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SUBJECT: An Assessment of the Impact of Diverting ORNL Steam Plant Aqueous Wastes to the Coal Yard Runoff Treatment Plant

TO: Distribution

FROM: J. F. Walker, Jr., and J. R. Parrott, Jr.

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1. INTRODUCTION

The wastewater streams generated at the Oak Ridge National Laboratory (ORNL) steam plant are currently treated at the 3518 treatment facility, where they are neutralized with calcium hydroxide before being released to White Oak Creek. The future plans are to treat these wastewater streams at the Coal Yard Runoff Treatment Facility (CYRTF). Contained herein is the final report of a program to assess the feasibility of treating these streams at the CYRTF by: (1) acquiring samples of the wastewater streams to be treated at the CYRTF, (2) characterizing these samples, (3) performing a bench-scale evaluation of the CYRTF flowsheet, and (4) temporarily diverting the wastewater streams from the ORNL steam plant to the CYRTF and monitoring the operation of the CYRTF on these diverted wastewaters.

2. SAMPLE ACQUISITION

There are five major effluent streams to be treated at the CYRTF. These include: (1) coal yard runoff, (2) hydrogen ion-exchange regeneration waste, (3) sodium ion-exchange regeneration waste, (4) boiler blowdown, and (5) ash rinse waste.

A summary of these major streams to be treated at the CYRTF, including the annual discharge, the discharge frequency, and the environmental concerns of each stream is presented in Table 1.

2.1 COAL YARD RUNOFF SAMPLES

The coal yard is located south of the steam plant and covers approximately 3.9 acres.[3] Typical coal yard runoff (CYR) characteristics include high levels of suspended solids, low pH, high trace element concentrations, and high sulfate concentrations.[4,5,6] These characteristics depend on the topography and drainage of the coal yard, the configuration and volume of the coal pile, the type of coal in the coal pile, the type and intensity of precipitation, the particle size of the coal, and the reaction time within the coal pile.

The ORNL coal yard was designed to divert the wastewater draining from the coal yard to an ~200,000-gal collection basin where it could be

Table 1. Summary of effluent waste streams to be treated in the CYRTF

Waste stream	Annual discharge (gal/year)[1]	Discharge frequency	Reported environmental concerns[2]
Coal yard runoff	3.8×10^6	Intermittent	Suspended solids (coal fines); low pH (2 - 3); high metals concentrations; high sulfate concentration
Hydrogen ion-exchange regeneration waste	4.2×10^6	Daily	Low pH; high sulfate concentration
Sodium ion-exchange regeneration waste	1.2×10^6	Daily	None
Boiler blow-down	2.5×10^6	Continuous	High pH (11); high temp (212°F)
Ash rinse waste	7.9×10^5	Daily	Suspended solids (ash fines); high temp (212°F)

stored until treatment. The samples used to characterize the CYR stream were obtained from this collection basin within 24 h following a rainfall event.

2.2 ION-EXCHANGE REGENERATION STREAM SAMPLES

Hydrogen zeolite and sodium zeolite ion-exchange columns are used in the steam plant to remove minerals from the boiler feed water. The columns are regenerated periodically by (1) backwashing to loosen the resin bed; (2) washing with a dilute sulfuric acid or dilute sodium chloride solution to regenerate the hydrogen or sodium resin, respectively; and (3) rinsing the bed with water. Typically, 8,000 - 13,000 gal of wastewater is generated for each hydrogen ion-exchange unit regeneration, and 4,000 - 6,000 gal of wastewater is generated for each sodium ion-exchange unit regeneration. The environmental concerns associated with the hydrogen ion-exchange regeneration waste include high sulfate concentrations and low pH. There are generally no environmental concerns associated with the sodium ion-exchange regeneration waste stream.[2]

Representative samples of the ion-exchange regeneration waste streams were collected and composited according to the flow rates during all three phases of the regeneration process.

2.3 BOILER BLOWDOWN AND ASH RINSE STREAM SAMPLES

Boiler blowdown is generated during the normal operation of the steam plant boilers. As steam is produced, dissolved solids build up in the remaining water. Continuous blowdown is provided to reduce the buildup of solids in the boiler. Since this stream is produced continuously, a representative sample was obtained from a side stream over approximately a 1-h period.

Ash is removed from the boilers daily. The ash is quenched with water to prevent the release of solids into the atmosphere. This produces a wastewater stream which may contain a high concentration of suspended solids and a high temperature. During the daily ash rinse, ~2200 gal of wastewater is produced over an ~3-h period. A representative sample of this ash rinse stream was obtained by compositing the wastewater from one daily rinse.

3. SAMPLE CHARACTERIZATION

The results for the characterization of the effluent streams sampled for this program are presented in Table 2. The NPDES permit discharge limits for the CYRTF are presented in Table 3. Because the NPDES permit lists several components which may be added at a later date (without giving the discharge limit for these components) if significant quantities of these components are recorded, the Drinking Water Standards[8] and the Tennessee Effluent Limitations and Standards for Industrial Wastewater Treatment Plants[9] are also included in Table 3 for reference. If discharge limits are set for these components at a later date, the limits may be within the ranges specified by these standards. By comparing Tables 2 and 3, it can be seen that most of the components listed do not violate the NPDES permit, even before treatment. Those that do include the boiler blowdown stream for copper and TSS, the sodium ion-exchange regeneration waste for zinc, and the coal yard runoff streams for iron, manganese, and zinc, with copper being marginal. In addition, the composition of lead and selenium in the CYR steams violates the Drinking Water Standards before treatment. (Selenium also violates the Tennessee Effluent Standards.)

By observing Table 2, it can also be seen that the largest loading of pollutants comes from the CYR stream. Most coal contains metal sulfides, which are oxidized to sulfates on the surface of the coal pile. These in turn form sulfuric acid when combined with water. The sulfuric acid soaks into the pile, causing many of the chemicals in the coal to become water soluble. These chemicals are then washed out of the coal pile by precipitation. It should also be noted that the CYR stream composition is extremely variable and depends to a large extent on the amount of rainfall and the interval between rainfalls. This variability is evident, from Table 2, in the differences in the concentration of iron and TDS in the two CYR samples obtained. Presented in Table 4 are the typical characteristics of coal pile runoffs compiled from various studies.[10] This table highlights the extreme variability which can be expected from CYR streams.

The TOC for the wastewater samples ranged from 1.2 to 32.2 mg/L, with the highest concentration being found in the boiler blowdown. No

Table 2. Characterization of the effluent streams to be treated in the CYRTF

Parameter	Boiler blowdown (mg/L)	IX sodium regeneration (mg/L)	IX acid regeneration (mg/L)	Ash rinse (mg/L)	7/9/86 basin sample (mg/L)	7/14/86 basin sample (mg/L)
pH	12.3	7.5	1.5	7.5	2.5	2.5
Ag	<0.015	<0.075	<0.014	<0.014	<0.10	<0.050
Al	0.18	<0.30	0.68	0.20	19	23
As	0.007	<0.002	<0.002	0.333	0.100	0.274
B	0.15	<0.12	<0.023	0.13	1.2	0.74
Ba	0.027	0.79	0.15	0.046	0.20	0.16
Be	<0.00060	0.0086	0.001	<0.00058	0.010	0.011
Ca	0.47	1,100	180	37	110	150
Cd	0.001	0.003	0.001	0.001	0.021	0.017
Co	<0.0030	<0.015	<0.0029	0.0081	0.17	0.22
Cr	0.002	<0.002	0.025	<0.002	0.014	0.012
Cu	1.2	0.067	0.028	0.015	0.70	0.71
Fe	0.20	0.17	0.38	0.14	100	210
Hg	<0.0001	0.0001	0.0002	<0.0001	<0.0001	<0.0001
Li	0.28	0.38	0.067	0.22	<0.40	0.24
Mg	0.16	>28	>5.4	>5.4	19	24
Mn	0.0034	0.026	0.017	0.019	1.0	1.7
Mo	<0.012	<0.060	<0.012	0.073	<0.080	<0.040
Na	600	2,200	25	12	29	22
Ni	<0.018	<0.090	0.018	0.033	0.43	0.50
P	12	<0.45	1.8	0.53	0.71	2.5
Pb	0.004	0.012	0.011	0.001	0.099	0.109
Sb	0.079	0.026	0.004	0.023	0.005	0.008
Se	<0.002	<0.002	<0.002	0.005	0.01	0.021
Si	2.3	1.5	1.5	0.80	14	11
Sn	<0.015	<0.075	<0.014	0.014	<0.10	<0.050
Sr	<0.0015	3.1	0.60	0.48	1.2	0.78
Ti	0.060	0.048	0.072	0.10	0.059	0.045
U	<0.0030	0.026	0.0063	0.081		
Zn	0.61	2.7	0.45	0.075	1.6	1.7
Zr	<0.0060	<0.030	<0.0058	<0.0058	<0.040	<0.020
SO_4	630	98	3600	100	1400	1800
NO_3	64	<25	<25	<25	<50	<50
F	26	<10	<10	<10	<10	<10
Cl	200	7100	10	7.2	<10	<10
Br	11	<25	<25	<25	<50	<50
PO_4	30	<25	<25	<25	<50	<50
TOC	32.2	7.7	13.4	8.4	1.3	1.2
CN	0.002	<0.002	0.002	<0.002	<0.002	<0.002
Oil & Grease	<2	<2	<2	<2	<2	<2
TSS	52.7	36.7	29.7	29.7	34.2	27.2
TDS	2094	13,681	3854	195	1227	2029

Table 3. Water quality criteria and standards

Component	NPDES Permit[7] (mg/L)	Drinking Water[8] (mg/L)	Tennessee Effluent Limitations and Standards for Industrial Wastewater Treatment Plants[9] (mg/L)
Arsenic	*	0.050	1.0
Cadmium	*	0.01	0.01
Chromium	0.2	0.050	3.0
Copper	1.0	1.0	1.0
Iron	1.0	0.3	10
Lead	*	0.05	0.1
Manganese	*	0.05	10
Nickel	*	-	3.0
Selenium	*	0.01	0.01
Silver	*	0.05	0.05
Sulfate	*	-	-
Zinc	1.0	5.0	2.0
Oil and Grease	20	-	30
pH	-	6.0-9.0	6.0-9.0
Total Suspended Solids (TSS)	50	-	40

*The NPDES permit states that if significant quantities of these pollutants are recorded, or the results of the Toxicity Control and Monitoring Program (TCMP) indicate the presence of toxicity, the permit may be modified to reflect appropriate monitoring requirements and/or effluent limitations.

Table 4. Typical characteristics of coal yard runoff

Parameter	Concentration, mg/L
Total solids	1500-48000
Total dissolved solids	700-44000
Total suspended solids	20-3300
Total hardness ($CaCO_3$)	130-1850
Alkalinity ($CaCO_3$)	15-80
Acidity ($CaCO_3$)	10-27800
Manganese	90-180
Copper	1.6-3.9
Sodium	160-1260
Zinc	6-23.0
Aluminum	825-1200
Sulfate	130-20000
Phosphorus	0.2-1.2
Iron	0.4-2.0
Chloride	20-480
Nitrate	0.3-2.3
Ammonia	0.4-1.8
BOD	3-10
COD	100-1000
Turbidity (in JTU)	6-605
pH (in units)	2.8-7.8

Source: Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for Steam Electric Powerplants, EPA 440-1-73/029, March 1974.

attempt was made to determine the organic constituents which comprised the TOC.

It should also be noted that the ion-exchange acid regeneration stream and the CYR streams contained in excess of 1400 mg/L of sulfate. The NPDES permit lists sulfate as one of the components which may be regulated if significant quantities are recorded. Since neither the Drinking Water Standards nor the Tennessee Effluent Limitations list sulfate as a component, the concentration at which sulfate becomes a problem was not determined.

