Laboratory Experiments on the Mixture of Alkaline Solids with Sulfide Bearing Rock

Minnesota Department of Natural Resources
Division of Minerals
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0. Executive summary

Rotary kiln fines (a waste generated during the conversion of limestone to lime), -10 mesh limestone, and -0.25-inch/+10 mesh limestone were each mixed with Duluth Complex rock to examine their effectiveness in reducing the release of acid and trace metals with drainage from the rock. Five different loadings of each solid (0.79, 1.58, 3.15, 4.72, and 7.88 g) were mixed with 75 g of the rock, which contained 2.1 percent sulfur (1.58 g sulfur). This yielded ratios of alkaline solids:sulfur present in the rock of 0.5:1, 1:1, 2:1, 3:1, and 5:1. Two control reactors, containing 75 g of rock only, were also leached to provide a measure of treatment effectiveness. The samples have been rinsed weekly for 80 weeks.

The drainage pH from the control reactors was below 6 after 8 weeks and reached pH 3.7 after 70 weeks. Except for the 0.5:1 loading of rotary kiln (RK) fines, all of the RK fines and -10 mesh limestone treatments produced drainage with a pH above 7. The drainage pH from the 0.5:1 RK fines reactor remained below 6.0 after week 75. Concentrations of nickel, cobalt, and zinc from this reactor reached maximums after pH dropped below 7.0, and copper concentrations increased continually as pH decreased. All other loadings of these solids neutralized the acid produced as a result of oxidation of iron sulfides present in the rock. Typical drainage pH values for these solids ranged from 8.0 to 9.2, with net alkalinities from 10 to 30 mg/L. These treatments also reduced the rate of sulfide oxidation by approximately 70 to 85 percent, as indicated by comparison of sulfate concentrations with those from controls. The treatments reduced trace metal concentrations by 80 to 99 percent in comparison with the controls, and iron concentrations were reduced by more than 99 percent. Field tests are required to determine if a similarly high level of treatment could be obtained under operational conditions.

The -0.25-inch/+10 mesh limestone treatment produced acidic drainage with trace metal and iron concentrations similar to those in drainage from the controls. These reactors were discontinued after 40 weeks. The experiment will continue to examine the duration of effective treatment for the rotary kiln fines and the -10 mesh limestone.

1. Introduction

Acid release from stockpiled gabbro may be decreased by mixing alkaline solids, such as limestone, with the stockpiled rock. The alkaline solids neutralize acid produced by the oxidation of sulfide minerals. This neutralization has two secondary effects. First, as pH increases the equilibrium concentrations of trace metals decrease. The decrease in concentrations is due to increased trace metal precipitation (as oxides, hydroxides, and/or carbonates) and adsorption. Secondly, the elevated pH yields an environment which is unsuitable for Thiobacillus ferrooxidans, a strain of bacteria which catalyzes sulfide mineral oxidation. The elimination of these bacteria limits the rate of oxidation and, therefore, the rate of sulfide oxidation. It must be noted, however, that at low applications of alkaline solids an increase in the rate of sulfide oxidation has been reported (Burt and Caruccio, 1986), indicating that the dosage of alkaline solids is of importance.

The limestone requirement can be estimated based on theory or on empirical evidence. The theoretical alkalinity requirement can be calculated assuming that each mole of sulfur produces two moles of acid while each mole of calcium carbonate consumes two moles. If no other solids consume acid, the limestone required would be 3.12 times the sulfur content $(40.1 + 12.0 + 3 \times 16)/32.1 = 3.12)$.

The estimation of the limestone requirement can be refined by accounting for the buffering capacity of the host rock and the fact that some sulfur is bound in minerals which do not produce acid. Earlier experiments on the dissolution of Duluth Complex solids indicated that the silicate mineral buffering capacity was overcome when the sulfur content exceeded 0.9 percent (Lapakko, 1988). Furthermore, the actual acid producing sulfur content is only about 0.8 times the total sulfur content, since only about 80 percent of the sulfur is associated with iron. Assuming that the silicate minerals can buffer the acid produced by a sulfur content of 0.9 percent and that 80 percent of the sulfur

is associated with acid producing minerals, the estimate of the theoretical limestone requirement can be refined as follows:

$L = 3.12[0.8(P - 0.9)] = 2.5P - 2.25$, where
L = the limestone requirement (percent of gabbro mass) and
P = the sulfur content of the gabbro (percent of gabbro mass).

For a sulfur content of 2 percent the limestone requirement would be:

$L = 3.12[0.8(2 - 0.9)] = 5.0 - 2.25 = 2.75\%$

Empirical evidence on the limestone required also exists. O'Hagan (1986) found that 5 percent $CaCO_3$ was required to neutralize drainage from coal waste with a 1 percent pyritic sulfur content, while others found that coal seams containing 2 percent $CaCO_3$ produced neutral drainage (see references in O'Hagan, 1986). Earlier experiments on the dissolution of Duluth Complex solids indicated that a limestone/sulfur ratio of 2.6 would be adequate to produce neutral drainage (Lapakko, 1988).

2. Objectives

The objective of this experiment is to examine the influence of five different dosages (or loadings) of rotary kiln (RK) fines, -10 mesh limestone, and +10 mesh/-0.25-inch limestone on the drainage from waste rock containing sulfide minerals. In particular, examine the influence of solid and dosage on

1. pH, alkalinity, and acidity of the drainage,
2. trace metal concentrations in the drainage,
3. the rate of alkalinity release with the drainage,
4. the rate of trace metal release with the drainage, and
5. the rate of sulfide oxidation as indicated by the release of sulfate with the drainage.

This report presents the results from May 17, 1988 through November 29, 1989, the first 80 weeks of the experiment.

3. Methods

3.1. Materials

The solids selected for examination were:

1) -0.25-inch/+10 mesh high calcium limestone,
2) -10 mesh high calcium limestone, and
3) rotary kiln fines, a waste product generated when limestone is converted to lime.

The limestone was obtained from the Presque Isle Company and the rotary kiln fines from Cutler-Magner Company in Duluth. Chemical and particle size analyses of these solids are presented in table 1. The gabbro used was from the Duluth Complex in northeastern Minnesota (drill core sample 355-1338) and contained 2.1 percent sulfur. The copper, nickel, cobalt, and zinc contents were 0.17, 0.053, 0.007, and 0.069 percent, respectively.

3.2. Procedure

The information presented in the introduction suggested that the ratio of limestone to sulfur examined span the range of 2 to 5. For added information, two ratios below this range were examined. The alkaline solid/sulfur ratios used were 0, 0.5, 1, 2, 3, and 5, with duplicates run at the ratios of 0, 1, and 3 (table 2). In order to thoroughly blend the alkaline solids with the gabbro (75 g), the alkaline solids/gabbro mixtures were passed through a sample splitter 10 times.

The alkaline solids/gabbro mixtures were subjected to oxidation in the presence of atmospheric oxygen and water vapor. The mixtures were placed onto a 1.6 micron Whatman GF/A glass fiber filter (5.5 cm diameter) which covered a plastic plate in the upper section of a two-stage filter unit or reactor (figure 1). The reactors and solids were stored in a box to dry and oxidize.

A cover was placed about 5 cm above the upper edge of the box to allow drying of the solids and prohibit the input of airborn debris. A thermostatically controlled heating pad was placed beneath the box to maintain a constant temperature. Water containers were placed in the box in an attempt to maintain a fairly constant humidity. Temperature and relative humidity in the box were monitored four to five times per week. The temperature ranged from 23 to 32 ^{o}C, with a mean of 26.7 ^{o}C and a standard deviation of 1.55 ^{o}C. The relative humidity ranged from 18 to 83 percent, with a mean of 56.1 and a standard deviation of 10.6.

The solids were rinsed weekly with 200-mL volumes of distilled deionized water. The 200 mL of rinse water was added to the upper section. After the water rose into the standpipe, it was drawn through the solids, glass fiber filter, plastic plate, a 0.45 micron Millipore filter, and into a receiving flask under a vacuum of 4 inches (10.2 cm) mercury.

The rinse water, or drainage, was analyzed for specific conductance, pH, alkalinity, acidity, copper, nickel, cobalt, zinc, iron, calcium, and sulfate. The volume of rinse water, specific conductance, pH, alkalinity, and/or acidity were determined weekly, and sulfate was analyzed biweekly. Trace metals (Cu, Ni, Co, Zn), Fe, Ca, and Mg were analyzed biweekly for the first 20 weeks and monthly subsequently.

Specific conductance was analyzed using a Myron L conductivity meter, while either a Radiometer 29 or an Orion SA 720 meter was used for pH analyses. Alkalinity and acidity were analyzed using standard techniques for endpoints of 4.5 and 8.3, respectively (APHA et al., 1975). Metals were analyzed with a Perkin Elmer 603 atomic absorption spectrophotometer. Sulfate was analyzed using the barium sulfate turbidimetric technique (APHA et al., 1975).

4. Results and discussion

4.1. Controls

This report presents the results from May 17, 1988 through November 29, 1989, the first 80 weeks of the experiment. The two controls initially generated drainage which was near neutral, with pH in the range of 6.2 to 6.8 during the first five weeks. Over about the next 15 weeks the pH decreased steadily, dropping below pH 6 by week 8 and to pH 4 by about week 20. After week 20 the values decreased very gradually, leveling near pH 3.7 at about week 70 (Figure 2).

Similarly, the net alkalinity (alkalinity - acidity) was initially above zero. After week 6 the values decreased steadily to approximately -80 mg/L at week 20. Unlike pH after week 20, the net alkalinity oscillated quasi-sinusoidally. Values increased to about -31 mg/L just after week 40, decreased to an average of -200 mg/L at week 60, and increased to about -60 mg/L at week 80 (Figure 2). The average net alkalinity was about -70 mg/L.

The pH and net alkalinity were strongly influenced by the oxidation rate of iron sulfide minerals, for which sulfate concentration is an indicator. The oxidation of the iron sulfide minerals leads to the production of acid. Thus, elevated sulfate concentrations indicate an elevated rate of acid production. Over the first six weeks (when the drainage was circumneutral) the sulfate concentrations decreased from about 50 to 15 mg/L, apparently due to the removal of sulfate present on the sample at the beginning of the experiment.

Sulfate concentrations from the controls then increased through about week 24, concurrent with the decrease in pH and net alkalinity, and oscillated through the remainder of the experiment. The oscillation was of the same wave length as that for net alkalinity but was in the the opposite direction. The maximum sulfate concentration was observed after 62 weeks, approximately the same time as minimum alkalinity occurred (Figure 2). The average sulfate concentration, representing the average sulfide oxidation rate, over the first 80 weeks was about 58 mg/L.

The rate of dissolution of acid consuming mineral dissolution reactions (buffering) is reflected by calcium and magnesium concentrations. Calcium concentration decreased through week 12 and then plateaued at 2 to 4 mg/L until week 40. This suggests the removal of solid phase calcium readily available for acid neutralization, for example, calcium carbonate. Values then increased to a maximum of about 8 mg/L at week 60 and decreased through week 80 (Figure 3). The average calcium concentration was 6.7 mg/L.

In contrast, magnesium concentrations decreased over the first 5 weeks then increased to about 5 mg/L at week 20. At this time the molar concentration of magnesium was almost twice that of calcium, indicating that dissolution of magnesium-containing minerals was providing the majority of buffering at this time. This period of preferential magnesium release may have been from magnesium carbonate minerals present in the rock. Concentrations decreased to about 1 mg/L at week 30 and subsequently followed the same temporal trend as calcium, peaking at week 60 and subsequently decreasing (Figure 3). During this period, both metals were apparently released from silicate minerals. The average magnesium concentration was 2.4 mg/L.

Concentrations of trace metals and iron were higher after the drainage became acidic. Maximum concentrations of copper (0.3 mg/L), nickel (2.1 mg/L), cobalt (0.27 mg/L), zinc (2.2 mg/L) were observed during weeks 8 and 10, shortly after the drainage became acidic. They subsequently decreased and were fairly stable after week 20 (Figures 4, 5). Iron concentrations increased fairly steadily through week 25, reaching about 27 mg/L. Values then fluctuated erratically, typically between 18 and 28 mg/L, with a maximum of about 42 mg/L at week 54. Mean concentrations of copper. nickel, cobalt, zinc, and iron were 0.074, 0.65, 0.072, 0.31, and 12 mg/L, respectively.

4.2. Rotary kiln fines

The 75 grams of 2.1 percent sulfur rock contained about 1.58 g of sulfur. The ratio of rotary kiln (RK) fines to sulfur present in the rock for the various treatments were 0.5:1 (0.79 g), 1:1 (1.58 g), 3:1 (4.72 g), and 5:1 (7.88 g). Throughout the first 45 weeks the drainage pH values from these reactors typically ranged from 8.0 to 9.4 (Figure 6). The pH of the drainage from the 0.5:1 mixture dropped below 8 at week 45 and remained below pH 6 after week 75. At ratios exceeding 0.5:1, the rotary kiln (RK) fines have continued to neutralize the acid produced by the oxidation of iron sulfide minerals.

For the 0.5:1 loading the mass of calcium carbonate dissolved was calculated by two methods. First it was assumed that the carbonate released was either consumed during acid neutralization or remained in solution as excess alkalinity. The total H^+ released was assumed to be twice the sulfate release, a slight overestimate since some of the sulfate was probably contributed by the oxidation of copper and nickel sulfides, which does not produce acid. The molar calcium carbonate dissolution was calculated as the molar sum of the sulfate (4 millimoles) and alkalinity release (2 millimoles). The second calculation used calcium release to represent the calcium carbonate dissolution in a similar manner. The estimated masses of calcium carbonate dissolved based on these calculations were 0.600 and 0.680 g, respectively, as compared with the actual 0.79 g of RK fines added.

