation depicts a relationship (expressed by a set of equations) between the influent, effluent, and recycle liquid flows that is both predictable and measurable. Therefore, the factors provide the means to avoid circular equations and, using other process assumption factors, estimate steady-state liquid concentrations and flow quantities for the 31 flows in the process.

Figure 1. Simplified Schematic of the 300 Area Treated Effluent Disposal Facility.



Data from laboratory experiments and engineering judgement were used in developing the recycle factors. Laboratory experiments using synthetic and actual process sewer liquids and data from similar operating facilities provided the means to estimate the initial factors for the radionuclide, inorganic, and organic components. Where sample data are lacking, conservative factors using engineering judgement were used. In the laboratory, ferric chloride, sodium hydroxide, and a high molecular weight anionic polymer added to solutions simulating 300 Area TEDF feed flows provided data on the concentrations in the supernate and sludge after settling of the solids. Dividing the sludge concentration by the initial solution concentration gives the precipitation factor for each component. Similar applications using the ferric chloride precipitation process suggest that a recycle rate of 20 kg of sludge solids per 1 kg of new solids formed in the feed flow enhances metals removal and sludge settleability. Similarly, laboratory data from ion exchange column mercury removal simulation, simulated filtration, and organic destruction using ultraviolet light with hydrogen peroxide additions provided estimates of the factors for these unit processes.

Equations in the spreadsheet, placed in the spreadsheet to estimate concentrations for the flows in the 300 Area TEDF process, use the factors, data from similar applications, and process assumptions to calculate the steady-state concentrations. Figure 2 shows an example calculation for estimating ^{90}Sr flow quantity in liquid flow from the clarifiers to the filters (Flow #5). The example demonstrates the use of factors and process flow assumptions. The quantity in Flow #5 includes unprecipitated ^{90}Sr, a filter backwash quantity, an ion exchange backwash quantity, a backwash solution quantity, and minus a quantity contained in the solution mixed with the sludge effluent. Values for the quantities are also shown in Figure 2. This example uses three factors to estimate the flow quantity in the clarifier overflow: the precipitation factor, the filter backwash factor and the IX backwash factor.

Figure 2. Sample Calculations for the Clarifier Effluent Flow (Flow #5).

		^{90}Sr (pCi/min)
Flow #5 = Unprecipitated	1,136 pCi/min * (1 - 0.25[a])	+852
- Product Sludge Loss	852 pCi/min * (0.451/1262)	-0.3
+ Filter Recycle	1136 pCi/min * 0.02[b]	22.7
+ IX Recycle	1136 pCi/min * .0001[c]	0.1
+ Solution Recycle		42.5
Flow #5 ^{90}Sr		917.0

[a]precipitation factor.
[b]Filter backflush factor.
[c]IX backflush factor.

Figure 3 shows a sample calculation for estimating component destruction within the UV/H_2O_2 oxidation units. The reaction equation (Figure 3) shows that 8 moles of hydrogen peroxide are needed for every mole of acetone and that the reaction yields 3 moles of carbon dioxide and 11 moles of water. The flowsheet contains reaction equation information for all of the organics, including the inorganics (CN^-, NO_2^-, and S^-) which are oxidized in the UV/H_2O_2 oxidation units. The byproducts of acetone oxidation are carbon dioxide and water. Carbon dioxide leaves the solution as a gas while the water from the reaction remains in the solution. The oxidation of some organics produces other ions (NO_3^-, Cl^-, F^- and $SO_4^{=}$) which remain in solution and flow with the effluent flow to the river.

Figure 3. Sample Calculation--Acetone Destruction in the UV/H_2O_2 Oxidation Unit.

Unprecipitated		Sludge Loss		IX Adsorbed Loss		Flow #8
79,500	-	28.4	-	0	⇒	29,472 µg/min

UV/H_2O_2 Destruction		Quantity in Effluent
79,472 µg/min * (1 - 0.95[a])	=	3,974 µg/min

Acetone Destruction Reaction

Acetone		Hydrogen Peroxide		Carbon Dioxide		Water
C_3H_6O	+	8 H_2O_2	⇒	3 CO_2	+	11 H_2O

[a]Acetone destruction factor.
UV = ultraviolet.
H_2O_2 = hydrogen peroxide.