4. BENCH-SCALE EVALUATION OF THE CYRTF

A flow diagram of the CYRTF is presented in Fig. 1. The wastewater to be treated in the facility is stored in a 200,000-gal collection basin until enough wastewater is collected to run the CYRTF. The wastewater from the collection basin is pumped into the pH adjustment tank (Tank T-2) where it is mixed with a lime slurry (1.0 - 1.5 lbs of lime per gal) from the lime slurry tank (Tank T-3) until a pH of ~10.5 is obtained. From the pH adjustment tank, the wastewater flows to the clarifier where polymer is added and the solids are settled. The solids from the settler are stored in the sludge storage tank (Tank T-7) until enough sludge has been collected to be treated by the rotary drum vacuum filter. The liquid effluent from the clarifier enters a recycle tank (Tank T-12) where sulfuric acid is added to adjust the pH of the wastewater to the 6.0 - 9.0 range. The effluent from the recycle tank flows to a discharge basin before being discharged to White Oak Creek. The facility is designed to automatically recycle the wastewater to the recycle tank should the pH recorder or turbidity meter indicate the wastewater is out of specification. This flow path is indicated in Fig. 1 by the dashed line.

In order to simulate this flow scheme on a bench scale, the following were examined:

(1) waste stream mixing,

(2) pH adjustment,

(3) reactor/clarifier jar tests, and

(4) sludge dewatering by filtration.

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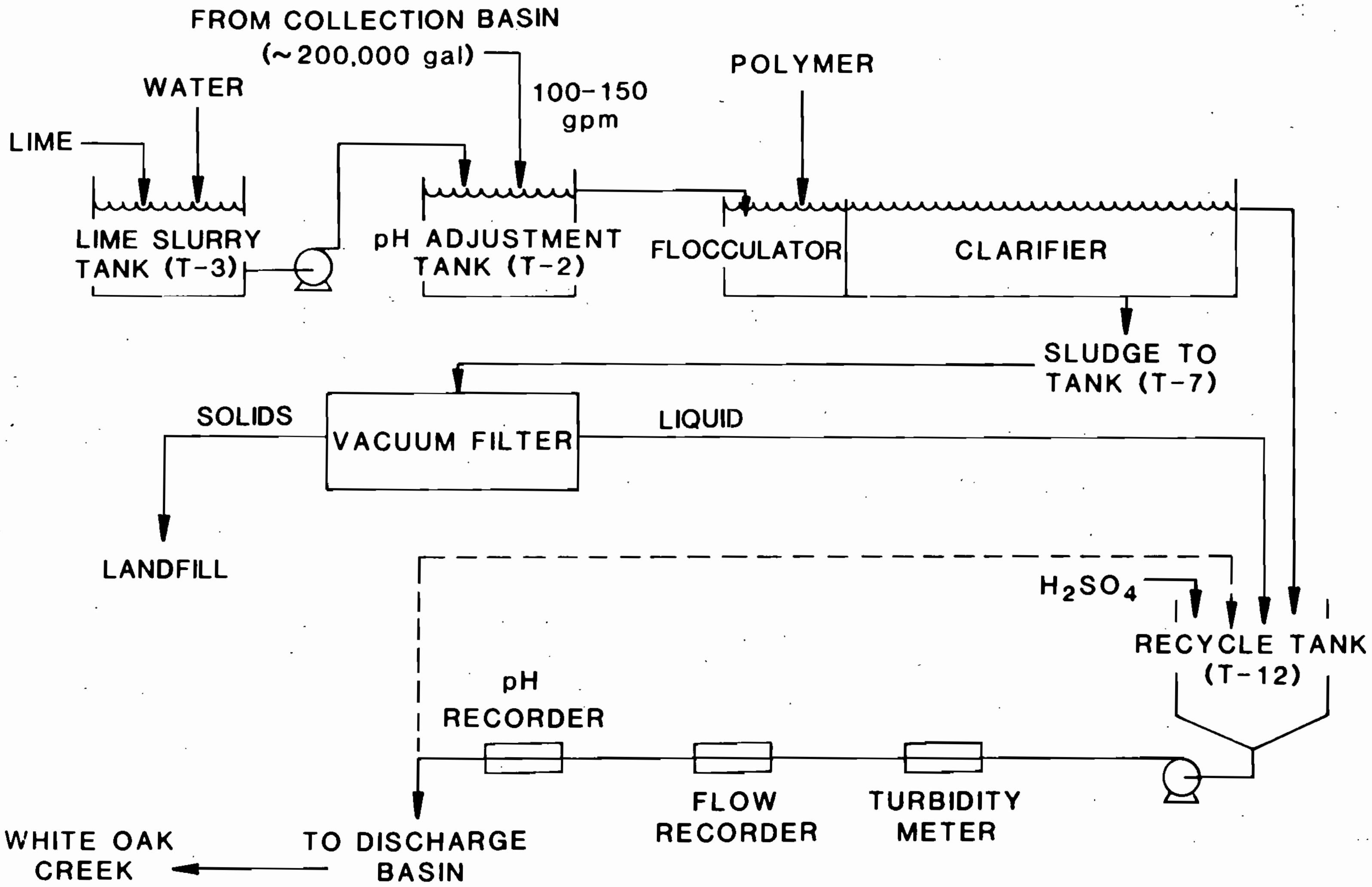

Fig. 1. Flow diagram of the CYRTF.

4.1 STREAM MIXING

Various mixing combinations were examined to determine the resultant concentration of regulated compounds. Samples representative of each of the mixing events were obtained by compositing the appropriate constituents in proportion to their annual discharge rates. The following mixing combinations were examined:

<u>(1) mixing event #1</u>

48.9% ion-exchange acid regeneration,
13.3% ion-exchange sodium regeneration,
28.8% boiler blowdown, and
9.0% ash rinse.

<u>(2) mixing event #2</u>

53.7% ion-exchange acid regeneration,
14.6% ion-exchange sodium regeneration, and
31.7% boiler blowdown.

<u>(3) mixing event #3</u>

26.8% ion-exchange acid regeneration,
7.3% ion-exchange sodium regeneration,
15.9% boiler blowdown, and
50.0% coal yard runoff.

<u>(4) mixing event #4</u>

40.2% ion-exchange acid regeneration,
11.0% ion-exchange sodium regeneration,
23.8% boiler blowdown, and
25.0% coal yard runoff.

<u>(5) mixing event #5</u>

100% coal yard runoff (obtained 7/9/86).

<u>(6) mixing event #6</u>

100% coal yard runoff (obtained 7/14/86).

Mixing event 1 is typical of the wastewater stream the CYRTF would be likely to encounter on a daily basis since all of the components in mixing event 1 are produced daily.

Mixing event 2 is typical of the wastewater streams the CYRTF would be likely to encounter on a daily basis if the ash rinse component were eliminated. A bag house is scheduled to be installed in 1987, and the ash rinse stream would be eliminated when the bag house becomes operational.

Mixing events 3, 4, 5, and 6 have varying amounts of CYR and are typical of wastewater streams the CYRTF would be likely to encounter following various rainfall events. Mixing events 5 and 6 both contain 100% CYR but were taken from two separate rainfall events. In events 3 and 4 CYR, taken from the 7/14/86 sample was used.

The concentration of the components listed in the NPDES permit for each of the mixing events is presented in Table 5. By comparing with the water quality standards in Table 3, it can be seen that all mixing events violate the NPDES discharge limit for zinc (mixing event 1 is included because it is only 0.01 mg/L from the NPDES discharge limit). In addition, mixing events 5 and 6 violate the NPDES discharge limit for copper and iron, while mixing events 1,3, and 4 violate the NPDES limit for iron. It should be noted that a material balance for iron indicates that mixing event 1 should contain 0.28 mg/L of iron instead of the 1.1 mg/L listed. It is possible that some iron contamination was picked up while mixing the samples. The concentrations of other components in the mixing events seem to agree fairly well with the material balances.

For those components which are included in the NPDES permit without a discharge limit, the pH for all mixing events, the manganese for mixing events 3, 4, 5, and 6, and the cadmium for mixing events 5 and 6 violate either (or both) the Drinking Water Standards or the Tennessee Effluent Limitations. It should be emphasized that these violations are prior to any treatment.

4.2 pH ADJUSTMENT

The six mixing combinations produced a composite pH ranging from 1.9 to 2.5 with no solids precipitation. For each mixing event, the quantity

Table 5. Concentration of regulated pollutants in mixing events

Parameter	Mixing event 1 (mg/L)	Mixing event 2 (mg/L)	Mixing event 3 (mg/L)	Mixing event 4 (mg/L)	Mixing event 5 (mg/L)	Mixing event 6 (mg/L)
pH	2.0	1.9	2.1	2.0	2.5	2.5
TSS	8	—	10	12	34	27
Cr	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
Cu	0.66	0.45	0.69	0.39	1.1	1.1
Fe	1.1	0.30	>53	59	110	210
Zn	0.99	1.4	1.4	1.3	1.8	1.8
As	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Cd	<0.010	<0.010	<0.010	<0.010	0.016	0.016
Pb	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Mn	0.025	0.026	0.81	0.47	1.1	1.7
Ni	<0.12	<0.12	0.24	0.16	0.43	0.49
Se	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Ag	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

of lime [$Ca(OH)_2$] necessary to bring the pH into the 6 to 9 range was determined. The results are presented in Fig. 2. This figure also shows the pH at which precipitate first appeared for each mixing event. From observing Fig. 2, it can be seen that those mixing events which contain CYR begin to precipitate in the 2.8 to 3.1 range, while those that contain no CYR begin to precipitate in the 10.0 to 10.5 range. This is because the mixing events that have the CYR contain large quantities of iron which will oxidize to the ferric form and precipitate as insoluble ferric hydroxide at pH as low as 2. The order of precipitation for various metal hydroxides in pure form as a function of pH is presented below:[11]

Ion	pH	Ion	pH
Fe^{3+}	2.0	Na^{+}	6.7
Al^{3+}	4.1	Cd^{2+}	6.7
Cr^{3+}	5.3	Zn^{2+}	7.0
Cu^{2+}	5.3	Hg^{2+}	7.3
Fe^{2+}	5.5	Mn^{2+}	8.5
Pb^{2+}	6.0		

Although the table above indicates that most metals should begin to precipitate by pH 8.5, no visible precipitate was observed for mixing events 1 and 2 until a pH of ~10.5. This was probably due to the very low concentration of metals present in these mixing events. The precipitate visible at a pH of ~10.5 was probably due to the calcium, from the calcium hydroxide, coming out of solution.

4.3 REACTOR/CLARIFIER JAR TESTS

Jar tests were performed for the mixing events, and the concentration of regulated components was followed as a function of pH. Two different polymers were used to evaluate the effect of polymers on the settling characteristics of the sludge. The following test procedure was a modified version of the various tests found in several sources.[12,13,14]

1) 800-mL samples were placed into 1000-mL beakers.
2) The stirrers were started at 110 rpm.