It is likely that buffering minerals, such as calcium carbonate or calcium oxide, comprised less than 100% of the RK fines mass. Based on the calcium content of the RK fines, about 0.50 g of $CaCO_3$ were present in the 0.79 g of RK fines (Table 1). This suggests that the dissolution of calcium carbonate present in the RK fines supplied about 0.5 g of $CaCO_3$ and while dissolution of the rock supplied the remaining 0.10 to 0.18 g of calcium mineral buffering. The calcium released from the controls over the first 75 weeks was equivalent to the dissolution of slightly more than 0.2 g of calcium carbonate, indicating that a contribution of 0.10 to 0.18 g of calcium mineral buffering from the rock is reasonable. Calcium release from the rock in the RK fine/rock mixture would be lower than that from the controls, due to the higher pH.

Prior to week 40 the net alkalinities from the lowest RK fine loading were typically in the range 5 to 20 mg/L, but these values decreased as pH decreased. The net alkalinity increased with the mass of RK fines and an average value of 31 mg/L was observed for the 5:1 ratio (Figure 7). The elevated pH and net alkalinity indicate an excess of neutralization capacity for the RK fines at ratios above 0.5:1.

The actual initial sulfide oxidation rate for the rock mixed with the RK fines was probably lower than that indicated by the sulfate concentrations, since the RK fines apparently released some of the sulfate. This is suggested by the fact that sulfate concentrations decreased over time and the initial sulfate concentrations increased as the mass of RK fines increased (see Appendix 1). To compensate for this, mean sulfate concentrations were calculated for time greater than 15 weeks. During this period the mean sulfate concentrations from the treated reactors ranged from 12 to 22 mg/L, as compared to 68 mg/L for the controls. This indicates that the treatments decreased the rate of sulfide oxidation by 68 to 82 percent. Sulfate concentrations for the 0.5:1 ratio reactor increased as pH from the reactor decreased, then returned to the range observed initially (Figure 8).

Calcium and magnesium release was also elevated at the beginning of the experiment, and averages after week 15 are used for the comparison. The average calcium concentrations after week 15 for the treated reactors ranged from 13 to 21 mg/L, increasing with the loading of RK fines. These values were considerably higher than the 4.6 mg/L average observed for the controls, suggesting that the pH elevation was due to dissolution of calcium carbonate and/or calcium oxide present in the RK fines. This hypothesis is further supported by the drainage quality of the 0.5:1 ratio reactor. As the pH decreased below 7, the calcium concentrations decreased (Figure 9). Both decreases are consistent with the depletion of the calcium carbonate and/or calcium oxide available for buffering. The average magnesium concentrations of 2.0 to 2.2 were slightly lower than the 2.6 mg/L average for the controls.

In addition to inhibiting sulfide oxidation, the pH elevation by ratios greater than or equal to 1:1 reduced average trace metal concentrations by 82 to 97 percent (Figures 10, 11, 12, 13). For the 0.5:1 ratio the maximum concentrations of nickel (0.57 mg/L), Co (0.13 mg/L), and Zn (0.31 mg/L) were observed at t = 54 weeks, after the drainage pH dropped below 7.0. Copper concentrations increased continually, in response to the continually decreasing pH (Figure 14). The mixture of RK fines reduced iron concentrations by 99 to 99.9 percent, with most treated values reported as less than 0.10 mg/L (Table 3).

4.3. -10 mesh limestone

The -10 mesh limestone also increased pH and alkalinity, and none of these reactors exhibited a pH below 6.3. The typical drainage pH range for the lowest loading was 6.8 to 8.1, while the remaining solids typically produced values of 8.0 to 9.0. Drainage pH increased with loading and decreased over time (Figure 15). The average net alkalinity for weeks 16 to 80 was 7 mg/L for the lowest loading, and increased to 19 mg/L at the highest limestone loading (Figure 16). These values were slightly lower than the associated values for the RK fines (Table 3). The elevated pH and net alkalinity indicate an excess acid neutralizing capacity for the first 80 weeks of dissolution.

For weeks 16 through 80 the average sulfate concentrations from the limestone treatments ranged from 13 to 19 mg/L, or 16 to 28 percent of the average for the controls. The observed range was slightly lower than that for the RK fines. This indicates that the -10 mesh limestone reduced the rate of sulfide oxidation by 72 to 84 percent. The inhibition is most likely the result of inhibited growth of and catalysis by Thiobacillus ferrooxidans, due to the pH elevation by dissolution of the alkaline solids. Since the sulfate concentrations have decreased over time (Figure 17), the extent of sulfide oxidation inhibition may even exceed 84 percent. Future data will permit more accurate quantification of the extent to which oxidation is inhibited.

Calcium concentrations for weeks 16 to 80 averaged 11 to 19 mg/L for the -10 mesh limestone reactors. These values were slightly lower than those observed for the RK fines, but considerably higher than the 4.6 mg/L average for the controls. This indicates dissolution of limestone was responsible for the neutralization of acid produced by the oxidation of iron sulfides present in the rock. Magnesium concentrations averaged 2.1 mg/L over this period, slightly lower than the values observed for the RK fines and controls (Table 3).

As with the RK fines, the pH elevation reduced trace metal concentrations in the drainage. The inhibited sulfide oxidation also contributed to this reduction, but to a much lesser extent. For weeks 16 to 80, the average concentrations of Cu, Ni, Co, and Zn were 88 to 99 percent lower than the corresponding averages for the controls (Figures 18 - 21). Iron concentrations were 99 percent lower than the control concentrations, with almost all values reported as less than 0.1 mg/L.

4.4. -1/4inch/+10 mesh limestone

The -1/4 inch/+10 mesh limestone was only minimally effective at acid neutralization and reduction of trace metal release. The drainage pH decreased over time, reaching values from 3.75 to 4.05 at week 40. In comparison, the pH values for drainage from the controls were 3.9 and 4.0 (Figure 22). Net alkalinities at week 40 ranged from about -20 to -60 mg/L, as compared with about -35 mg/L for the controls. These comparisons indicate the ineffectiveness of the larger limestone particles in buffering the acid produced by iron sulfide oxidation. Due to the ineffectiveness of this treatment the reactors were terminated at this time. Upon termination iron staining was clearly visible on virtually all of the limestone surface.

For weeks 16 to 40 the average sulfate concentrations typically ranged from 27 to 47 mg/L, roughly 50 to 90 percent of the 52 mg/L average for the controls. However, the 2:1 ratio reactor drainage averaged 67 mg/L sulfate.

Nonetheless, there was some inhibition of iron sulfide oxidation in most of the reactors. Average calcium concentrations for this period typically ranged from 5 to 7 mg/L, as compared with 4.6 mg/L for the controls. This indicates that the larger limestone was neutralizing some of the acid produced. Magnesium concentrations were slightly greater than of equal to those observed for the controls (Table 3).

With the exception of cobalt, average trace metal concentrations occasionally exceeded the values observed for the controls (Table 3). Copper concentrations were particularly high, with five of the seven averages exceeding the copper averages for the controls. Although the periods over which the control averages were calculated were different, it is clear that the larger limestone particles were of little benefit in reducing trace metal concentrations. The average iron concentrations ranged from 1 to 20 mg/L, indicating that treatment for iron release was also marginal at best.

Table 1. Chemical and screen analysis of Presque Isle limestone and rotary kiln fines.

Chemical Analysis, weight percent

Parameter	Presque Isle limestone	Rotary kiln fines
Fe_2O_3	0.23	2.63[1]
Mn		.03
Al_2O_3	.27	3.71
SiO_2	.75	NA
S	.085	NA
CaO	54.14	35.9
MgO	.99	1.1
R_2O_3	.49	NA
Loss on Ignition (LOI)	43.63	26.33
Equivalent $CaCO_3$	96.68	NA
Equivalent $MgCO_3$	2.08	NA

Screen Analysis

Size	% Passing by weight	
3/4 inch	99.9	100
5/8 inch	99.5	100
1/2 inch	95.7	100
3/8 inch	66.2	100
4 mesh	8.9	100
20 mesh	NA	99.97
200 mesh	NA	96.74

[1]Reported as 1.84 percent Fe

Table 2. Experimental ratios.

Ratio	-0.25-in/+10 mesh limestone	-10 mesh limestone	Rotary kiln fines
0	one pair of controls will serve all three solids		
0.5	X	X	X
1	X,X	X,X	X,X
2	X	X	X
3	X,X	X,X	X,X
5	X	X	X

23 reactors total.

To calculate the alkaline solid mass required:

A = RPG/100, where
A = the mass of alkaline solids required (grams),
R = the appropriate ratio (dimensionless),
P = the percent sulfur in the gabbro, and
G = the mass of gabbro (grams), in this case 75 g.

For example, using a sulfur content of 2.1%, the alkaline solids requirements would be:

A = R(2.1)(75)/100 = R(1.575).

R	A, g
0.5	0.7875
1	1.575
2	3.15
3	4.725
5	7.875

Table 3. Average[1] drainage quality for weeks 16 through 80 (mg/L).

Ratio	pH	SO_4	Ca	Mg	Net Alk.	Cu	Ni	Co	Zn	Fe[4]
					CONTROLS[2]					
0	3.83	63	4.5	2.5	-78	0.059	0.63	0.060	0.12	21
0	3.84	72	4.6	2.8	-88	.068	.63	.066	.14	23
					RK FINES					
0.5	7.35	22	13	2.2	6	.14	.24	.041	.11	0.26
1.0	8.81	21	16	2.1	17	.009	.013	.007	.011	.007
1.0	9.09	14	14	2.0	20	.006	.010	.006	.011	.017
3.0	8.91	12	17	2.2	25	.008	.013	.010	.009	.013
3.0	8.87	16	19	2.2	24	.007	.010	.006	.010	.017
5.0	8.71	17	21	2.2	30	.007	.006	.006	.008	.005
					-10 MESH LIMESTONE					
0.5	7.50	19	12	2.0	7	.014	.018	.006	.016	.004
1.0	8.06	11	11	1.9	11	.010	.022	.011	.007	.50[3]
1.0	7.89	18	14	2.5	11	.008	.011	.005	.008	.012
2.0	8.55	13	15	2.1	16	.007	.009	.009	.007	.013
3.0	8.68	17	18	2.2	18	.007	.035	.009	.010	.022
3.0	8.74	16	15	2.1	15	.007	.006	.008	.010	.016
5.0	8.94	13	15	2.2	19	.005	.015	.007	.007	.020
					-1/4 INCH/+10 MESH LIMESTONE[5]					
0.5	3.86	37	5.0	2.5	-59	.16	.59	.049	.68	14
1.0	4.01	34	4.5	3.2	-39	.15	.43	.048	.23	9.5
1.0	3.98	38	5.6	2.9	-59	.059	.51	.048	.10	13
2.0	3.91	67	10	3.4	-63	.047	.83	.057	.12	20
3.0	3.92	42	7.0	3.3	-48	.077	.40	.039	.11	8.8
3.0	4.18	27	6.0	2.6	-25	.20	.37	.048	.22	3.5
5.0	4.40	22	7.0	2.7	-18	.21	.28	.039	.21	1.4

[1] Values reported as less than the detection limit were set equal to half the detection limit to calculate averages.
[2] Trace metal concentrations decreased sharply after week 12.
[3] Anomalous value of 5.9 mg/L reported.
[4] Most iron concentrations in drainage from RK fines and -10 mesh limestone reported as less than 0.10 mg/L when analyzed by flame AA. The averages are more representative of the values determined by furnace AA.
[5] -1/4 inch/+10 mesh reactors were terminated after 40 weeks