3.0 RESULTS

The fully developed flowsheet for the 300 Area TEDF contains factors for 15 radionuclides, 42 inorganics, and 22 organic compounds. The spreadsheet containing the flowsheet includes all of the flow values, the equations, and the factors for 31 flows. Tables 1 and 2 display a sampling of the factors and concentrations for the primary radionuclide, inorganic, and organic compounds. For example, a feed concentration for ^{137}Cs of 46 pCi/L results in a waste water effluent flow concentration of 45.4 pCi/L and a sludge concentration of 950 pCi/L.

Table 1. Typical Factors for Radionuclides, Inorganic, and Organic Compounds.

Description	Precipitation Factor	Filter Backwash Factor	Ion Exchange Backwash Factor	UV/H_2O_2 Destruction Factor
Radionuclides				
^{90}Sr	0.25	0.02	0.0001	0
^{137}Cs	0.01	0.02	0.01	0
^{147}Pm	0.01	0.02	0.01	0
^{241}Am	0.95	0.02	0.01	0
Inorganics				
Al	0.95	0.02	0.01	0
CN^-	0.95	0.02	0.01	0.049
Hg	0.05	0.02	0.01	0.949
Zn	0.95	0.02	0.01	0
Organics				
Bis(ethyl-hexyl)phthalate	0	0.05	0.05	0.963
Chlorodifluoro methane	0	0.05	0.05	0.95
Methylene Chloride	0	0.05	0.05	0.95

Table 2. Partial List of Flowsheet Values.

Description	Units	Drain Collection Sump	300 Area TEDF Effluent	300 Area TEDF Sludge
Form	Liquid	Liquid	Liquid	Liquid
Flow	L/min	1136	1136	0.569
Temperature	°C	10	14.1	23
Specific Gravity	g/cc	1.0	1.0	1.1
Radionuclides				
^{90}Sr	pCi/L	1.0	0.748	499
^{137}Cs	pCi/L	46	45.4	950
^{147}Pm	pCi/L	9	8.89	186
^{241}Am	pCi/L	0.6	0.0299	1,140
Inorganics				
Al	µg/L	418	20.9	79,200
CN^-	µg/L	50	2.37	94,800
Hg	µg/L	3	0.003	301
Zn	µg/L	211	10.5	400,000
Organics				
Bis(ethyl hexyl)pthalate	µg/L	80	2.95	57
Chlorodifluoro methane	µg/L	20	0.998	14.3
Methylene Chloride	µg/L	5.1	0.254	3.63

TEDF = Treated Effluent Disposal Facility.

The radioactive concentrations, particularly the sludge concentrations, provided radiological source term information useful for estimating dose rates for operations people in the facility. Computer runs using a shielding computer code calculated direct dose rates expected to result from operations at the 300 Area TEDF. The calculated dose rates are below levels requiring that the facility have radiologically controlled areas. This means that radiological controls and equipment shielding are not needed to protect facility workers. A lesser form of control, a radiological surveillance program, is all that is required to verify that dose rates and contamination levels are maintained at levels below the levels that would have required a radiologically controlled area.

Similar calculations estimated resuspended radionuclide airborne concentrations from spilled slurry using the estimated radionuclide concentrations in the slurry. These calculations yielded airborne concentrations that were below 2% of the derived air concentration limits. This means that additional controls and containment for the slurry are not needed to protect facility workers. A lessor form of control, routine surveys, is all that is needed to verify that airborne contamination levels are below that required for a radiological controlled area.

In conclusion, a computer spreadsheet for the 300 Area TEDF uses factors based on feed concentrations to estimate stream concentrations for radionuclide, inorganic, and organic compounds. The factors are an improved method for estimating flow concentrations in the 300 Area TEDF process. The estimated radionuclide concentrations were used in shielding computer runs and confirmed that radiation doses should be low in the facility. Also, the airborne radionuclide concentrations should be below derived air concentration limits. The facility design, therefore, did not require radiation shielding, radiation containment, radiation controls, or a radiologically controlled area to protect facility workers. The improved flowsheet reduced the need for additional equipment, controls, and operating costs for the facility.

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