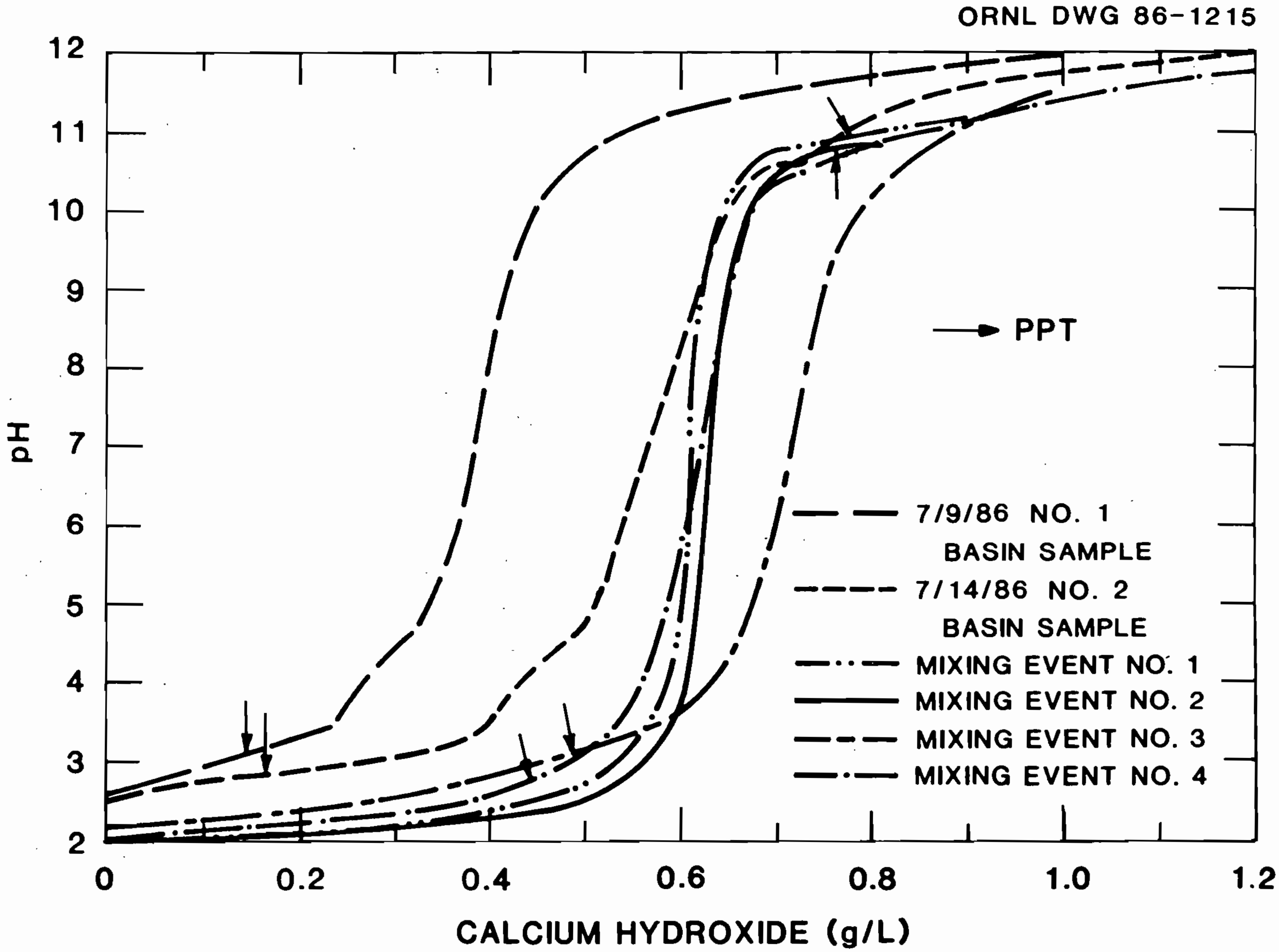

Fig. 2. pH curves for the various mixing events.

3) The coagulant [$Ca(OH)_2$] was injected, and the samples were agitated at 110 rpm for 20 min. (The 20 min simulates the time in the CYRTF pH adjustment tank.)
4) The mixing speed was reduced to 30 rpm, and the sample was gently agitated for 30 min.
5) The contents of the mixing jars were transferred to 1000 mL Imhoff cones and settled for 30 min. During this time the settled volume in the Imhoff cones was measured every 5 to 10 min.
6) After 30 min of settling, filtered and unfiltered samples were taken for ICP analysis.

The analyses at various pHs, for the components listed in the NPDES permit, are presented for the jar tests of the different mixing events in Tables 6 through 11.

As can be seen from these tables, the various mixing events violate the NPDES permit, before pH adjustment, for copper, iron, and zinc. In addition, several of the mixing events contain concentrations of manganese, before pH adjustment, which might violate the discharge limit if manganese were to be added to the NPDES permit.

By observing Tables 6 - 11, it can be seen that by the time the pH reaches 9 all of the components in the filtered samples and most of the components in the unfiltered samples have been reduced to values less than those listed in the NPDES discharge permit. It can also be seen that there may be some advantage in raising the pH to the 10.5 - 11.0 range. The concentrations of several of the unfiltered components, notably zinc and manganese, seem to drop substantially as the pH is raised from 10 to 11. This is probably due to the calcium, from the calcium hydroxide, coming out of solution and creating a sludge that settles faster. As the calcium settles, it would sweep other metal hydroxides, which are more difficult to settle, along with it. By observing the pH curves in Fig. 2, it can be seen that little additional calcium hydroxide is required to raise the pH from 9 to 11. Therefore, the advantages gained by the higher pH would outweigh the cost.

The results of the jar tests presented in Tables 6 - 11 indicate that in one case the concentration of TSS slightly exceeded the NPDES

Table 6. Jar test for mixing event #1
(Neutralized with calcium hydroxide, settled for 30 min)

	pH	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	Sulfate (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Effluent Limits		50.0	0.2	1.0	1.0	1.0	*	*	*	*	*	*	*	*
Unfiltered**	2.0	8.0												
Filtered	2.0		<0.080	0.66	1.1	0.99		<0.20	<0.010	<0.40	0.025	<0.12	<0.40	<0.10
Unfiltered	8.0	30.0	<0.080	<0.040	0.48	0.65		<0.20	<0.010	<0.40	0.027	<0.12	<0.40	<0.10
Filtered	8.0		<0.080	<0.040	0.36	<0.040		<0.20	<0.010	<0.40	0.034	<0.12	<0.40	<0.10
Unfiltered	9.0	39.5	<0.080	<0.040	0.39	0.54		<0.20	<0.010	<0.40	0.024	<0.12	<0.40	<0.10
Filtered	9.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.014	<0.12	<0.40	<0.10
Unfiltered	10.0	40.5	<0.080	<0.040	0.30	0.42		<0.20	<0.010	<0.40	0.020	<0.12	<0.40	<0.10
Filtered	10.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Unfiltered	11.0	58.0	<0.080	<0.040	0.066	0.17		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Filtered	11.0		<0.080	<0.040	<0.060	<0.040		<0.20	0.011	<0.40	<0.010	<0.12	<0.40	<0.10

*The permit states that if significant quantities of these pollutants are recorded, or the results of the TCMP indicate the presence of toxicity, the permit may be modified to reflect appropriate monitoring requirements and/or effluent limitations.

**The analysis for the unfiltered sample was not presented because there were several errors in the analyses.

MIXING EVENT # 1

48.9% Ion-Exchange Acid Regeneration
13.3% Ion-Exchange Sodium Regeneration
28.8% Boiler Blowdown
9.0% Ash Rinse

Table 7. Jar test on mixing event #2
(Neutralized with CaO, settled for 30 min)

	pH	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	Sulfate (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Effluent Limits		50.0	0.2	1.0	1.0	1.0	*	*	*	*	*	*	*	*
Unfiltered	1.9		<0.080	0.45	0.30	1.4		<0.20	<0.010	<0.40	0.026	<0.12	<0.40	<0.10
Filtered	1.9		<0.080	0.095	0.30	0.82		<0.20	<0.010	<0.40	0.018	<0.12	<0.40	<0.10
Unfiltered	7.0		<0.080	<0.040	0.45	0.67		<0.20	<0.010	<0.40	0.031	<0.12	<0.40	<0.10
Filtered	7.0		<0.080	<0.040	<0.060	0.20		<0.20	<0.010	<0.40	0.028	<0.12	<0.40	<0.10
Unfiltered	8.0		<0.080	<0.040	0.42	0.67		<0.20	<0.010	<0.40	0.027	<0.12	<0.40	<0.10
Filtered	8.0		<0.080	<0.040	0.068	<0.040		<0.20	<0.010	<0.40	0.025	<0.12	<0.40	<0.10
Unfiltered	9.0		<0.080	<0.040	0.42	0.66		<0.20	<0.010	<0.40	0.025	<0.12	<0.40	<0.10
Filtered	9.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.016	<0.12	<0.40	<0.10
Unfiltered	10.0		<0.080	<0.040	0.40	0.57		<0.20	<0.010	<0.40	0.025	<0.12	<0.40	<0.10
Filtered	10.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Unfiltered	11.0		<0.080	<0.040	0.079	0.075		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Filtered	11.0		<0.080	<0.040	0.15	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10

*NOTE: The Permit states that if significant quantities of these pollutants are recorded, or the results of the TCMP indicate the presence of toxicity, the permit may be modified to reflect appropriate monitoring requirements and/or effluent limitations.

MIXING EVENT #2

53.7% Ion-Exchange Acid Regeneration
14.6% Ion-Exchange Sodium Regeneration
31.7% Boiler Blowdown

Table 8. Jar test for mixing event #3
(Neutralized with calcium hydroxide, settled for 30 min)

	pH	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	Sulfate (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Effluent Limits		50.0	0.2	1.0	1.0	1.0	*	*	*	*	*	*	*	*
Unfiltered	2.1	10.0	<0.080	0.69	>53.0	1.4		<0.20	<0.010	<0.40	0.81	0.24	<0.40	<0.10
Filtered	2.1		<0.080	0.96	>53.0	1.5		<0.20	<0.010	<0.40	0.78	0.24	<0.40	<0.10
Unfiltered	8.0	22.5	<0.080	<0.040	3.8	0.046		<0.20	<0.010	<0.40	0.37	<0.12	<0.40	<0.10
Filtered	8.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.34	<0.12	<0.40	<0.10
Unfiltered	9.0	18.0	<0.080	<0.040	3.8	0.048		<0.20	<0.010	<0.40	0.080	<0.12	<0.40	<0.10
Filtered	9.0		<0.080	0.31	<0.060	<0.040		<0.20	<0.010	<0.40	0.050	<0.12	<0.40	<0.10
Unfiltered	10.0	22.5	<0.080	<0.040	3.1	0.046		<0.20	<0.010	<0.40	0.042	<0.12	<0.40	<0.10
Filtered	10.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.013	<0.12	<0.40	<0.10
Unfiltered	11.0	23.5	<0.080	<0.040	2.1	<0.040		<0.20	<0.010	<0.40	0.026	<0.12	<0.40	<0.10
Filtered	11.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10

*NOTE: The permit states that if significant quantities of these pollutants are recorded, or the results of the TCMP indicate the presence of toxicity, the permit may be modified to reflect appropriate monitoring requirements and/or effluent limitations.

MIXING EVENT #3

26.8% Ion-Exchange Acid Regeneration
7.3% Ion-Exchange Sodium Regeneration
15.9% Boiler Blowdown
50.0% Coal Yard Runoff

Table 9. Jar test for mixing event #4
(Neutralized with calcium hydroxide, settled for 30 min)

	pH	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	Sulfate (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Effluent Limits		50.0	0.2	1.0	1.0	1.0	*	*	*	*	*	*	*	*
Unfiltered	2.0	12	<0.080	0.39	59.0	1.3		<0.20	<0.010	<0.40	0.47	0.16	<0.40	<0.10
Filtered	2.0		<0.080	0.50	52.0	1.4		<0.20	<0.010	<0.40	0.49	0.16	<0.40	<0.10
Unfiltered	8.0	24	<0.080	<0.040	4.4	0.21		<0.20	<0.010	<0.40	0.32	<0.12	<0.40	<0.10
Filtered	8.0		<0.080	<0.040	0.12	0.24		<0.20	<0.010	<0.40	0.25	<0.12	<0.40	<0.10
Unfiltered	9.0	23	<0.080	0.049	4.6	0.28		<0.20	<0.010	<0.40	0.14	<0.12	<0.40	<0.10
Filtered	9.0		<0.080	<0.040	0.11	0.085		<0.20	<0.010	<0.40	0.080	<0.12	<0.40	<0.10
Unfiltered	10.0	25	<0.080	<0.040	4.2	0.24		<0.20	<0.010	<0.40	0.057	<0.12	<0.40	<0.10
Filtered	10.0		<0.080	<0.040	0.43	<0.040		<0.20	<0.010	<0.40	0.020	<0.12	<0.40	<0.10
Unfiltered	11.0	21	<0.080	<0.040	1.1	0.12		<0.20	<0.010	<0.40	0.014	<0.12	<0.40	<0.10
Filtered	11.0		<0.080	0.042	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10

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MIXING EVENT # 4

40.3% Ion-Exchange Acid Regeneration
11.0% Ion-Exchange Sodium Regeneration
23.8% Boiler Blowdown
25.0% Coal Yard Runoff

Table 10. Jar test on CYR basin obtained 7/9/86
(Neutralized with calcium hydroxide, settled for 30 min)

	pH	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	Sulfate (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Effluent Limits		50.0	0.2	1.0	1.0	1.0	*	*	*	*	*	*	*	*
Unfiltered	2.5		<0.080	1.1	110.0	1.8		<0.20	0.016	<0.40	1.1	0.43	<0.40	<0.10
Filtered	2.5		<0.080	1.3	99.0	1.9		<0.20	0.018	<0.40	1.0	0.43	<0.40	<0.10
Unfiltered	8.0		<0.080	0.049	5.7	0.099		<0.20	<0.010	<0.40	0.18	<0.12	<0.40	<0.10
Filtered	8.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.11	<0.12	<0.40	<0.10
Unfiltered	9.0		<0.080	0.061	6.6	0.12		<0.20	<0.010	<0.40	0.11	<0.12	<0.40	<0.10
Filtered	9.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.035	<0.12	<0.40	<0.10
Unfiltered	10.0		<0.080	0.055	6.4	0.12		<0.20	<0.010	<0.40	0.081	<0.12	<0.40	<0.10
Filtered	10.0		<0.080	<0.040	0.086	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Unfiltered	11.0		<0.080	0.049	5.2	0.088		<0.20	0.015	<0.40	0.064	<0.12	<0.40	<0.10
Filtered	11.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10

*The permit states that if significant quantities of these pollutants are recorded, or the results of the TCMP indicate the presence of toxicity, the permit may be modified to reflect appropriate monitoring requirements and/or effluent limitations.