L: less than

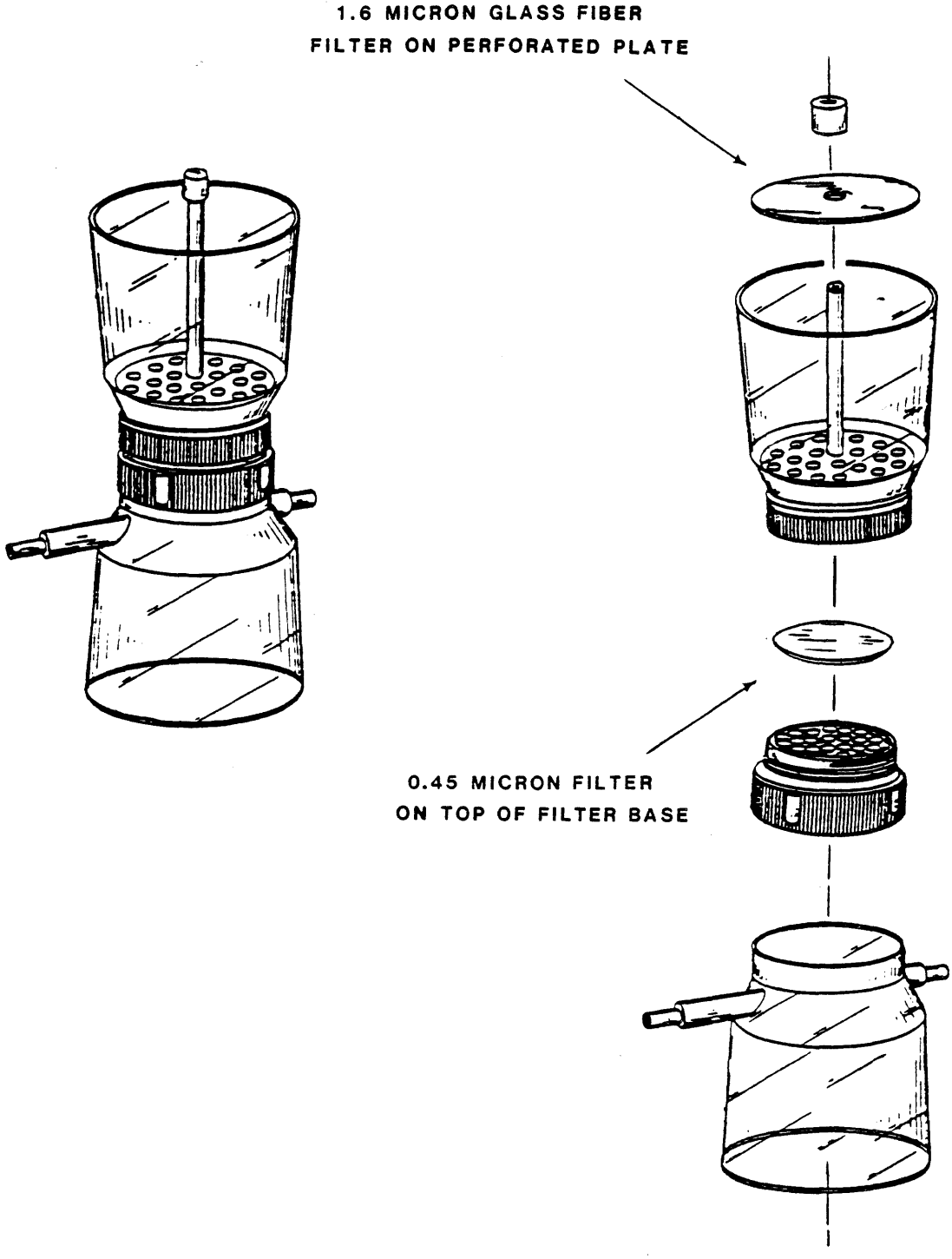


Figure 1. Reactor design.

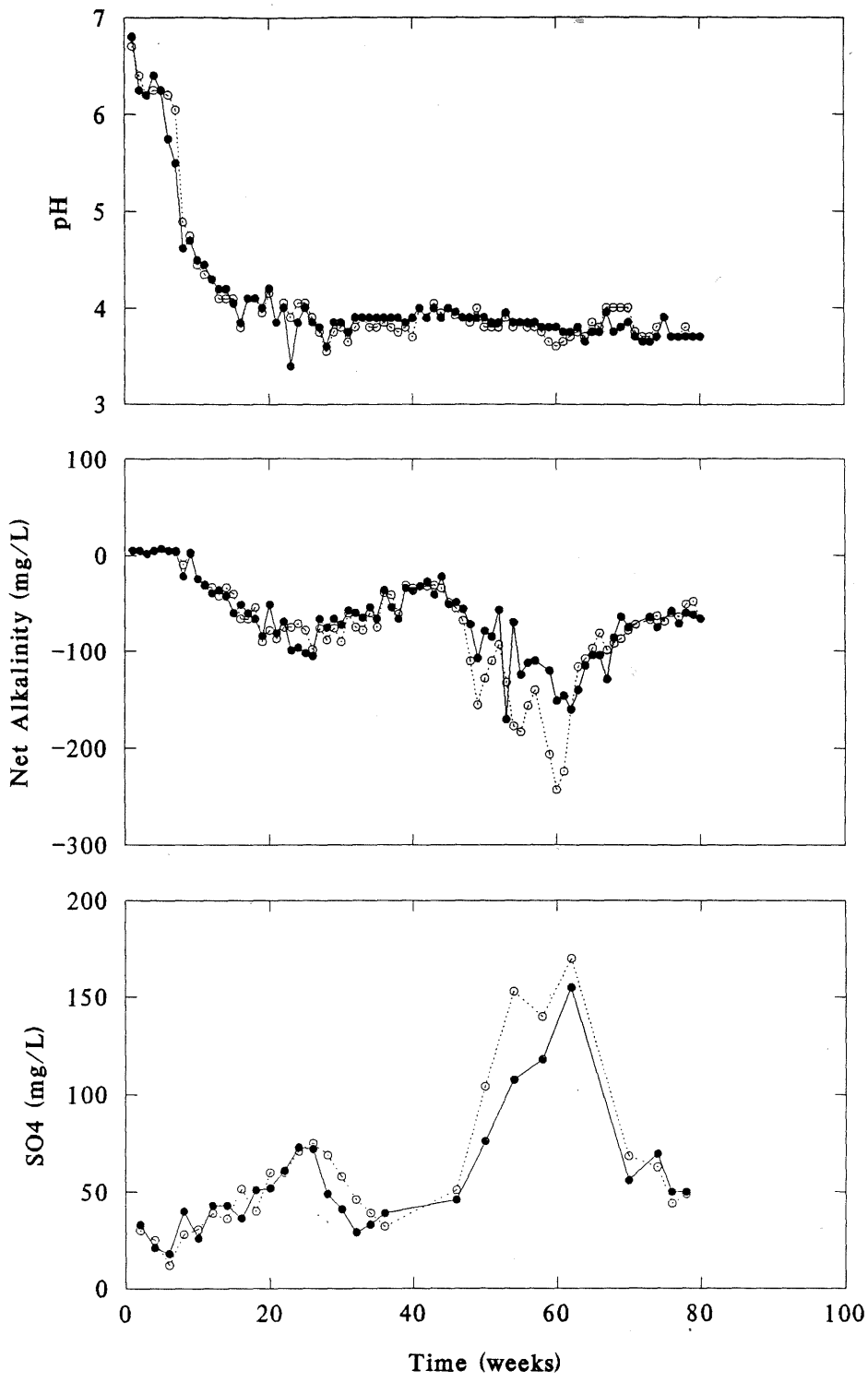


Figure 2. pH, net alkalinity and sulfate vs time for controls.

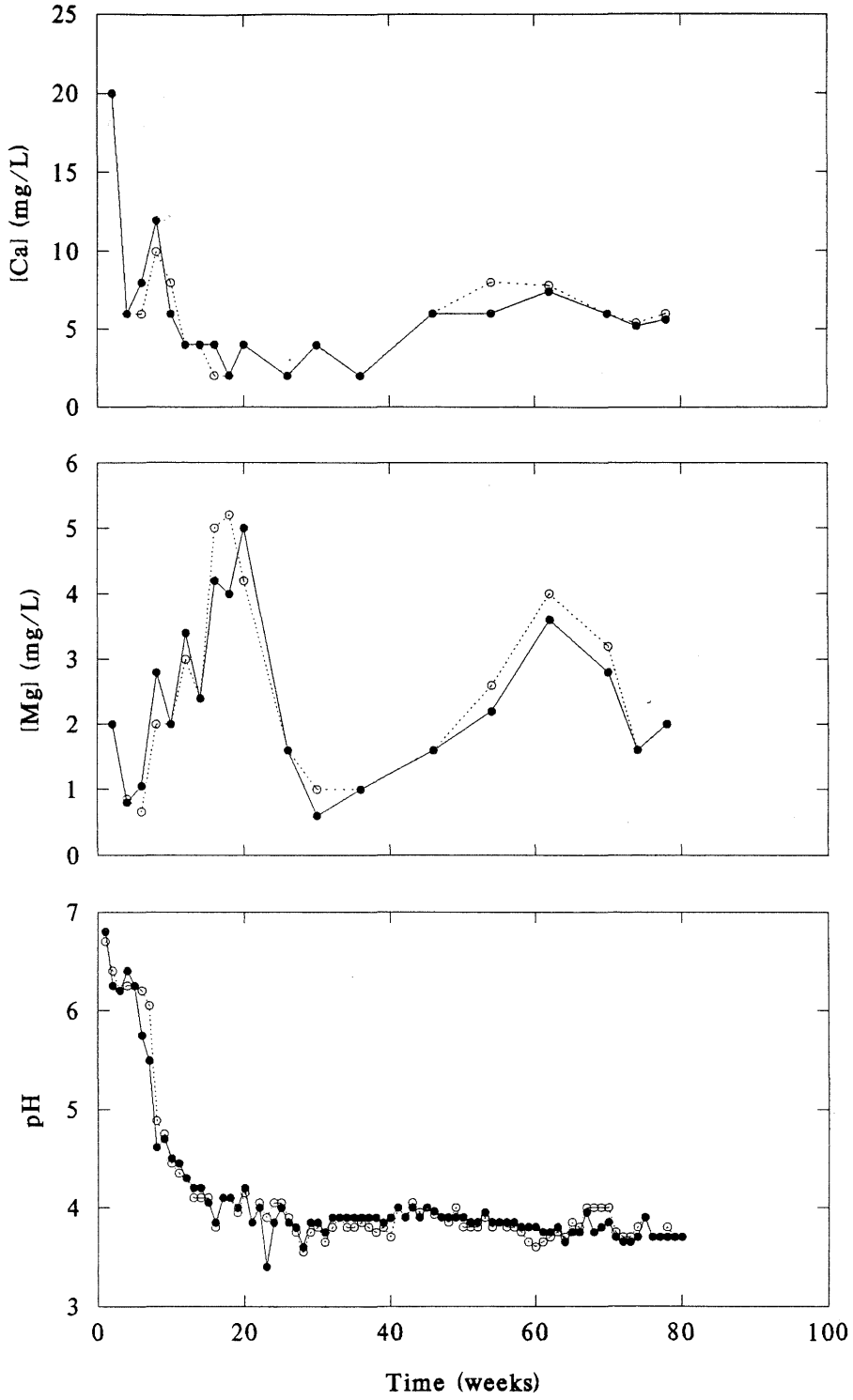


Figure 3. Calcium, magnesium and pH vs time for controls.

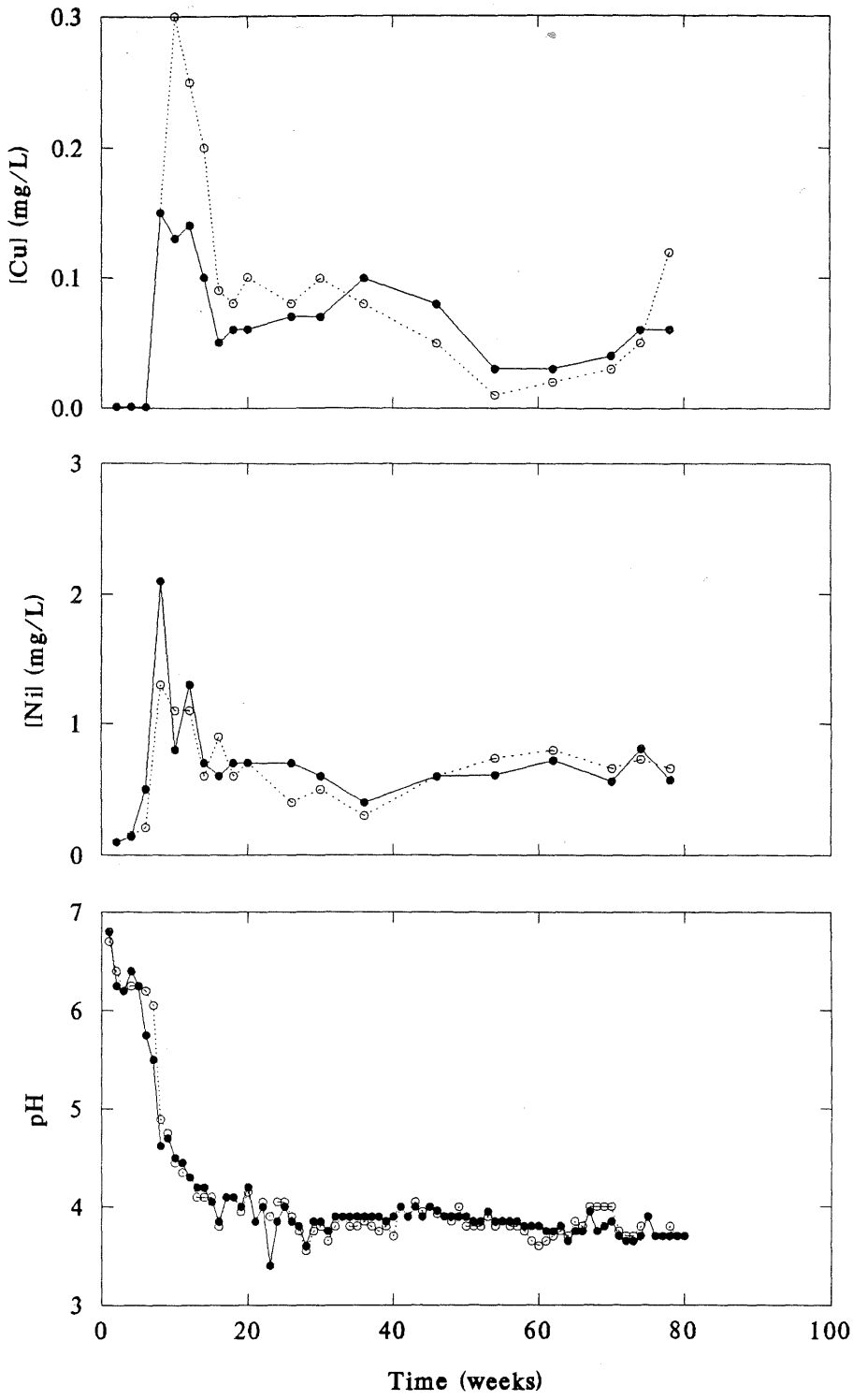


Figure 4. Copper, nickel and pH vs time for controls.