MIXING EVENT #5

100% Coal Yard Runoff
Obtained 7/9/86

Table 11. Jar test on CYR basin obtained 7/14/86
(Neutralized with calcium hydroxide, settled for 30 min)

	pH	TSS	Cr	Cu	Fe	Zn	Sulfate	As	Cd	Pb	Mn	Ni	Se	Ag
Effluent Limits		50.0	0.2	1.0	1.0	1.0	*	*	*	*	*	*	*	*
Unfiltered	2.5		<0.080	1.1	210.0	1.8		<0.20	0.016	<0.40	1.7	0.49	<0.40	<0.10
Filtered	2.5		<0.080	1.3	200.0	2.0		<0.20	0.016	<0.40	1.7	0.49	<0.40	<0.10
Unfiltered	8.0		<0.080	<0.040	5.2	0.048		<0.20	<0.010	<0.40	0.26	<0.12	<0.40	<0.10
Filtered	8.0		<0.080	<0.040	0.089	<0.040		<0.20	<0.010	<0.40	0.21	<0.12	<0.40	<0.10
Unfiltered	9.0		<0.080	<0.040	7.2	0.091		<0.20	<0.010	<0.40	0.098	<0.12	<0.40	<0.10
Filtered	9.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	0.026	<0.12	<0.40	<0.10
Unfiltered	10.0		<0.080	<0.040	5.2	0.086		<0.20	<0.010	<0.40	0.057	<0.12	<0.40	<0.10
Filtered	10.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Unfiltered	11.0		<0.080	<0.040	4.0	0.046		<0.20	<0.010	<0.40	0.046	<0.12	<0.40	<0.10
Filtered	11.0		<0.080	<0.040	<0.060	<0.040		<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10

*The permit states that if significant quantities of these pollutants are recorded, or the results of the TCMP indicate the presence of toxicity, the permit may be modified to reflect appropriate monitoring requirements and/or effluent limitations.

MIXING EVENT #6

100% Coal Yard Runoff
Obtained 7/14/86

discharge limit, and the concentration of iron in several cases exceeded the NPDES discharge limit. It should also be noted that in all cases in which the concentration of iron exceeded the NPDES, CYR had been added to the mixture. While the iron has been precipitated, as can be seen by the filtered samples, some of it has not settled, as indicated by the unfiltered samples. It should be noted that all ICP samples were preserved to a pH less than 2 with nitric acid. Therefore, any metals not filtered out of the solution would be redissolved and detected by the ICP analysis.

It should also be noted that some of the solids had a tendency to stick to the side of the Imhoff cone as it was settled. Some of these solids may have been siphoned into the samples taken for ICP analysis. This could account for the high TSS and iron concentrations in some of the samples. Therefore, the TSS and iron might not be a problem in the actual CYRTF.

Since coagulation with calcium hydroxide resulted in a clarified liquid which met the NPDES discharge limit for all components (with the possible exception of iron and TSS), flocculation with two different polymers, in conjunction with calcium hydroxide addition, was tested in an attempt to improve the settling characteristics of the sludge. Since the best solids precipitation and settling in the jar test occurred in the 10 - 11 pH range, the settling tests were run at a pH of 10.5. The results of these settling tests for the CYR sample obtained on 7/14/86 are presented in Figs. 3 and 4 for the Magnifloc 6220 and Betz 1100 polymers, respectively. (The Magnifloc polymer is currently used in the CYRTF.) These graphs indicate that the use of a polymer greatly improves the settling characteristics of the sludge. Further, there was not a noticeable difference in the performance of the Magnifloc and Betz polymers. The best results were obtained in the 2 to 5 mg/L polymer range. Similar results were obtained with the other mixing events.

4.4 VACUUM FILTRATION

To examine the feasibility of vacuum filtration, Büchner funnel tests were run on the various mixing events. Procedures for the Büchner funnel tests can be found in several sources.[12,15,16] The rate of

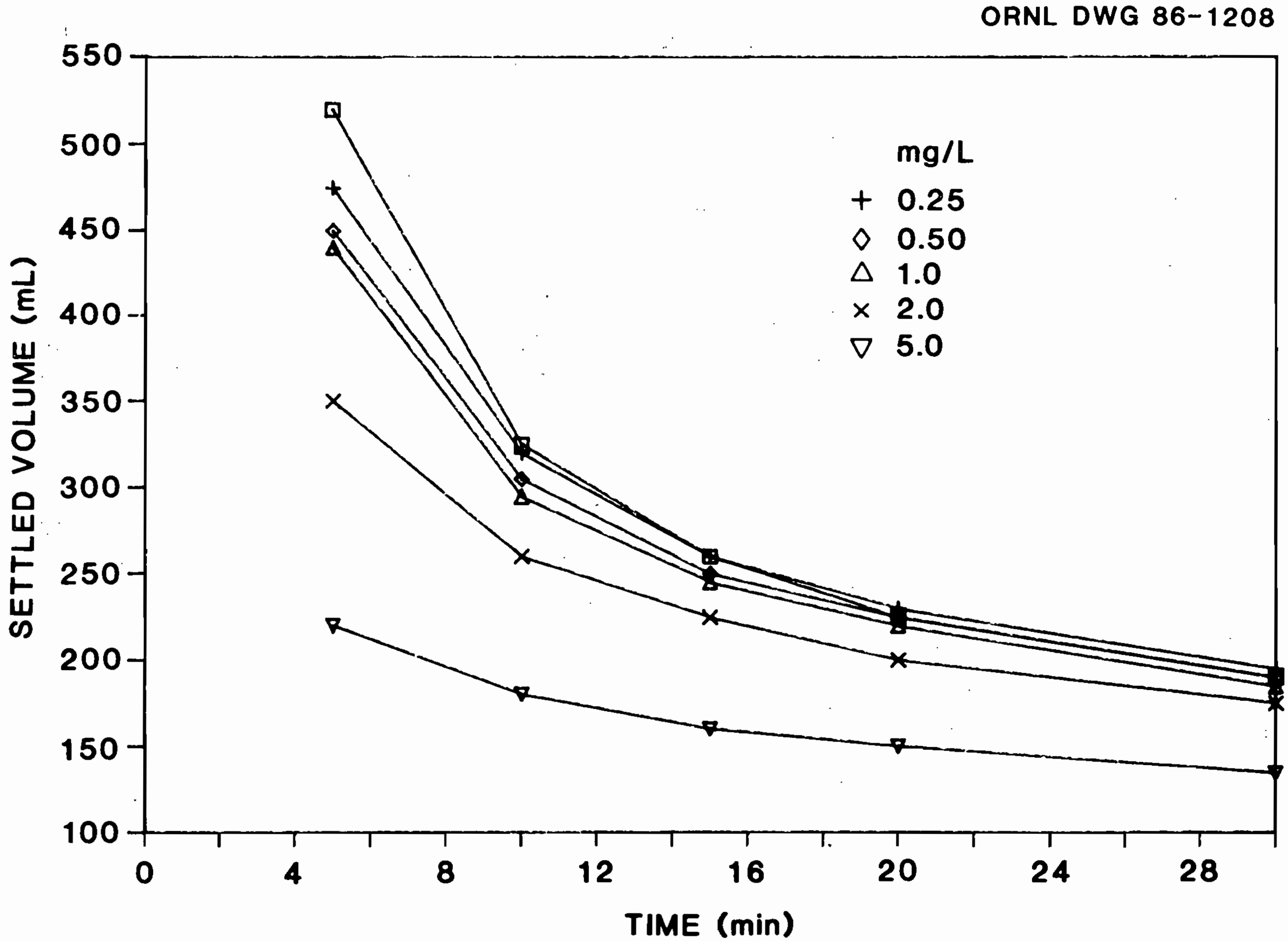

Fig. 3. Settling curve for 7/14/86 CYR sample utilizing Magnifloc 6220 polymer after pH adjustment with calcium hydroxide.

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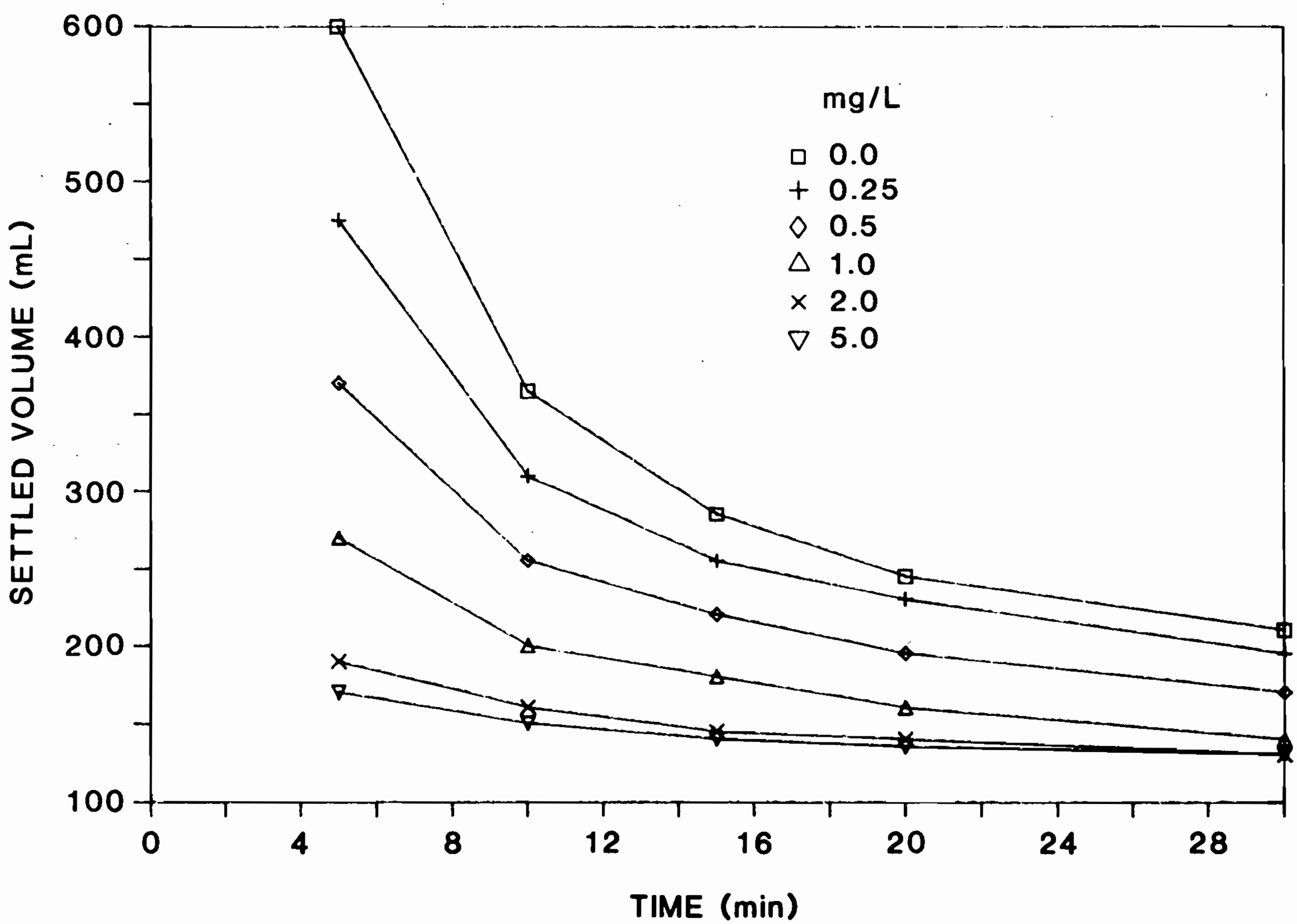

Fig. 4. Settling curve for 7/14/86 CYR sample utilizing Betz 1100 polymer after adjustment with calcium hydroxide.

filtration of sludge generally obeys the following equation (derived from Poiseuille's and Darcy's laws)[16]:

$$\frac{dV}{dt} = \frac{PA^2}{\mu(rcV + R_m A)} ,$$

where

V = volume of filtrate,

t = cycle time,

P = pressure,

A = filtration area,

μ = filtrate viscosity,

r = specific resistance,

c = weight of solids/unit volume filtrate,

R_m = initial resistance of filter media.

The specific resistance (r) is a measure of the filterability of the sludge and is numerically equal to the pressure difference required to produce a unit rate of filtrate flow of unit viscosity through a unit weight of cake. The specific resistance can be obtained by rearranging and integrating the above equation to obtain,

$$\frac{t}{V} = \frac{\mu rc}{2PA^2} V + \frac{\mu R_m}{PA} .$$

A linear relationship will result from a plot of t/V vs V, and r can be computed from the slope (b) of this plot:

$$r = \frac{2bPA^2}{\mu c} .$$

The specific resistance is useful for comparing the filterability of different sludges. In general, sludges with similar specific resistances can be expected to behave similarly when filtered on the same equipment. The literature indicated that sludges typically handled by vacuum filtration have specific resistances ranging from ~1 - 2200 x 10^7 s^2/g at 15 in. Hg vacuum.[15] The specific resistances for several of the mixing events are presented in Table 12. As can be seen, all of the specific resistance falls in this range. Also, there is little

Table 12. Specific resistances from the Büchner funnel tests at a pH of 10.5

Mixing event	Polymer	Vacuum (in. Hg)	Specific resistance ($s^2/g \times 10^7$)
#2	5 mg/L Betz	10	33
#2	5 mg/L Betz	20	101
#4	0.5 mg/L Magnifloc	10	42
#4	0.5 mg/L Magnifloc	20	62
#5	5 mg/L Magnifloc	10	107
#5	5 mg/L Magnifloc	20	177
#6	2 mg/L Betz	10	67
#6	2 mg/L Betz	20	133

variability in the specific resistances between the mixing events. Since the rotary drum vacuum filter has successfully run on the CYR sample, mixing event #6, there should be no problem running on wastewaters typical of the other mixing events.

5. CYRTF MONITORING

In order to test the operability of the CYRTF on various mixing events, the wastewater from the steam plant was pumped from the 3518 basin to the CYR collection basin. The water from the steam plant was held in the CYR collection basin until enough wastewater to run the CYRTF was obtained. A total of six events were monitored during this program. The dates and compositions of these events are summarized in Table 13. During these monitoring events, samples were taken from the collection basin, the recycle tank, and the effluent weir draining into White Oak Creek. These samples were analyzed for those components listed in the NPDES permit. The results for each of the monitoring events are presented in Tables 14 - 19. During these monitoring events, the pHs in both the pH adjustment tank and the recycle tank were also monitored and recorded. These operational data are presented in Figs. 5 - 10. From these figures, it can be seen that the pH of the pH adjusted tank ranged from ~3.5 - 11 and generally operated in the 10 - 11 range. The recycle tank generally operated in the 6 - 9 range.

From the data taken during the monitoring events, it can be seen that only iron violates the NPDES discharge limits. Of the 40 unfiltered samples taken from the recycle tank and the effluent weir, ~28% of these were in violation of the 1.0 mg/L NPDES discharge limit for iron. It is interesting to note that of this 28%, 18% occurred during the August 25 run. This was the only run monitored in which essentially all of the wastewater originated from the steam plant. It is also interesting to note the high concentration of iron present in the wastewater during this run, even though the wastewater streams from the steam plant, which were originally characterized, contained very little iron. Since a large quantity of coal particles has been carried into the collection basin along with the CYR since the basin was installed, it is probable that the

Table 13. Summary of events during the monitoring of the CYRTF

Date	Monitoring duration (h)	Estimated wastewater composition
7/10/86	10	~100% coal yard runoff (CYR)
7/14/86	6	~100% CYR
8/18/86	7	40% ion-exchange acid regeneration (IEAR) 26% CYR 15% ion-exchange sodium regn. (IESR) 10% ash rinse waste (ARW) 9% boiler blowdown (BB)
8/19-20/86	15	39% IEAR 16% CYR 26% IESR 9% ARW 10% BB
8/20-21/86	37	21% IEAR 60% CYR 6% IESR 5% ARW 8% BB
8/25/86	7	46% IEAR 0% CYR 28% IESR 10% ARW 16% BB

Table 14. Data summary for operation of the CYR Facility on July 10, 1986

Sample point	Time (hours)	pH in Basin	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Upper Basin	1300	2.8	<0.080	0.67	99.0	1.6	<0.20	0.011	<0.40	0.97	0.40	<0.40	<0.10
Upper Basin	1600	2.8	<0.080	0.64	95.0	1.4	<0.20	0.011	<0.40	0.92	0.38	<0.40	<0.10
Recycle Tank	1300	2.8	<0.080	0.15	22.0	0.38	<0.20	<0.010	<0.40	0.22	<0.12	<0.40	<0.10
Recycle Tank	1500	-	<0.080	<0.040	0.60	<0.040	<0.20	<0.010	<0.40	0.014	<0.12	<0.40	<0.10
Recycle Tank	1700	-	<0.080	<0.040	0.86	<0.040	<0.20	<0.010	<0.40	0.017	<0.12	<0.40	<0.10
Recycle Tank	1900	-	<0.080	<0.040	0.79	<0.040	<0.20	<0.010	<0.40	0.016	<0.12	<0.40	<0.10
Recycle Tank	2100	-	<0.080	<0.040	1.8	<0.040	<0.20	<0.010	<0.40	0.023	<0.12	<0.40	<0.10
Recycle Tank	2300	-	<0.080	<0.040	1.4	<0.040	<0.20	<0.010	<0.40	0.021	<0.12	<0.40	<0.10

Table 15. Data summary for operation of the CYR Facility on July 14, 1986

Sample point	Time (hours)	pH in Basin	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Upper Basin	1000	2.92	<0.080	0.68	210.0	1.5	<0.20	0.012	<0.40	1.7	0.49	<0.40	<0.10
Recycle Tank	1000	2.92	<0.080	<0.040	2.7	<0.040	<0.20	<0.010	<0.40	0.060	<0.12	<0.40	<0.10
Recycle Tank	1200	-	<0.080	<0.040	2.3	<0.040	<0.20	<0.010	<0.40	0.24	<0.12	<0.40	<0.10
Recycle Tank	1400	-	<0.080	0.066	24.0	0.099	<0.20	0.010	<0.40	0.28	<0.12	<0.40	<0.10

Table 16. Data summary for operation of the CYR Facility on August 18, 1986

Sample point	Filtered (Y/N)	Time (hours)	pH in Basin	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Upper Basin	N	1000	3.2		<0.080	0.51	85	1.3	<0.20	0.013	<0.40	0.69	0.27	<0.40	<0.10
Upper Basin	N	1400	2.6		<0.080	0.41	70	1.2	<0.20	0.010	<0.40	0.58	0.22	<0.40	<0.10
Upper Basin	Y	1400	2.6		<0.080	1.1	63	1.5	<0.20	0.010	<0.40	0.56	0.21	<0.40	<0.10
Recycle Tank	N	1100	-		<0.080	<0.040	0.77	0.063	<0.20	<0.010	<0.40	0.27	<0.12	<0.40	<0.10
Recycle Tank	Y	1100	-		<0.080	<0.040	<0.060	0.066	<0.20	<0.010	<0.40	0.24	<0.12	<0.40	<0.10
Recycle Tank	N	1300	-	8.0	<0.080	<0.040	0.68	0.071	<0.20	<0.010	<0.40	0.015	<0.12	<0.40	<0.10
Recycle Tank	N	1500	-		<0.080	<0.040	0.91	0.046	<0.20	<0.010	<0.40	0.015	<0.12	<0.40	<0.10
Recycle Tank	Y	1500	-		<0.080	<0.040	0.064	0.047	<0.20	<0.010	<0.40	0.011	<0.12	<0.40	<0.10
Effluent Weir	N	1200	-	2.0	<0.080	<0.040	0.13	0.066	<0.20	<0.010	<0.40	0.019	<0.12	<0.40	<0.10
Effluent Weir	Y	1200	-		<0.080	<0.040	<0.060	0.073	<0.20	<0.010	<0.40	0.019	<0.12	<0.40	<0.10
Effluent Weir	N	1600	-		<0.080	<0.040	0.39	0.055	<0.20	<0.010	<0.40	0.024	<0.12	<0.40	<0.10
Effluent Weir	Y	1600	-		<0.080	<0.040	0.15	0.086	<0.20	<0.010	<0.40	0.029	<0.12	<0.40	<0.10

Table 17. Data summary for operation of the CYR Facility on August 19 - 20, 1986

Sample point	Filtered (Y/N)	Date	Time (hours)	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Upper Basin	N	8/19/86	1600		<0.080	0.43	130	1.5	<0.20	0.013	<0.40	0.59	0.24	<0.40	<0.10
Upper Basin	Y	8/19/86	1600		<0.080	0.45	72	1.5	<0.20	0.020	<0.40	0.56	0.23	<0.40	<0.10
Upper Basin	N	8/19/86	2000		<0.080	0.42	84	1.1	<0.20	<0.010	<0.40	0.56	0.22	<0.40	<0.10
Upper Basin	Y	8/19/86	2000		<0.080	0.61	71	1.4	<0.20	0.010	<0.40	0.53	0.21	<0.40	<0.10
Recycle Tank	N	8/19/86	1600	7.0	<0.080	<0.040	0.91	0.30	<0.20	<0.010	<0.40	0.011	<0.12	<0.40	<0.10
Recycle Tank	Y	8/19/86	1600		<0.080	<0.040	0.14	0.39	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Recycle Tank	N	8/19/86	2000		<0.080	<0.040	0.46	0.34	<0.20	<0.010	<0.40	0.011	<0.12	<0.40	<0.10
Recycle Tank	Y	8/19/86	2000		<0.080	<0.040	<0.060	0.22	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Recycle Tank	N	8/19/86	2200	8.0	<0.080	<0.040	1.2	0.31	<0.20	<0.010	<0.40	0.017	<0.12	<0.40	<0.10
Recycle Tank	N	8/19/86	0000		<0.080	<0.040	0.59	0.33	<0.20	<0.010	<0.40	0.013	<0.12	<0.40	<0.10
Recycle Tank	N	8/20/86	0200		<0.080	<0.040	0.65	0.34	<0.20	<0.010	<0.40	0.014	<0.12	<0.40	<0.10
Recycle Tank	Y	8/20/86	0200		<0.080	<0.040	<0.060	0.22	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Recycle Tank	N	8/20/86	0400		<0.080	<0.040	0.42	0.30	<0.20	<0.010	<0.40	0.014	<0.12	<0.40	<0.10
Effluent Weir	N	8/19/86	1600	12.0	<0.080	<0.040	0.97	0.30	<0.20	<0.010	<0.40	0.026	<0.12	<0.40	<0.10
Effluent Weir	Y	8/19/86	1600		<0.080	<0.040	0.087	0.29	<0.20	<0.010	<0.40	0.023	<0.12	<0.40	<0.10
Effluent Weir	N	8/19/86	2200		<0.080	<0.040	0.30	0.33	<0.20	<0.010	<0.40	0.019	<0.12	<0.40	<0.10
Effluent Weir	N	8/20/86	0300		<0.080	<0.040	0.61	0.76	<0.20	<0.010	<0.40	0.015	0.15	<0.40	<0.10
Effluent Weir	Y	8/20/86	0300	5.0	<0.080	<0.040	<0.060	0.24	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10