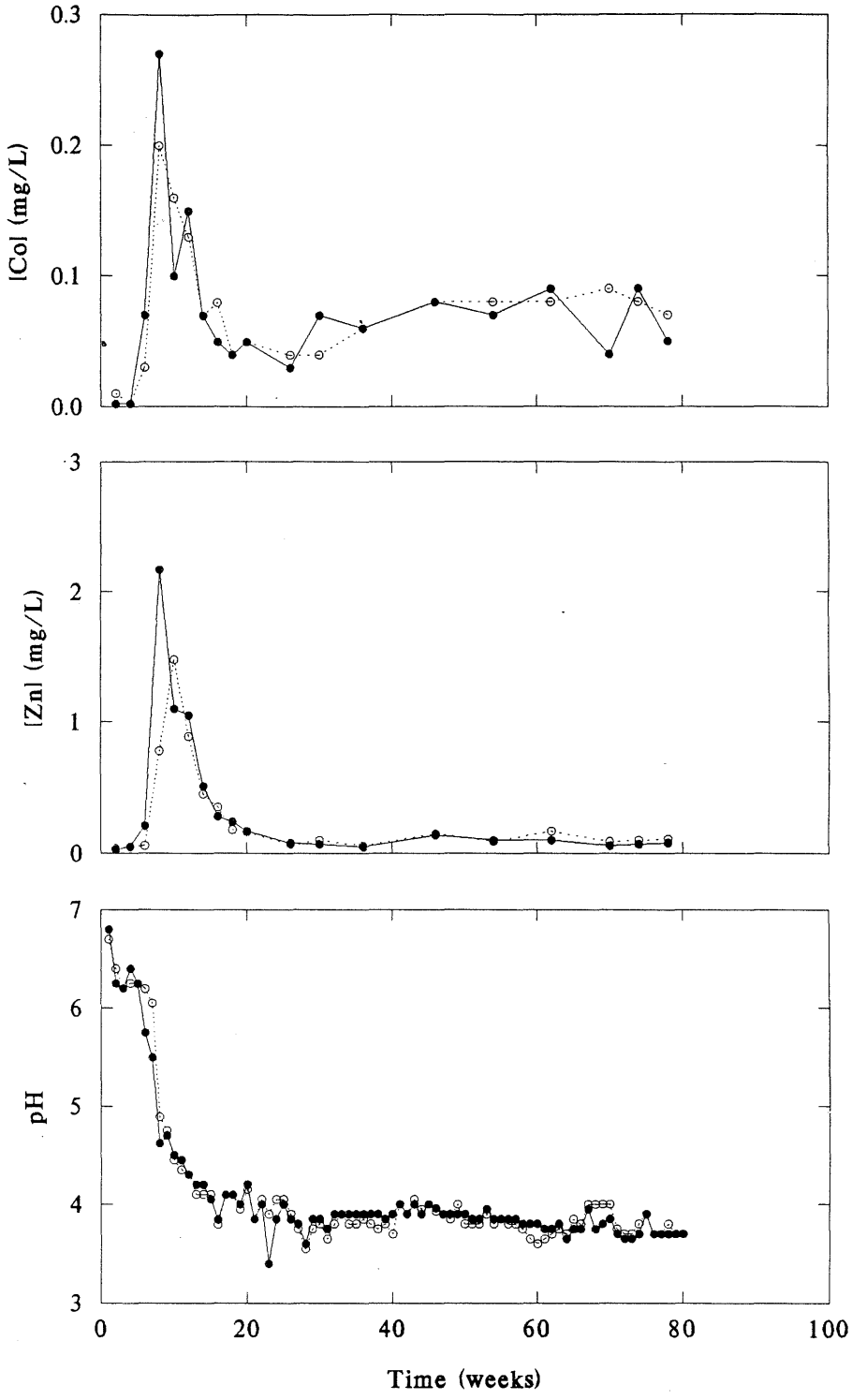


Figure 5. Cobalt, zinc and pH vs time for controls.

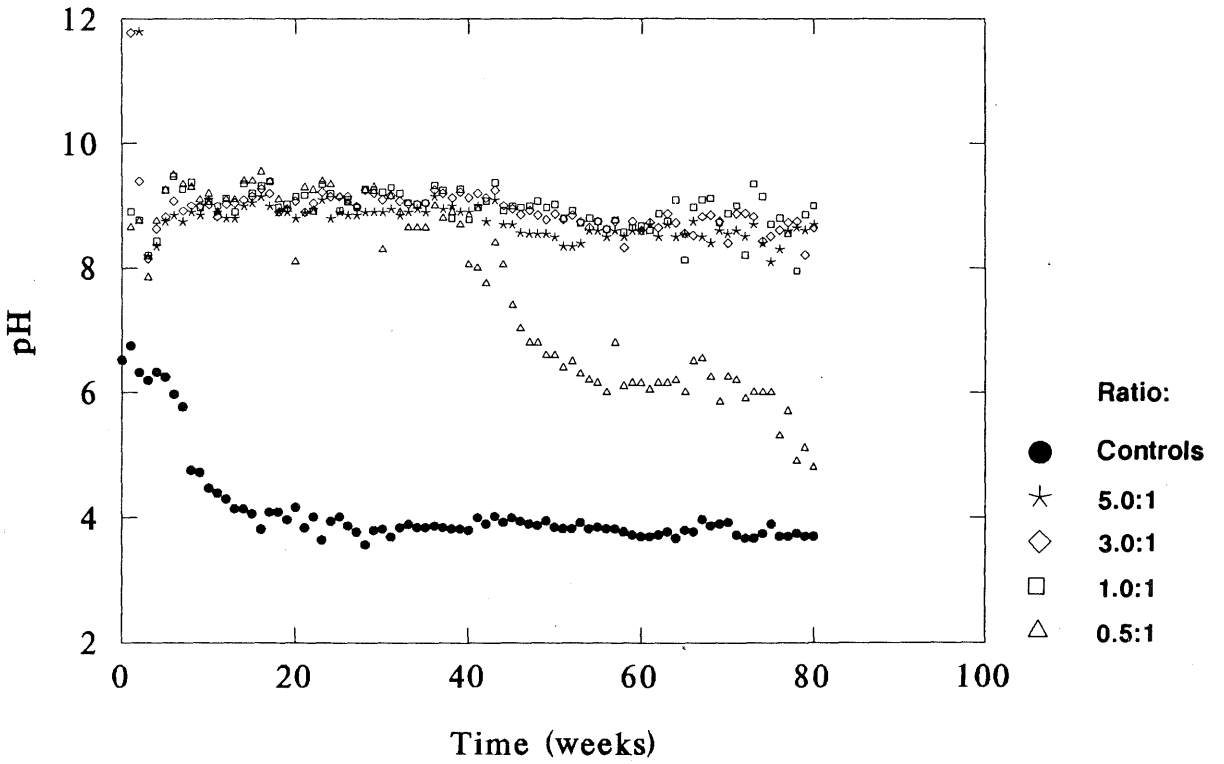


Figure 6. pH vs time for RK fines.

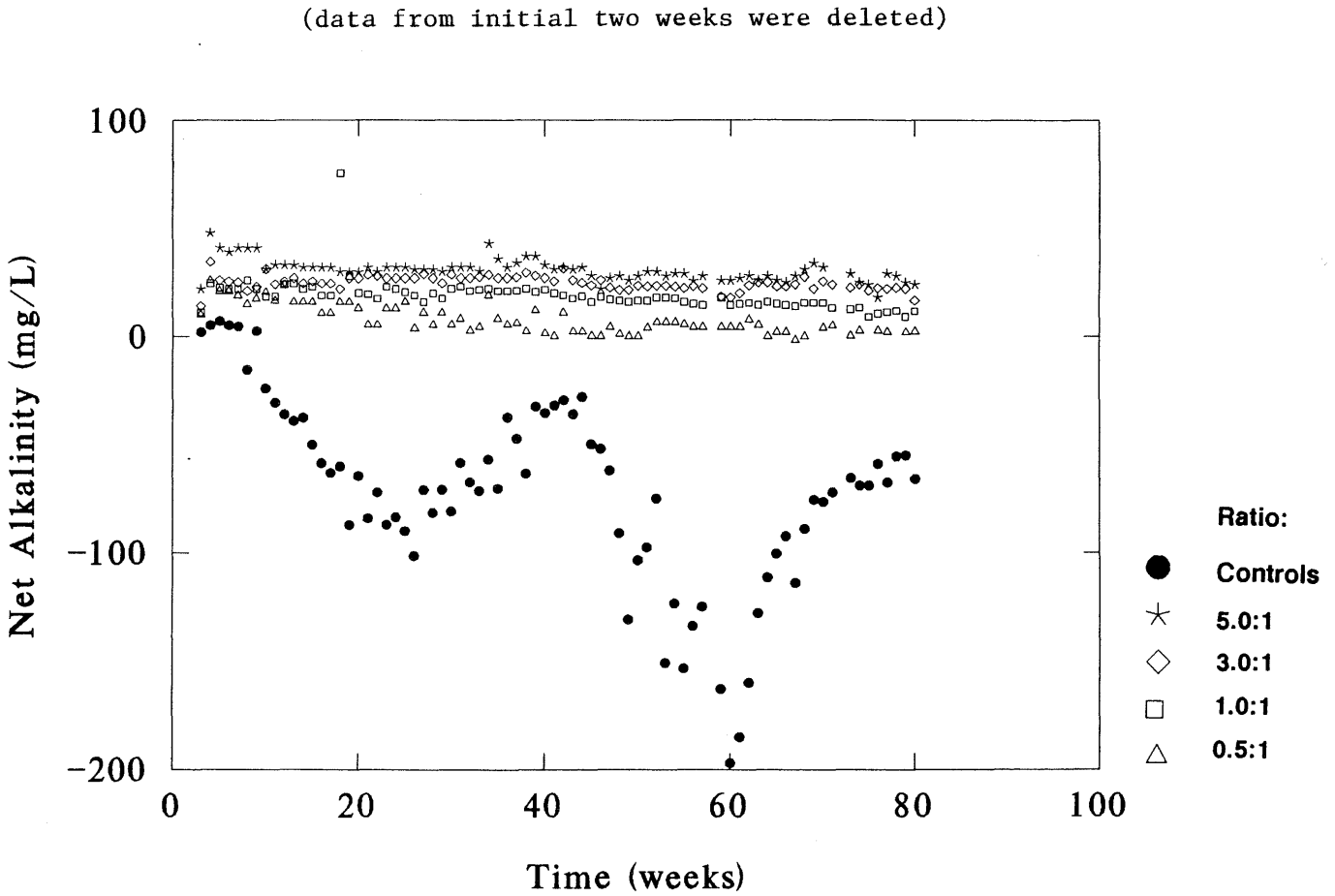


Figure 7. Net alkalinity vs time for RK fines.

(data from initial six weeks were deleted)

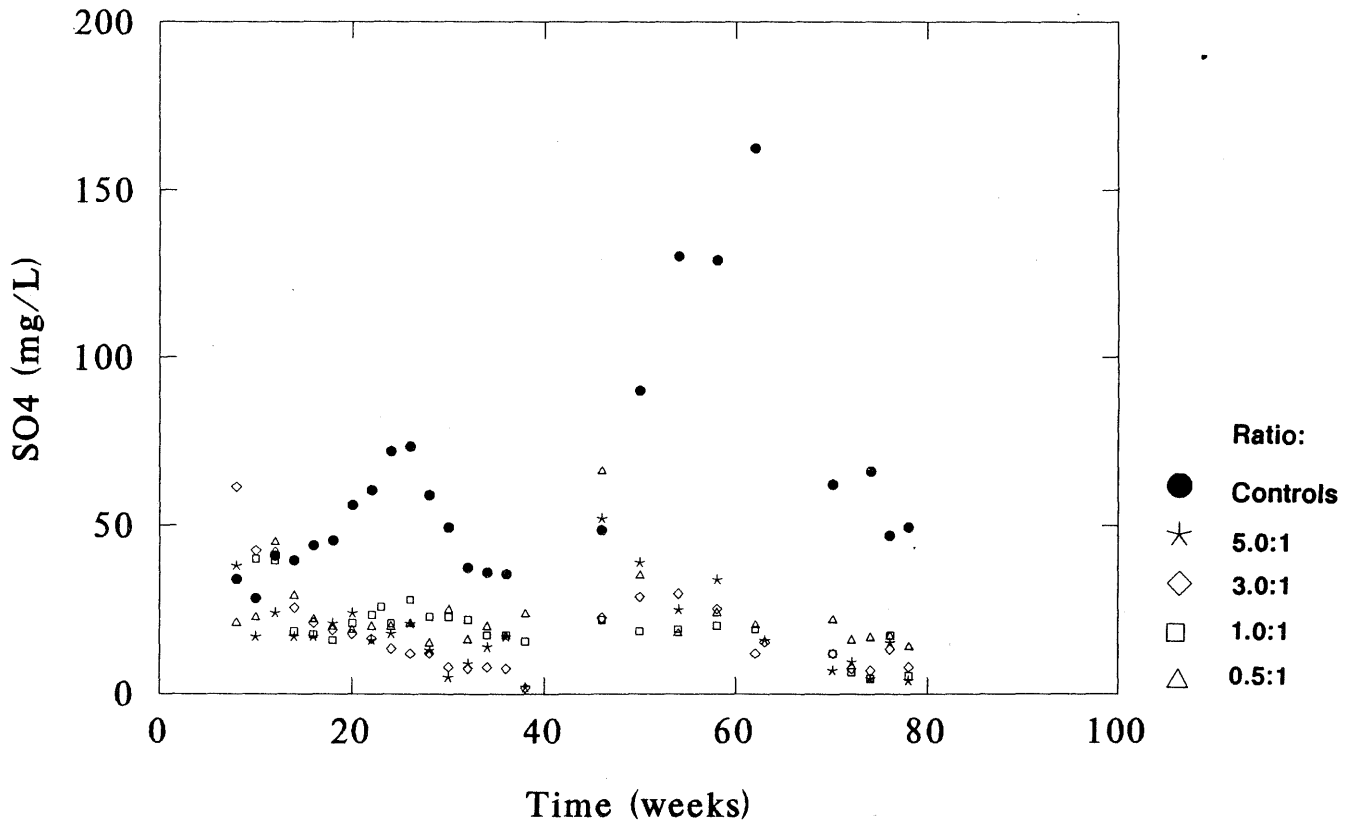


Figure 8. Sulfate vs time for RK fines.