Table 18. Data summary for operation of the CYR Facility on August 20 - 21, 1986

Sample point	Filtered (Y/N)	Date	Time (hours)	pH in Basin	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Upper Basin	N	8/20/86	1600	3.0		<0.080	0.34	130	1.3	<0.20	<0.010	<0.40	0.97	0.26	<0.40	<0.10
Upper Basin	Y	8/20/86	1600	3.0		<0.080	0.44	120	1.5	<0.20	0.020	<0.40	0.94	0.25	<0.40	<0.10
Upper Basin	N	8/21/86	0400	3.0		<0.080	0.40	170	1.2	<0.20	<0.010	<0.40	1.1	0.31	<0.40	<0.10
Upper Basin	Y	8/21/86	0400	3.0		<0.080	0.43	160	1.2	<0.20	0.010	<0.40	1.0	0.31	<0.40	<0.10
Upper Basin	N	8/21/86	1200	3.0		<0.080	0.45	180	1.2	<0.20	<0.010	<0.40	0.97	0.33	<0.40	<0.10
Upper Basin	Y	8/21/86	1200	3.0		<0.080	0.44	160	1.1	<0.20	<0.010	<0.40	0.01	0.29	<0.40	<0.10
Upper Basin	N	8/21/86	2000	2.6		<0.080	0.46	140	1.1	<0.20	<0.010	<0.40	0.70	0.28	<0.40	<0.10
Upper Basin	Y	8/21/86	2000	2.6		<0.080	0.44	130	1.0	<0.20	<0.010	<0.40	0.66	0.27	<0.40	<0.10
Recycle Tank	N	8/20/86	1500		23.0	<0.080	<0.040	0.68	0.43	<0.20	<0.010	<0.40	0.97	0.26	<0.40	<0.10
Recycle Tank	N	8/20/86	1800			<0.080	<0.040	0.74	0.41	<0.20	<0.010	<0.40	0.018	<0.12	<0.40	<0.10
Recycle Tank	Y	8/20/86	1800			<0.080	<0.040	0.094	0.43	<0.20	<0.010	<0.40	0.017	<0.12	<0.40	<0.10
Recycle Tank	N	8/20/86	2000		10.0	<0.080	<0.040	0.56	0.11	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Recycle Tank	N	8/20/86	2200			<0.080	<0.040	0.64	0.10	<0.20	<0.010	<0.40	0.013	<0.12	<0.40	<0.10
Recycle Tank	Y	8/20/86	2200			<0.080	<0.040	0.069	0.045	<0.20	<0.010	<0.40	0.011	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	0400		0.0	<0.080	<0.040	0.53	0.094	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Recycle Tank	Y	8/21/86	0400			<0.080	<0.040	<0.060	<0.040	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	0700			<0.080	<0.040	0.54	0.095	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	1200			<0.080	<0.040	0.62	0.12	<0.20	<0.010	<0.40	0.013	<0.12	<0.40	<0.10
Recycle Tank	Y	8/21/86	1200			<0.080	<0.040	1.9	0.086	<0.20	<0.010	<0.40	0.025	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	1400			<0.080	<0.040	0.59	0.10	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	1600			<0.080	<0.040	0.69	0.093	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	1900			<0.080	<0.040	0.59	<0.040	<0.20	<0.010	<0.40	0.011	<0.12	<0.40	<0.10
Recycle Tank	Y	8/21/86	1900			<0.080	<0.040	0.11	<0.040	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	2100			<0.080	<0.040	0.64	0.39	<0.20	<0.010	<0.40	0.021	<0.12	<0.40	<0.10
Recycle Tank	N	8/21/86	2300			<0.080	<0.040	0.93	0.33	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Recycle Tank	Y	8/21/86	2300			<0.080	<0.040	<0.060	<0.040	<0.20	<0.010	<0.40	<0.010	<0.12	<0.40	<0.10
Effluent Weir	N	8/20/86	2000		8.0	<0.080	<0.040	0.24	0.17	<0.20	<0.010	<0.40	0.017	<0.12	<0.40	<0.10
Effluent Weir	Y	8/20/86	2000			<0.080	<0.040	1.7	0.14	<0.20	<0.010	<0.40	0.033	<0.12	<0.40	<0.10
Effluent Weir	N	8/21/86	0400		0.0	<0.080	<0.040	0.33	0.040	<0.20	<0.010	<0.40	0.015	<0.12	<0.40	<0.10
Effluent Weir	Y	8/21/86	0400			<0.080	0.041	2.0	0.12	<0.20	<0.010	<0.40	0.029	<0.12	<0.40	<0.10
Effluent Weir	N	8/21/86	0700			<0.080	<0.040	0.30	0.12	<0.20	<0.010	<0.40	0.014	<0.12	<0.40	<0.10
Effluent Weir	N	8/21/86	1400			<0.080	<0.040	0.25	0.087	<0.20	<0.010	<0.40	0.013	<0.12	<0.40	<0.10
Effluent Weir	Y	8/21/86	1400			<0.080	<0.040	0.26	0.091	<0.20	<0.010	<0.40	0.013	<0.12	<0.40	<0.10
Effluent Weir	N	8/21/86	2000			<0.080	<0.040	0.29	0.13	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Effluent Weir	Y	8/21/86	2000			<0.080	<0.040	1.5	<0.040	<0.20	<0.010	<0.40	0.021	<0.12	<0.40	<0.10

Table 19. Data summary for operation of the CYR Facility on August 25, 1986

Sample point	Filtered (Y/N)	Time (hours)	pH in Basin	TSS (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Zn (mg/L)	As (mg/L)	Cd (mg/L)	Pb (mg/L)	Mn (mg/L)	Ni (mg/L)	Se (mg/L)	Ag (mg/L)
Upper Basin	N	1700	2.2		<0.080	0.60	230	1.3	<0.20	0.014	<0.40	0.87	0.36	<0.40	<0.10
Upper Basin	Y	1700	2.2		<0.080	0.63	230	1.4	<0.20	0.014	<0.40	0.88	0.36	<0.40	<0.10
Recycle Tank	N	1700	-		<0.080	<0.040	1.8	0.11	<0.20	<0.010	<0.40	0.024	<0.12	<0.40	<0.10
Recycle Tank	Y	1700	-		<0.080	<0.040	0.23	<0.040	<0.20	<0.010	<0.40	0.021	<0.12	<0.40	<0.10
Recycle Tank	N	1900	-	18	<0.080	<0.040	3.4	0.11	<0.20	<0.010	<0.40	0.032	<0.12	<0.40	<0.10
Recycle Tank	N	2100	-	16	<0.080	<0.040	2.9	0.12	<0.20	<0.010	<0.40	0.027	<0.12	<0.40	<0.10
Recycle Tank	N	2300	-	9	<0.080	<0.040	1.2	0.089	<0.20	<0.010	<0.40	0.015	<0.12	<0.40	<0.10
Recycle Tank	Y	2300	-		<0.080	<0.040	<0.060	<0.040	<0.20	<0.010	<0.40	0.011	<0.12	<0.40	<0.10
Recycle Tank	N	2400	-	12	<0.080	<0.040	1.3	0.087	<0.20	<0.010	<0.40	0.012	<0.12	<0.40	<0.10
Effluent Weir	N	1700	-		<0.080	<0.040	0.68	0.088	<0.20	<0.010	<0.40	0.039	<0.12	<0.40	<0.10
Effluent Weir	Y	1700	-		<0.080	<0.040	3.1	0.092	<0.20	<0.010	<0.40	0.051	<0.12	<0.40	<0.10
Effluent Weir	N	2300	-		<0.080	<0.040	1.0	0.10	<0.20	<0.010	<0.40	0.032	<0.12	<0.40	<0.10
Effluent Weir	Y	2300	-			<0.040	0.070	0.088	<0.20	<0.010	<0.40	0.028	<0.12	<0.40	<0.10

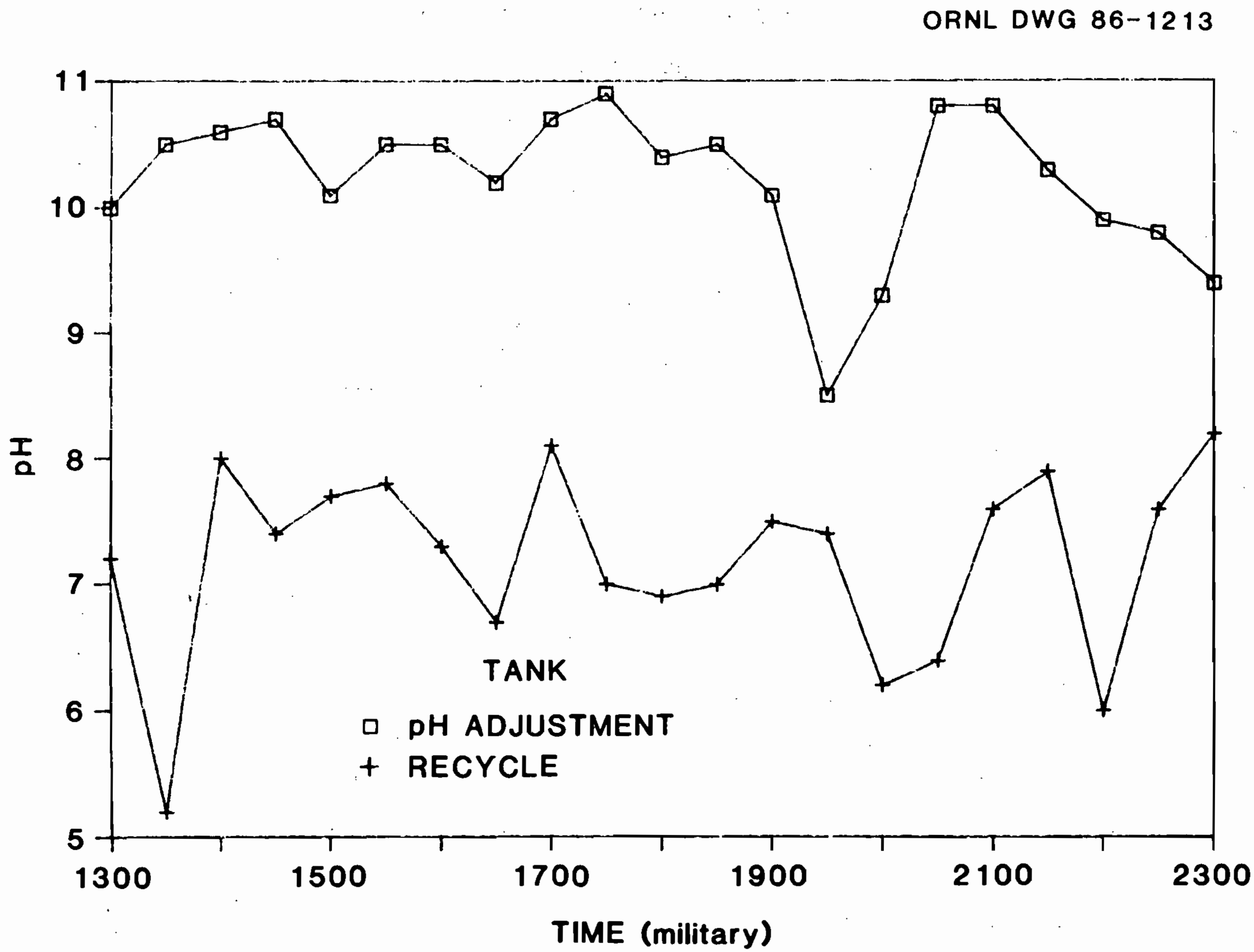

Fig. 5. Operational data for 7/10/86 run.