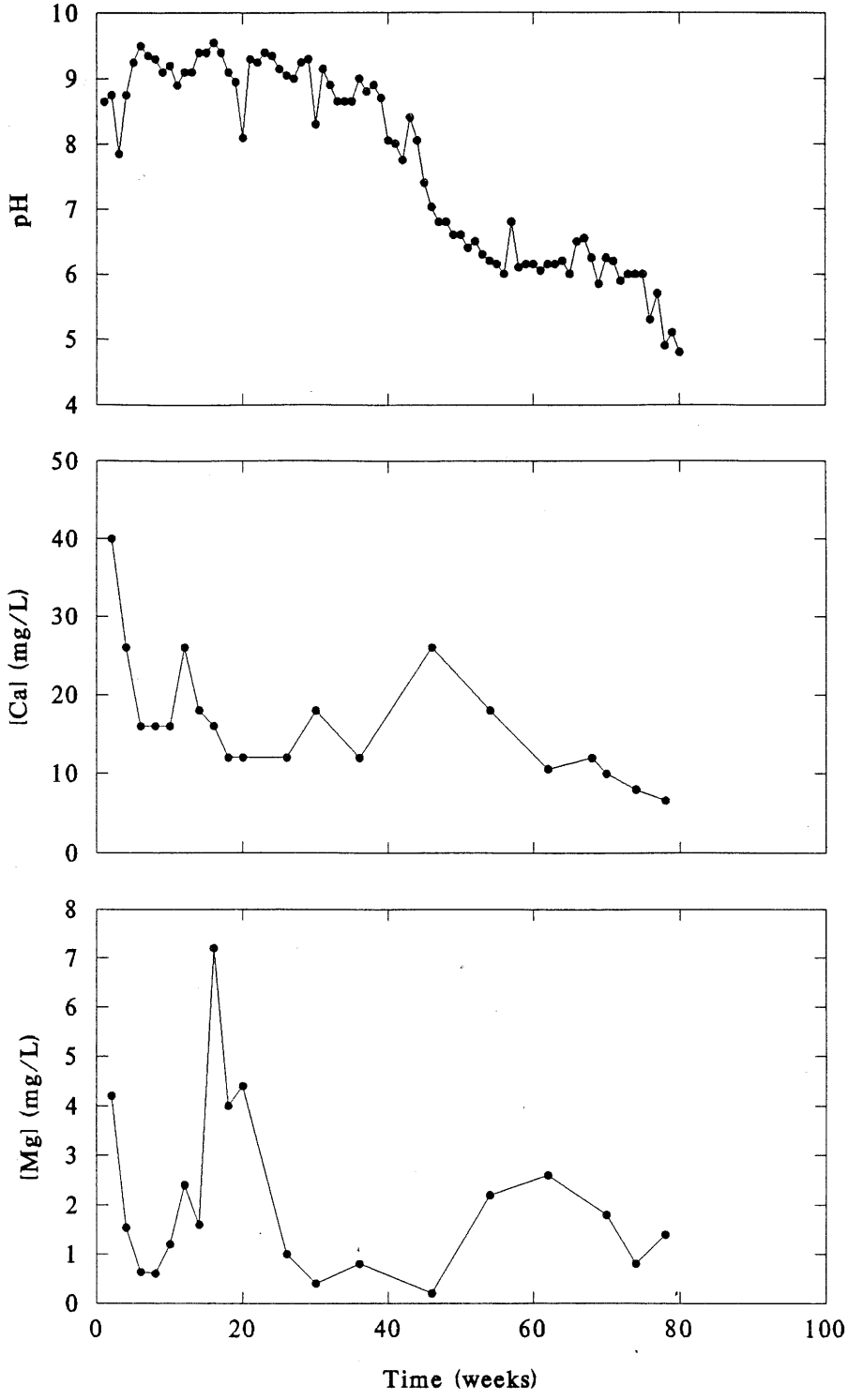
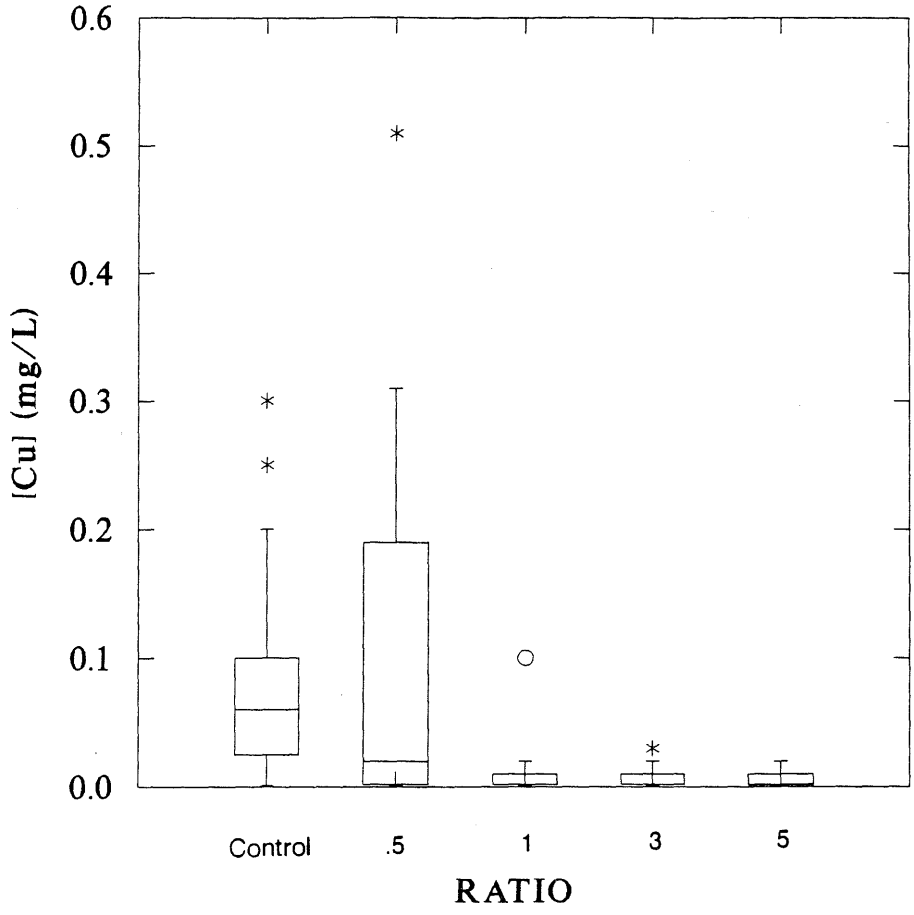
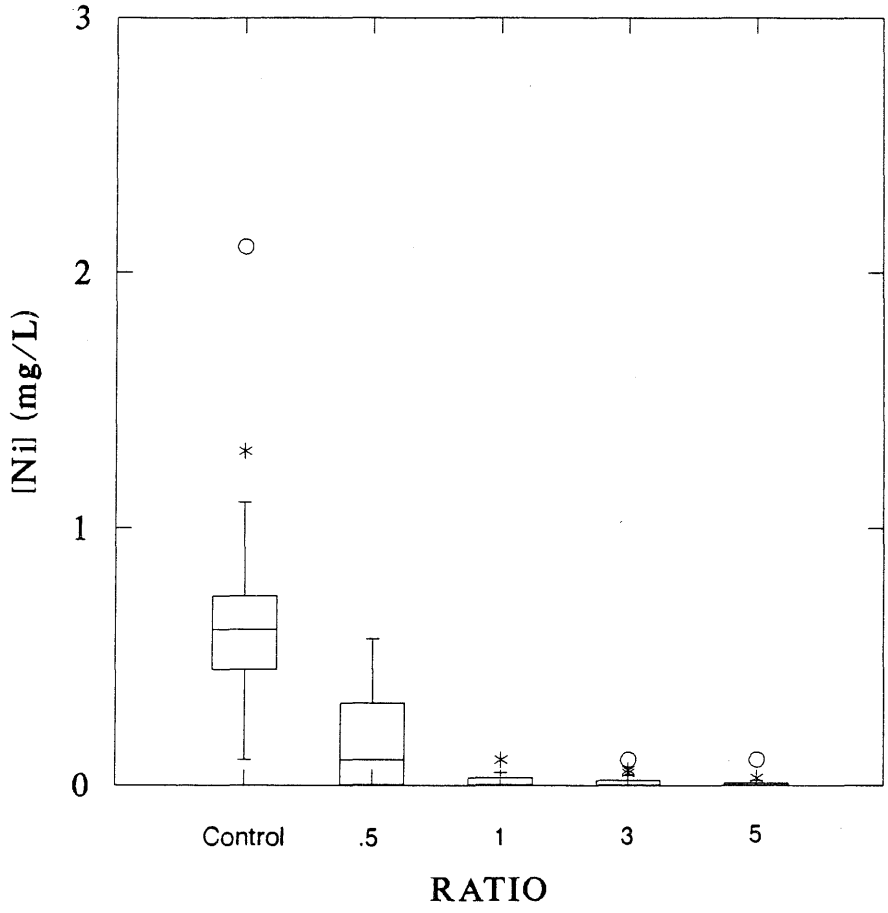


Figure 9. Calcium, magnesium and pH vs time for 0.5:1 RK fines (data from initial week was deleted).



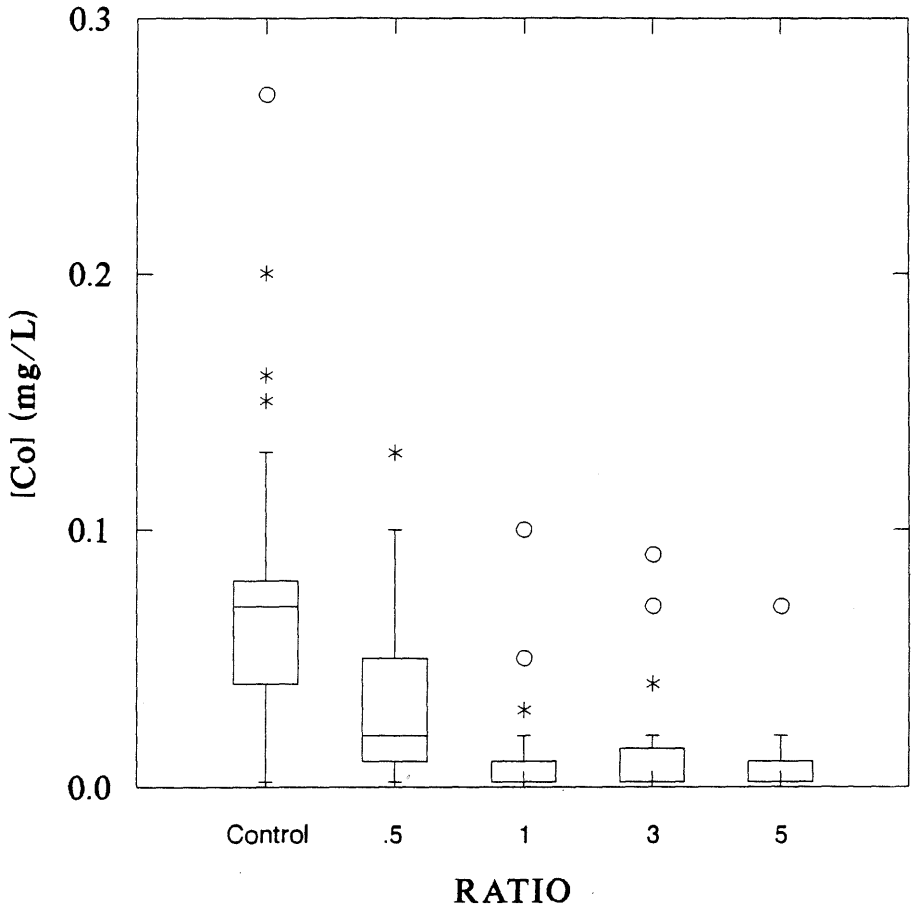
Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 10. Summary of copper concentrations from RK fines.



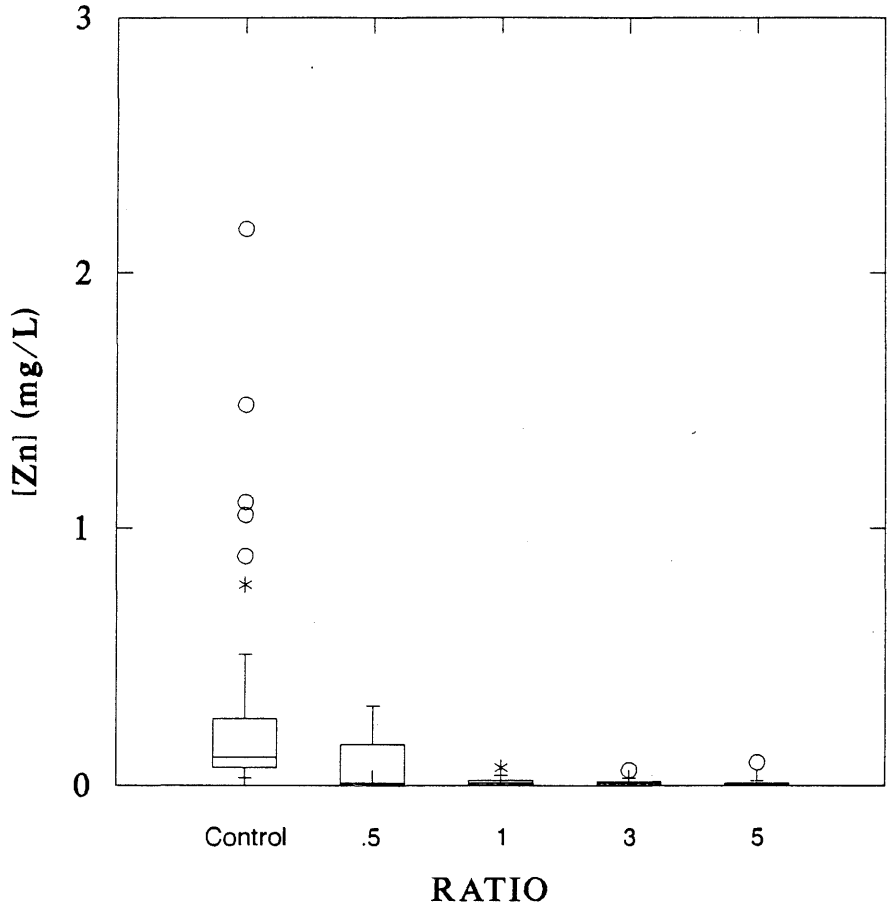
Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 11. Summary of nickel concentrations from RK fines.



Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 12. Summary of cobalt concentrations from RK fines.



Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 13. Summary of zinc concentrations from RK fines.

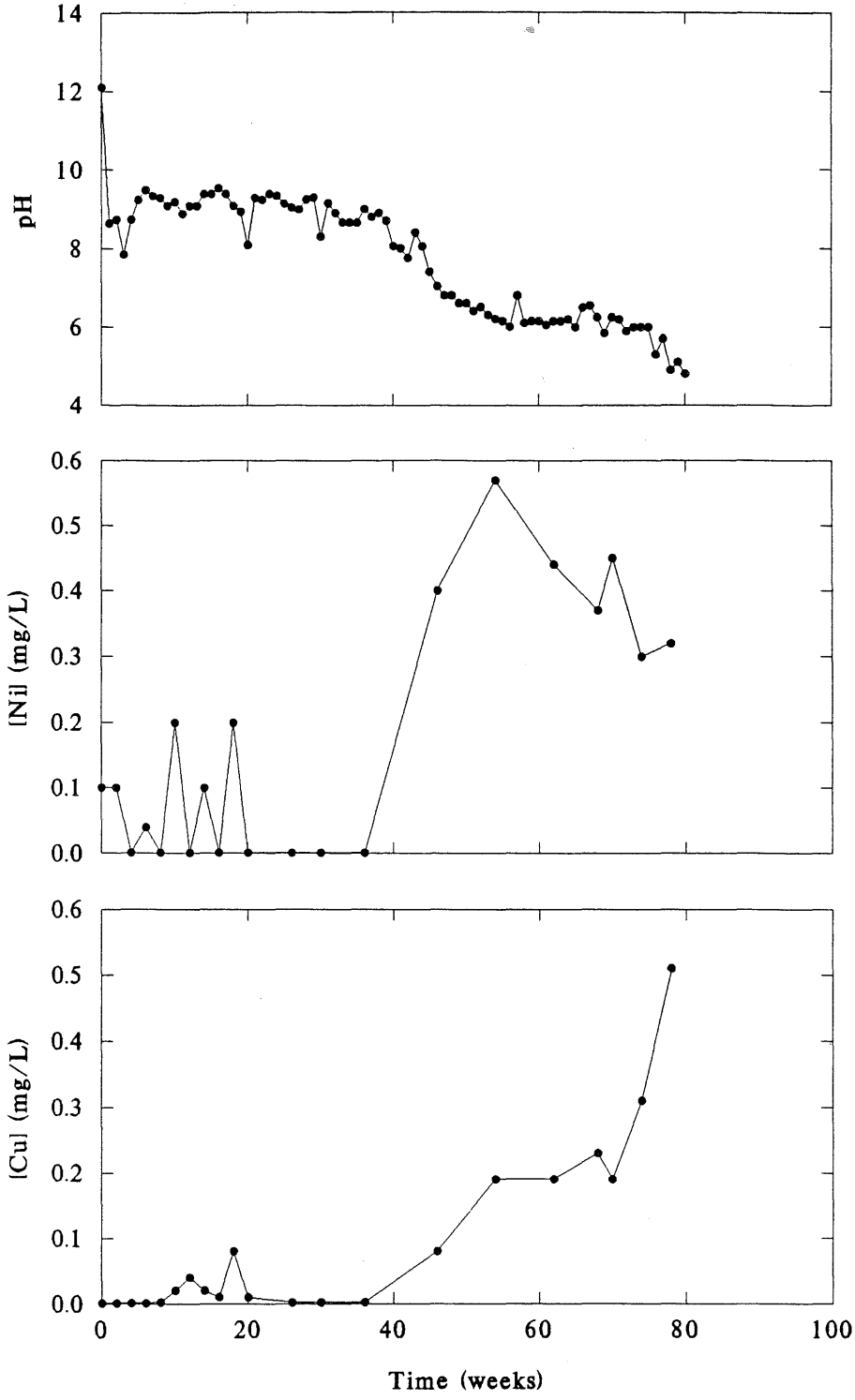


Figure 14. pH, nickel and copper vs time for 0.5:1 RK fines.

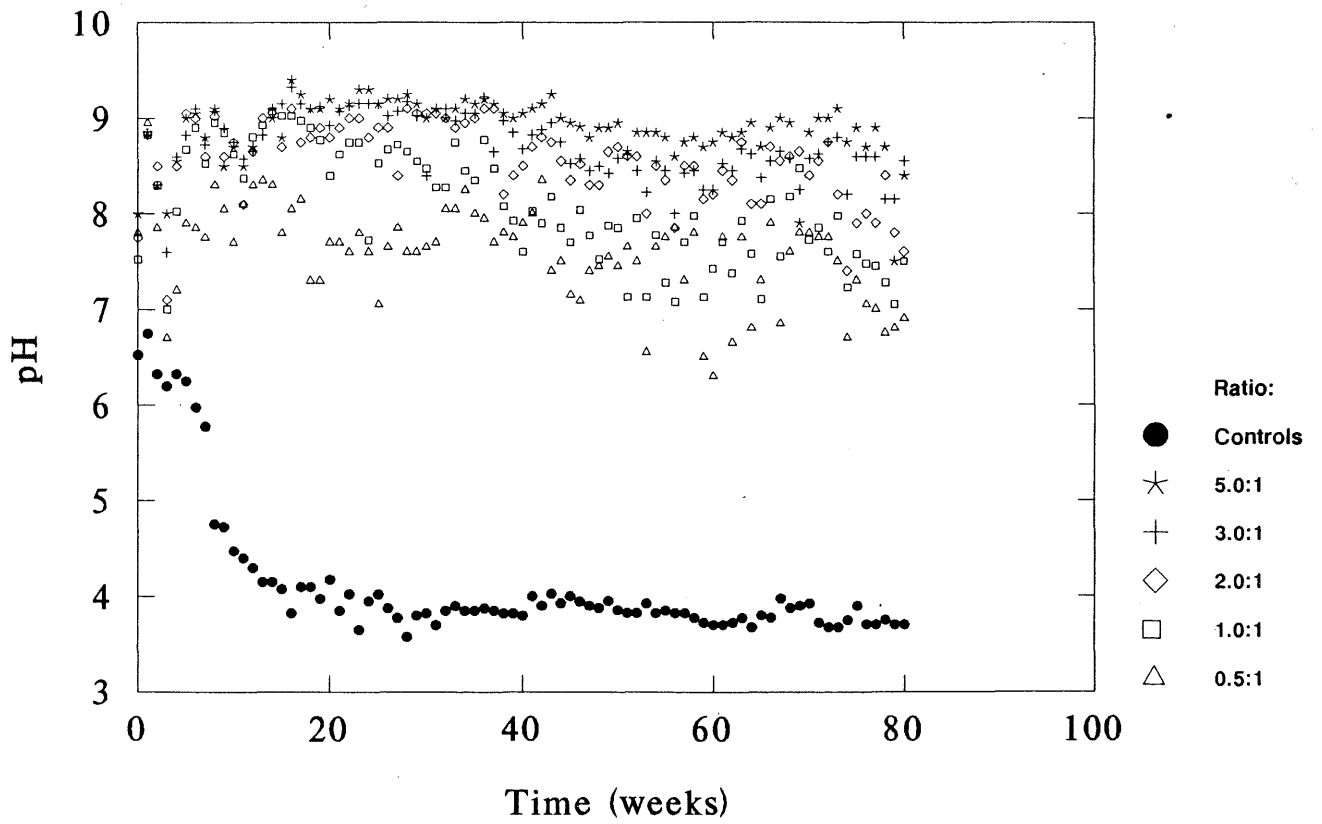


Figure 15. pH vs time for -10 mesh limestone.

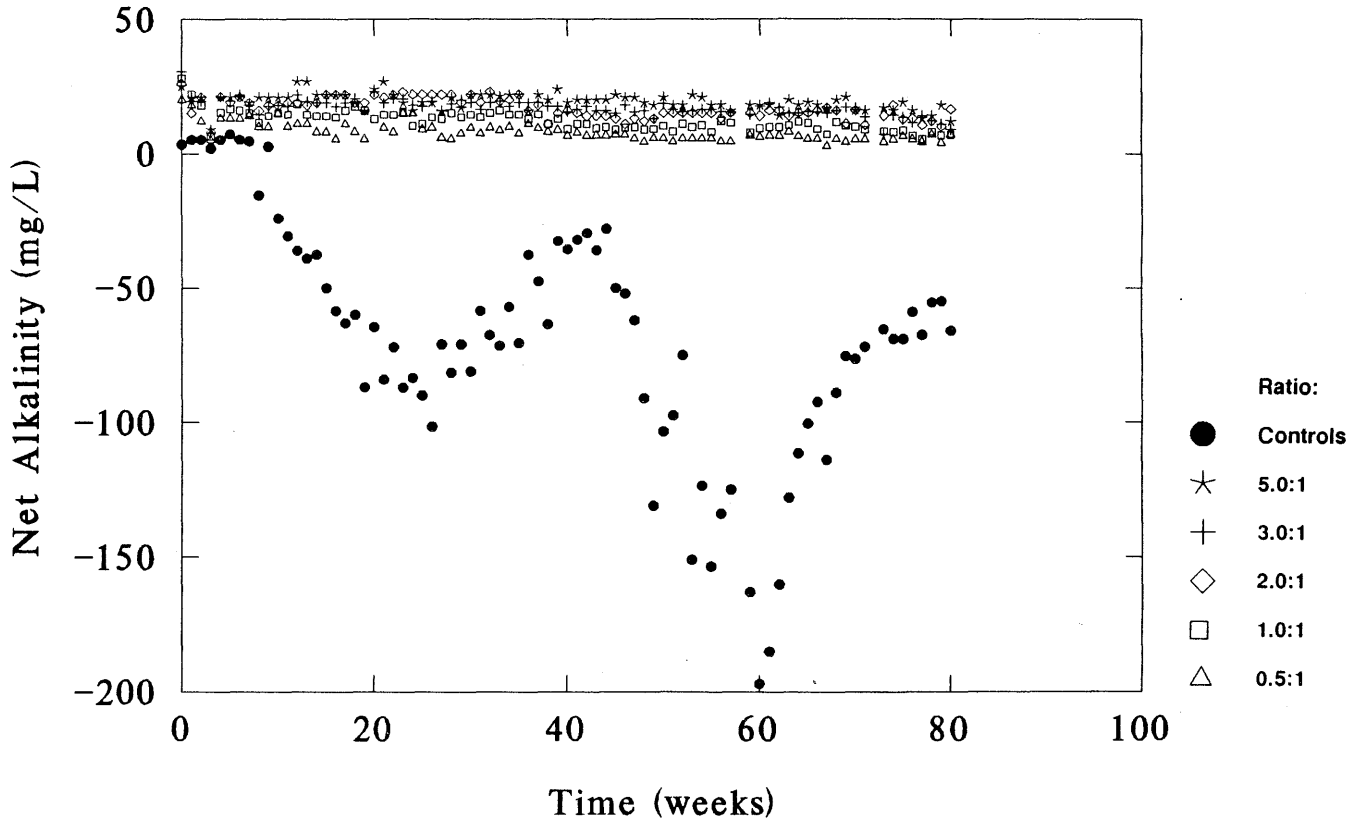


Figure 16. Net alkalinity vs time for -10 mesh limestone.