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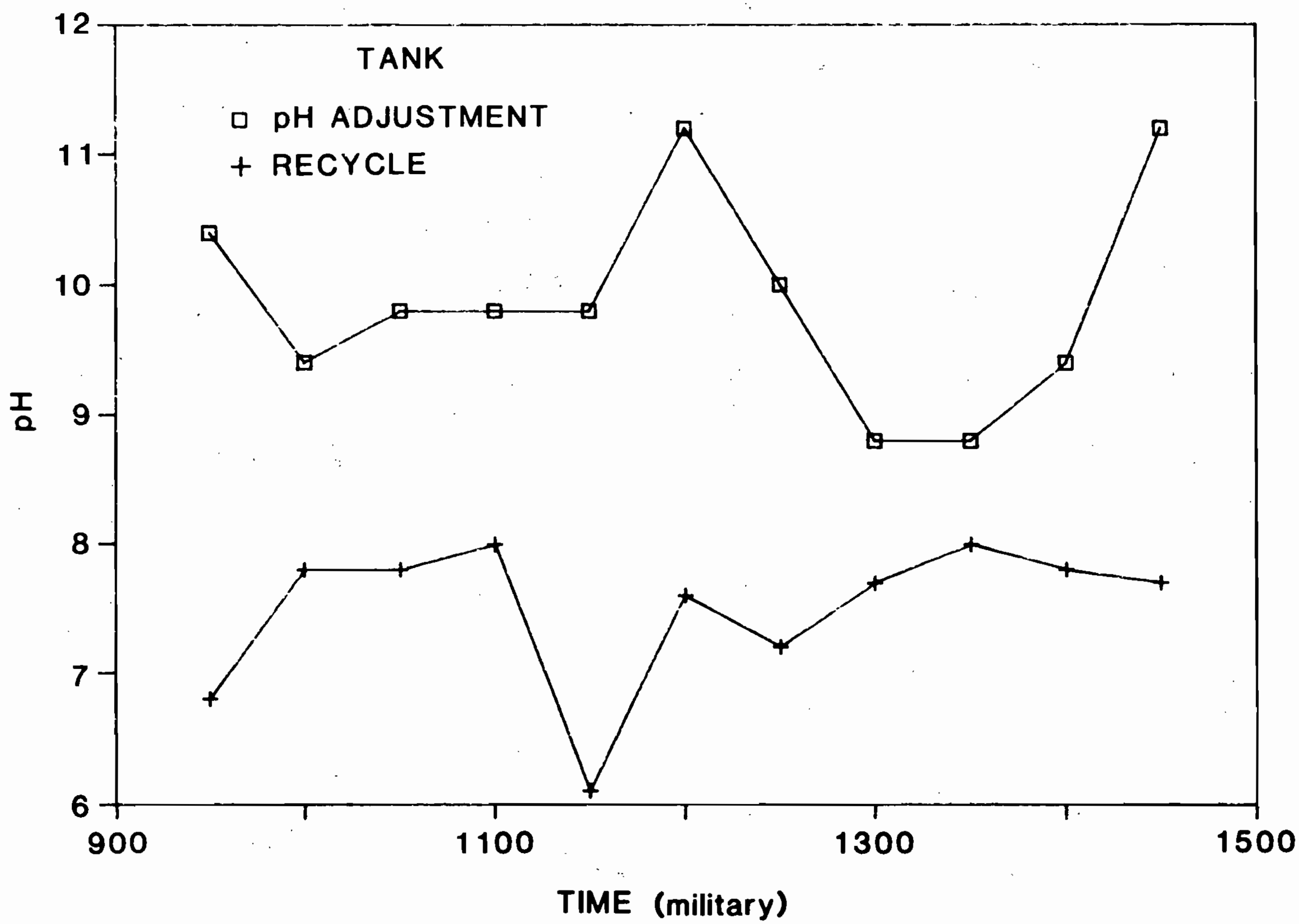

Fig. 6. Operational data for 7/14/86 run.

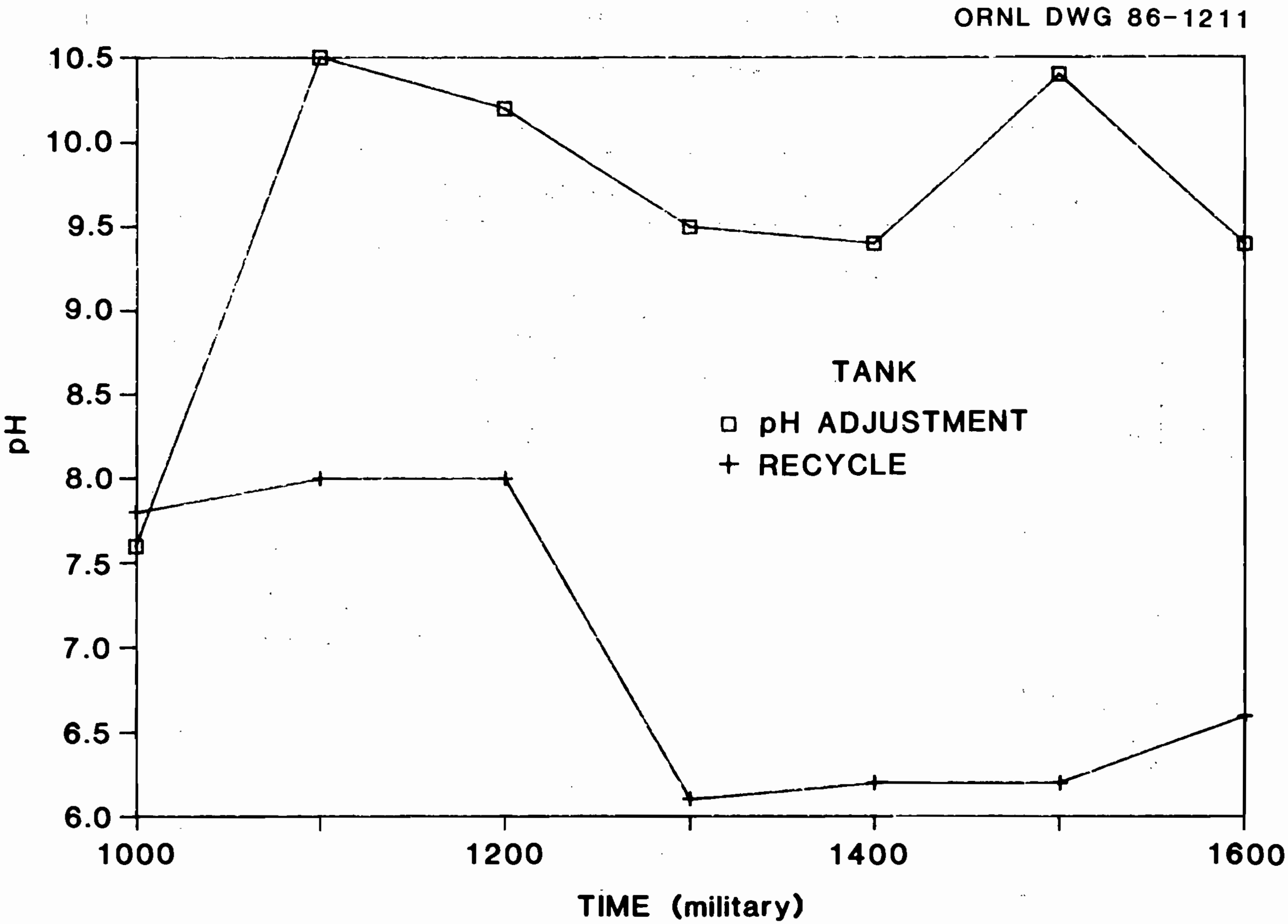

Fig. 7. Operational data for 8/18/86 run.

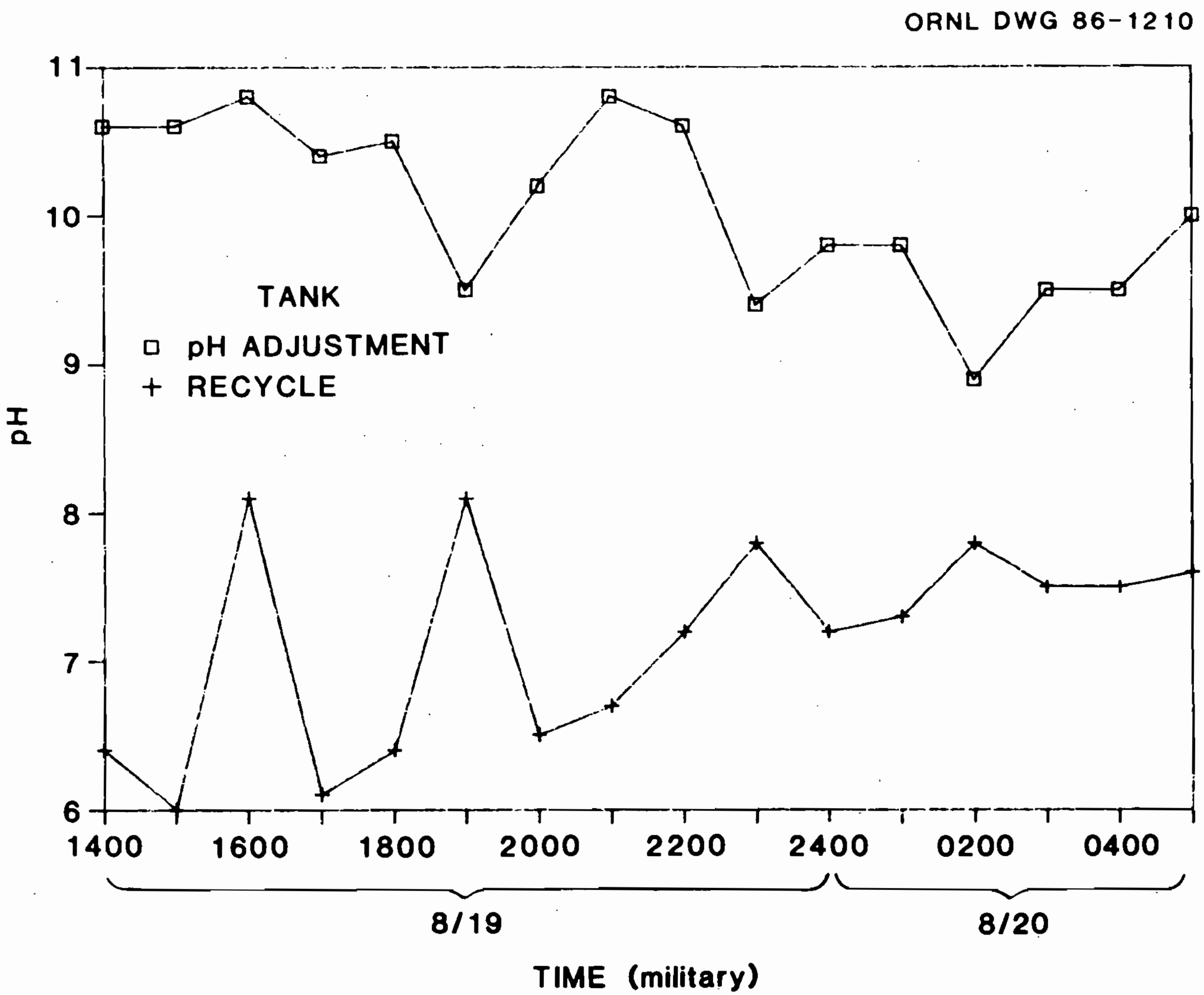

Fig. 8. Operational data for 8/19-20/86 run.