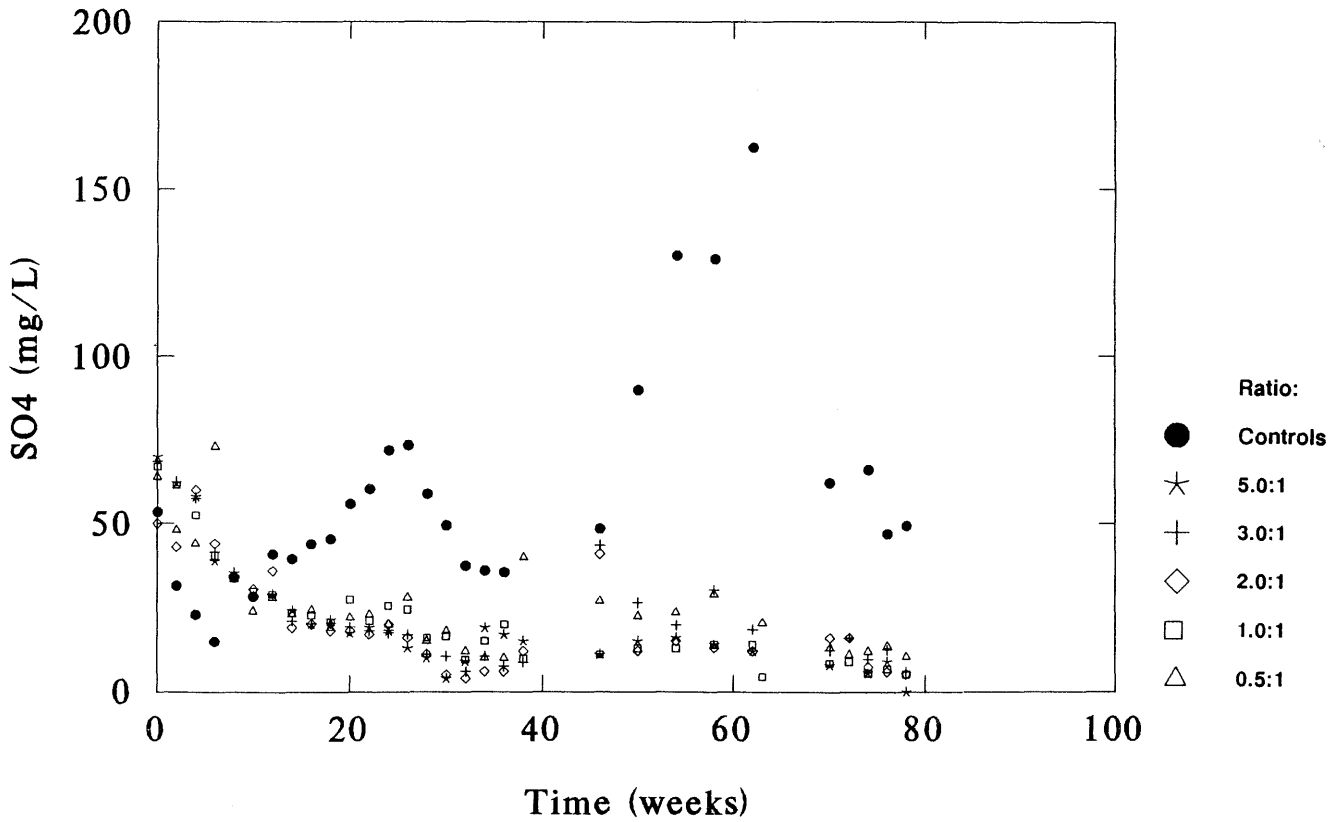
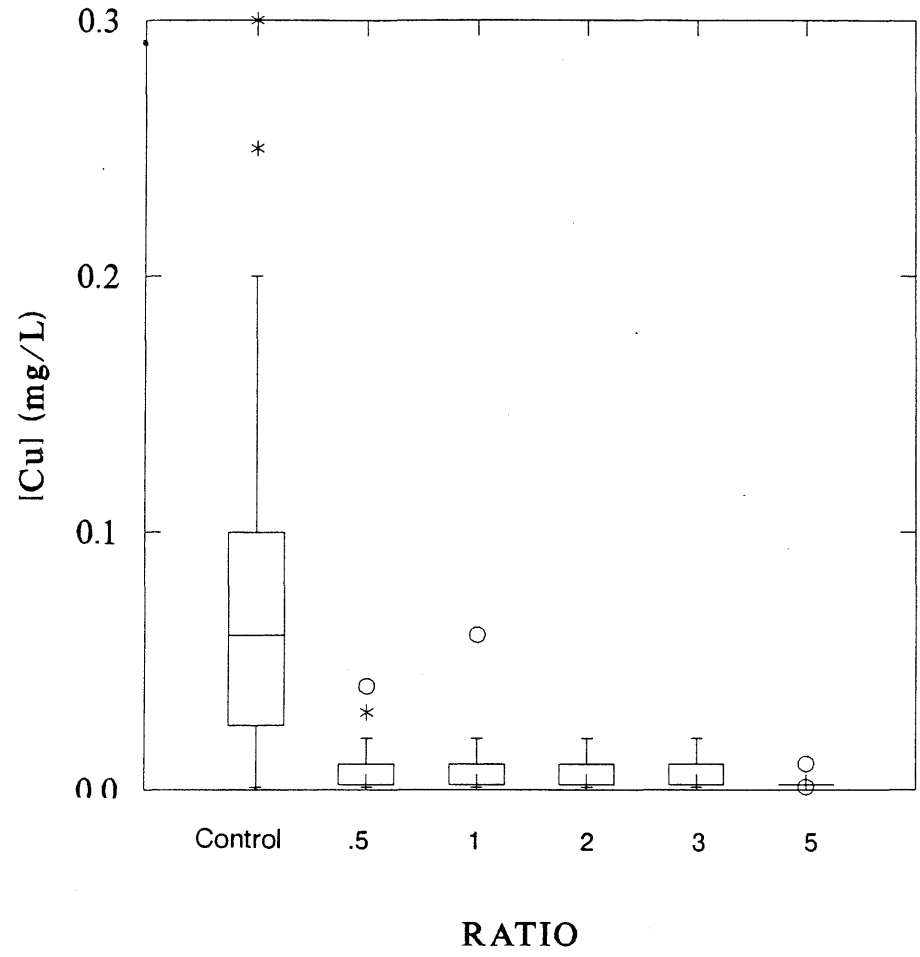
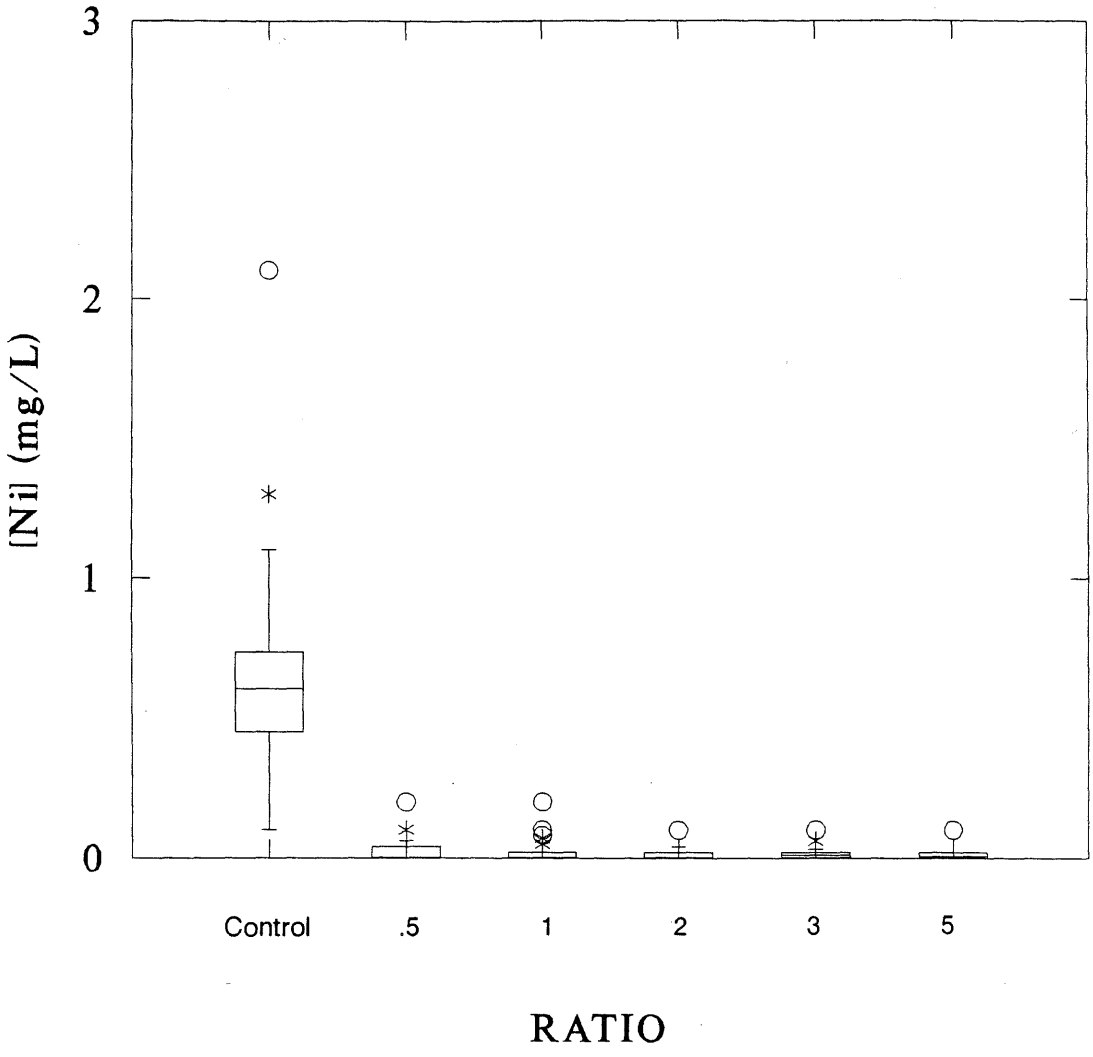


Figure 17. Sulfate vs time for -10 mesh limestone.



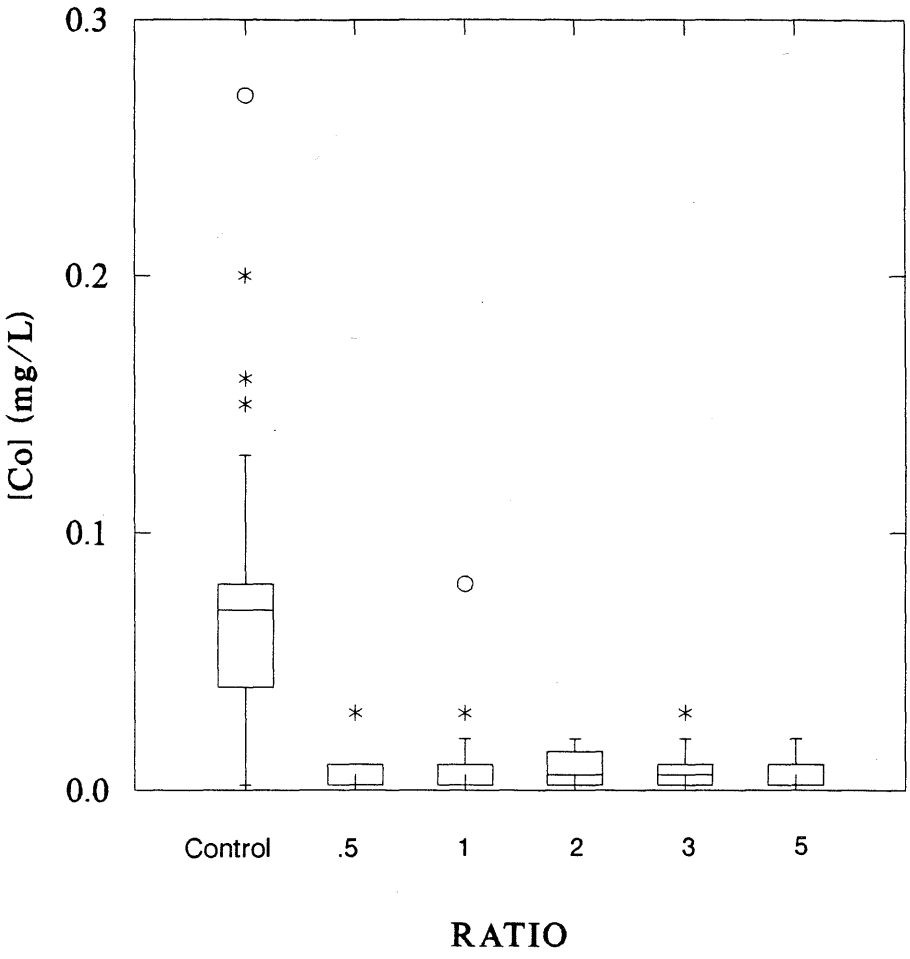
Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 18. Summary of copper concentrations from -10 mesh limestone.