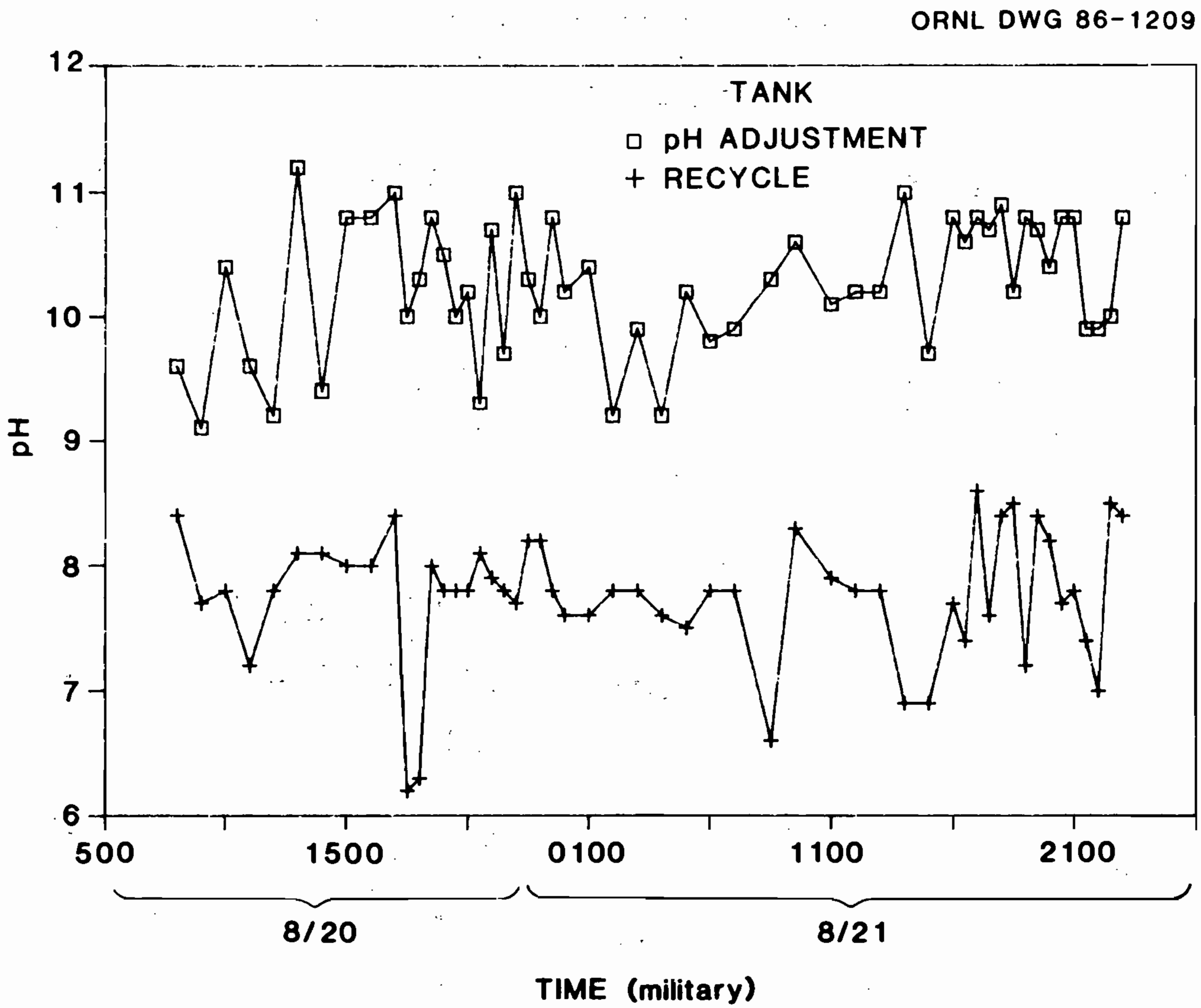

Fig. 9. Operational data for 8/20-21/86 run.

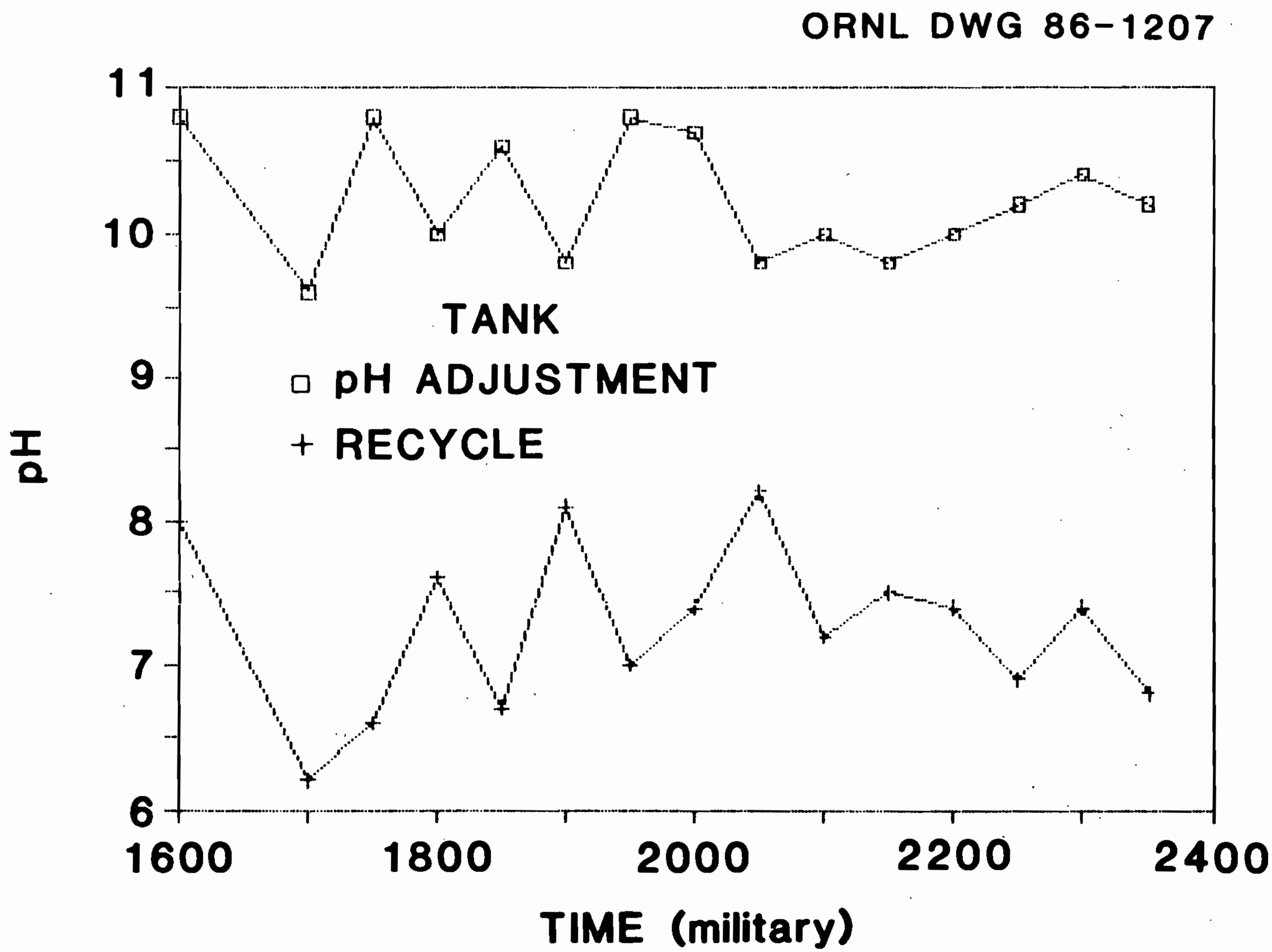

Fig. 10. Operational data for 8/25/86 run.

low pH wastewater leached the iron from the coal particles within the coal basin.

It should also be noted that on five samples taken during the monitoring program the concentration of iron in the filtered sample was higher than the unfiltered sample. The iron may have been introduced while removing the filter with the metal tweezers.

The problem with iron violating the NPDES permit limit occurred when treating pure coal yard runoff and when treating pure steam plant waste. When treating mixtures of the two, the iron in most instances was below 1 mg/L. Also, in most instances, the filtered samples were less than 1 mg/L even when the unfiltered sample was above 1 mg/L. This implies that the iron is precipitating but the solid/liquid separation is not taking place. This could be due to the clarifier not working properly, the solids not coagulating adequately, or possibly some other unidentified mechanism.

From discussions with A. V. Jones, the CYRTF supervisor, it was learned that the operators are having operational problems with the clarifier. The bridge which sweeps across the clarifier to promote flocculation has not been operating properly. This bridge is designed to operate automatically; however, during the monitoring period the plant operators had to trigger the change of direction manually. Also, the optical sensor which monitors the level of solids building up in the clarifier was operating erratically, and rust was being introduced into the treated wastewater from the interior surfaces of the clarifier and recycle tank because these surfaces have not been painted. This rust may be contributing to the concentration of iron in the effluent wastewater samples. Since a comparison of the filtered and unfiltered samples from the recycle tank and the effluent weir shows that most of the iron present is in a colloidal form, it is possible that after the operational problems with the clarifier are solved, the colloidal iron might settle out.

In other discussions with A. V. Jones, it was learned that the facility can only be operated at a maximum of 105 gal/min because an under-sized valve is restricting the gravity flow of water from the recycle tank to the effluent basin. While diverting wastewater from the steam plant to the CYRTF, the operators had a difficult time treating the load from both the CYR and the steam plant wastewater. This problem will have to be remedied before the steam plant wastewater can be permanently diverted to the CYRTF.

Two solids samples from the rotary drum vacuum filter were analyzed for moisture content, and one of these was analyzed for EP toxicity. The first solid sample, obtained on 7/28/86, contained 64.5% moisture. The second solids sample was obtained on 8/26/86 and contained 74.9% moisture. The results of the EP toxicity test can be seen in Table 20. For comparison, the concentration of each component considered EP toxic is also presented. As can be seen, each component is present in a concentration less than that considered to be EP toxic.

6. SUMMARY

Representative samples of the major effluent streams to be treated at the ORNL CYRTF were collected and characterized. These samples were mixed, and the various combinations that the CYRTF could be expected to treat were examined. It was found that the various mixing events contained concentrations of zinc, copper, and iron that were in violation of the NPDES discharge limits set for the CYRTF. Upon mixing, the various composite streams had pH values that ranged from 1.9 to 2.5, and none of the mixing event-formulations promoted solids precipitation.

Reactor/clarifier jar tests were run on the various mixing-event formulations, and the concentrations of regulated components in the clarified liquid, as well as the settling characteristics of the sludge, were followed. These tests indicate that coagulation with calcium hydroxide at a pH of 9 would reduce the concentration of all regulated components, except possibly iron, to concentrations less than those listed in the NPDES discharge limits. It was also determined that concentrations of several components, notably zinc and manganese, seemed to be greatly reduced as the coagulation pH was raised from 10 to 11. At a pH of 10 to 11, the sludge settled faster and seemed to sweep out additional metal hydroxides. Two polymers (Magnifloc 6220 and Betz 1100) were tested, in conjunction with calcium hydroxide precipitation, to promote sludge settling. Both polymers improved the settling

Table 20. Results of the EP toxicity test for the sludge obtained from the rotary vacuum filter on 8/26/86

Component	Concentration (mg/L)	Concentration considered EP toxic (mg/L)
As	<0.10	5
Ba	0.30	100
Cd	<0.0050	1
Cr	<0.040	5
Pb	<0.20	5
Se	<0.20	1
Ag	<0.050	5
Hg	<0.0001	0.2

characteristics of the sludge; however, there was not a noticeable difference in the performance between the two polymers.

The sludges produced were tested for dewatering by vacuum filtration. The results indicate that there should be no problem in dewatering the sludge from the various mixing events using vacuum filtration.

Solid samples from the rotary drum vacuum filter contained from ~65 to 75% moisture, and the results of the EP toxicity test show that all the elements regulated in the EP toxicity test were present in concentrations below the level considered EP toxic.

Wastewater from the steam plant was diverted to the CYR collection basin, and the CYRTF was monitored during six operational periods on different wastewaters. The results show that all regulated components, except iron, were present at concentrations less than those listed in the NPDES permit. On several occasions, the concentration of iron was slightly higher than the discharge limit. However, this may have been due to the operational problems occurring with the system clarifier.

Although a concentration of iron slightly higher than the NPDES permit limit was observed several times while monitoring the CYRTF, the study indicates the CYRTF can be utilized to treat the diverted wastewaters from the steam plant. While operating on CYR alone, ~67% of the unfiltered effluent samples violated the NPDES permit level for iron. When treating a mixture of CYR and diverted wastewater, or diverted wastewater alone, 31% of the unfiltered effluent samples violated the limit for iron. This indicates there may be some advantage to adding the diverted wastewater to the CYR wastewater stream. Since analyses indicated that the iron from those samples which violated the NPDES permit limit had been precipitated but not completely removed by the settling operation, it is probable that the operational problems occuring with the clarifier contributed to the iron violations.

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