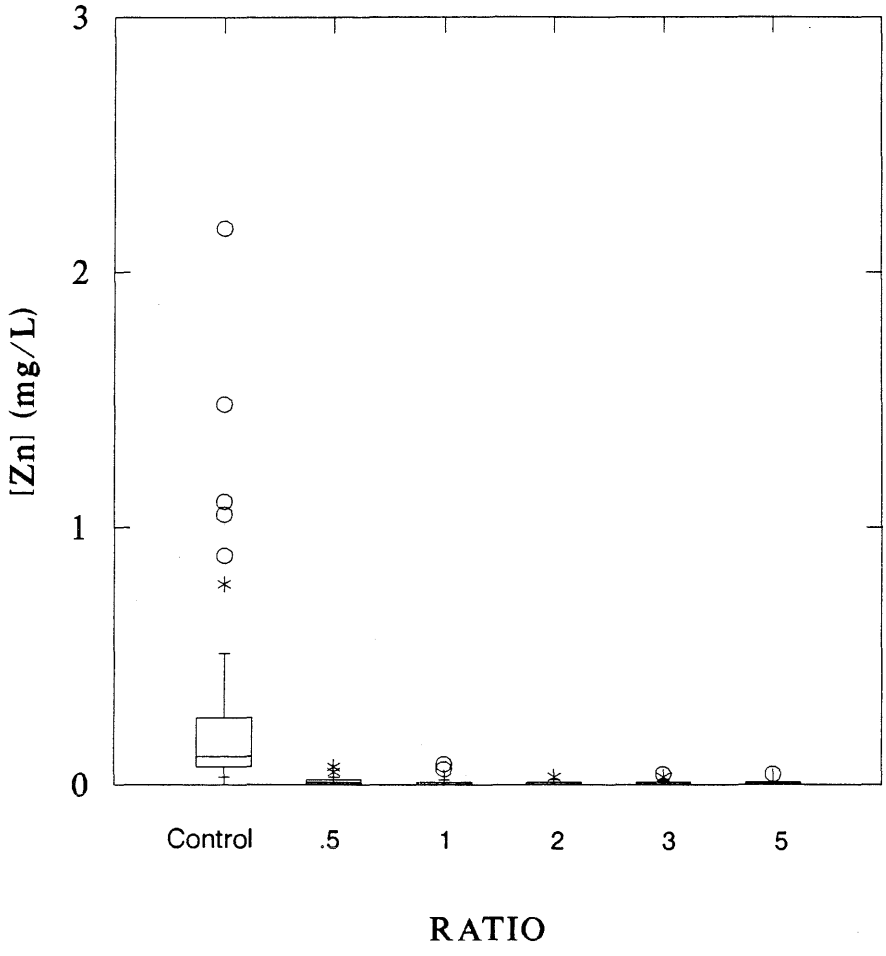
Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 19. Summary of nickel concentrations from -10 mesh limestone.



Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 20. Summary of cobalt concentrations from -10 mesh limestone.



Asterisks (circles) indicate values which exceed the 75th percentile value or are less than the 25th percentile value by 1.5 (3) times the difference between the 75th and 25th percentile values.

Figure 21. Summary of zinc concentrations from -10 mesh limestone.

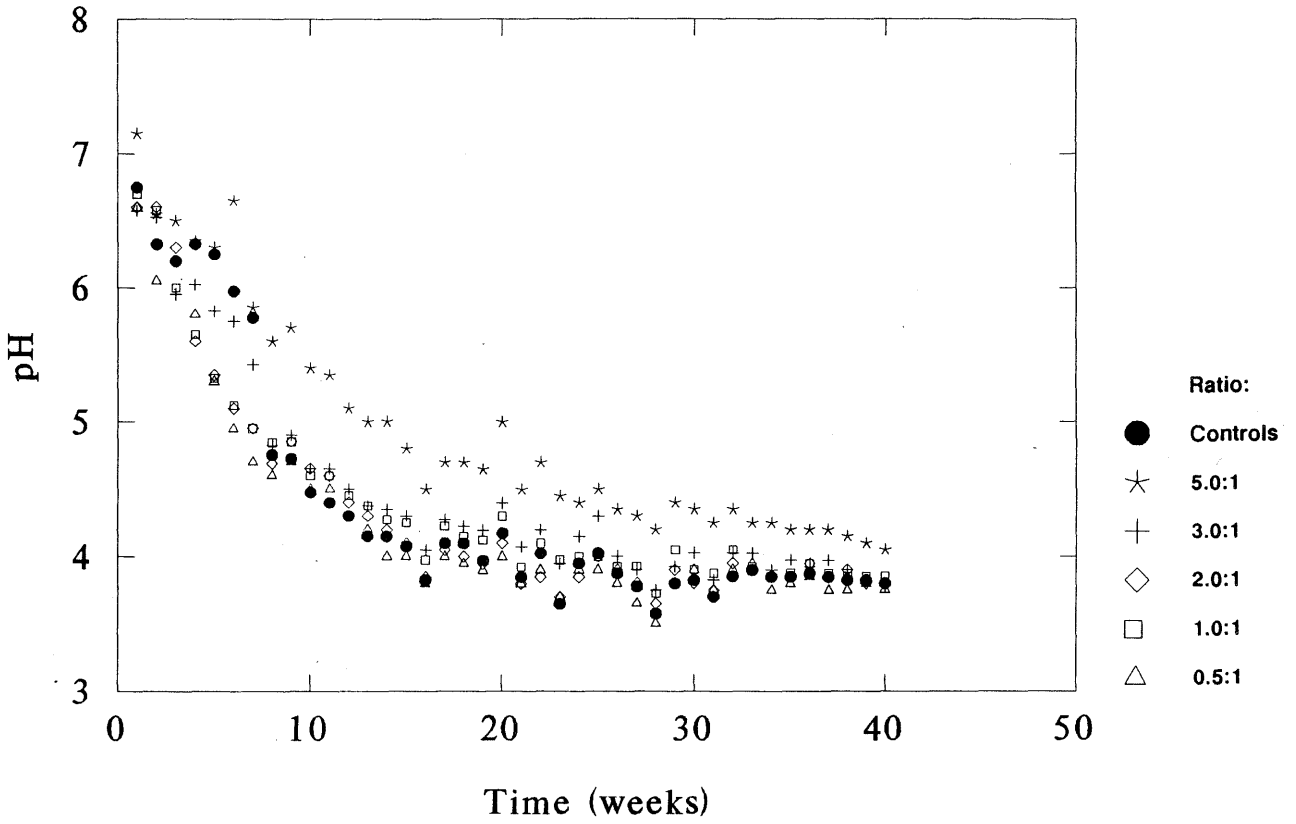


Figure 22. pH vs time for -0.25 inch/+10 mesh limestone.

ACKNOWLEDGEMENTS

Cal Jokela and Anne Jagunich assisted in water quality sampling and analysis of specific conductance, pH, acidity, and alkalinity. Trace metal and sulfate analyses were conducted by Albert Klaysmat and Jean Drotts, respectively. Tony Deneka and Jon Wagner were responsible for computer data management. Financial assistance was provided by LTV Steel Mining Company.

REFERENCES

American Public Health Association, American Water Works Association, Water Pollution Control Foundation. 1975. Standard methods for the examination of water and wastewater, 14th Edition American Public Health Association. Washington, D.C. 1193p.

Burt, R. A., Caruccio, F. T. 1986. The effect of limestone treatments on the rate of acid generation from pyritic mine gangue. Environ. Geochem. and Health. 8(3), p. 71-78.

Lapakko, K. A. 1988. Prediction of acid mine drainage from Duluth Complex mining wastes in northeastern Minnesota. In Proc. 1988 Mine Drainage and Surface Mine Reclamation Conference, April 19-21, 1988. Pittsburgh, PA. V. 1. Mine Water and Mine Waste. U.S. Bureau of Mines IC9183. p. 180-190.

O'Hagan, M. 1986. Admixing limestone with rocks having low, medium and high sulfur content to mitigate acid mine drainage. M.S. Thesis. Univ. South Carolina. 103p.

APPENDIX 1

Alkaline Addition Reactor Test

Drainage Water Quality

(Raw Data)

Table A1.1. Drainage from 0.5:1 ratio of RK fines (Reactor 1).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	172.000	2625.000	12.100	613.000	0.000	-0.100	0.100	0.040	0.030	-0.100	0.800	360.000	171.000
1	175.100	265.000	8.650	18.000	0.000	.	.	.	.	.	.	.	.
2	174.800	162.000	8.750	21.000	0.000	-0.100	0.100	0.030	-0.100	-0.100	4.200	40.000	119.000
3	173.600	143.000	7.850	10.000	0.000	.	.	.	.	.	.	.	.
4	173.700	130.000	8.750	26.000	0.000	-0.100	-0.100	-0.010	0.010	-0.100	1.540	26.000	39.000
5	176.700	103.000	9.250	21.000	0.000	.	.	.	.	.	.	.	.
6	176.100	94.000	9.500	21.000	0.000	-0.100	0.040	0.010	-0.010	-0.100	0.630	16.000	22.000
7	175.200	88.000	9.350	19.000	0.000	.	.	.	.	.	.	.	.
8	175.300	96.000	9.300	15.000	0.000	-0.010	-0.100	0.010	0.020	-0.100	0.600	16.000	21.000
9	174.600	92.000	9.100	17.500	0.000	.	.	.	.	.	.	.	.
10	173.100	95.000	9.200	20.600	0.000	0.020	0.200	0.020	0.010	-0.100	1.200	16.000	22.600
11	177.300	120.000	8.900	16.500	0.000	.	.	.	.	.	.	.	.
12	176.600	140.000	9.100	24.000	0.000	0.040	-0.100	0.020	-0.010	-0.100	2.400	26.000	45.000
13	173.700	133.000	9.100	16.000	0.000	.	.	.	.	.	.	.	.
14	171.700	98.000	9.400	16.000	0.000	0.020	0.100	0.100	0.010	-0.100	1.600	18.000	29.000
15	176.500	97.000	9.400	16.000	0.000	.	.	.	.	.	.	.	.
16	175.100	90.000	9.550	10.800	0.000	0.010	-0.100	0.020	0.030	-0.100	7.200	16.000	22.000
17	174.700	80.000	9.400	10.800	0.000	.	.	.	.	.	.	.	.
18	171.900	80.000	9.100	16.000	0.000	0.080	0.200	-0.010	-0.010	-0.100	4.000	12.000	20.000
19	174.300	75.000	8.950	16.000	0.000	.	.	.	.	.	.	.	.
20	172.800	78.000	8.100	13.000	0.000	0.010	-0.100	-0.010	0.010	-0.100	4.400	12.000	19.000
21	171.400	75.000	9.300	5.400	0.000	.	.	.	.	.	.	.	.
22	174.800	75.000	9.250	5.400	0.000	.	.	.	.	.	.	.	20.000
23	174.900	68.000	9.400	13.000	0.000	.	.	.	.	.	.	.	.
24	174.200	69.000	9.350	13.000	0.000	.	.	.	.	.	.	.	20.000
25	180.300	62.000	9.150	16.000	0.000	.	.	.	.	.	.	.	.
26	173.700	70.000	9.050	3.800	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.000	12.000	21.000
27	174.300	62.000	9.000	11.000	0.000	.	.	.	.	.	.	.	.
28	174.800	60.000	9.250	5.400	0.000	.	.	.	.	.	.	.	15.000
29	174.700	58.000	9.300	10.800	0.000	.	.	.	.	.	.	.	.
30	174.400	82.000	8.300	5.400	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.400	18.000	25.000
31	175.000	55.000	9.150	8.100	0.000	.	.	.	.	.	.	.	.
32	174.500	58.000	8.900	2.700	0.000	.	.	.	.	.	.	.	16.000
33	176.900	95.000	8.650	4.300	0.000	.	.	.	.	.	.	.	.
34	174.400	62.000	8.650	19.000	0.000	.	.	.	.	.	.	.	20.000
35	175.800	65.000	8.650	8.100	0.000	.	.	.	.	.	.	.	.
36	174.100	57.000	9.000	5.400	0.000	-0.010	-0.100	0.020	-0.100	-0.100	0.800	12.000	17.000
37	172.100	58.000	8.800	6.000	0.000	.	.	.	.	.	.	.	.
38	176.000	95.000	8.900	2.200	0.000	.	.	.	.	.	.	.	23.500
39	175.200	58.000	8.700	12.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.1. Drainage from 0.5:1 ratio of RK fines (Reactor 1).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
40	175.100	68.000	8.050	1.400	0.000	.	.	.	.	.	.	.	.
41	175.900	80.000	8.000	-0.100	0.000	.	.	.	.	.	.	.	.
42	175.700	112.000	7.750	11.000	0.000	.	.	.	.	.	.	.	.
43	174.600	92.000	8.400	2.200	0.000	.	.	.	.	.	.	.	.
44	174.400	105.000	8.050	2.200	0.000	.	.	.	.	.	.	.	.
45	175.300	142.000	7.400	-0.100	0.000	.	.	.	.	.	.	.	.
46	173.900	144.000	7.030	-0.100	0.000	0.080	0.400	0.050	0.210	-0.100	0.200	26.000	66.000
47	174.500	119.000	6.800	4.400	0.000	.	.	.	.	.	.	.	.
48	172.400	119.000	6.800	1.100	0.000	.	.	.	.	.	.	.	.
49	172.700	92.000	6.600	-0.100	0.000	.	.	.	.	.	.	.	.
50	174.400	95.000	6.600	-0.100	0.000	.	.	.	.	.	.	.	35.000
51	176.000	90.000	6.400	4.000	0.000	.	.	.	.	.	.	.	.
52	175.100	68.000	6.500	6.600	0.000	.	.	.	.	.	.	.	.
53	173.500	70.000	6.300	6.600	0.000	.	.	.	.	.	.	.	.
54	175.900	55.000	6.200	6.600	0.000	0.190	0.570	0.130	0.310	-0.100	2.200	18.000	18.000
55	174.300	55.000	6.150	5.500	0.000	.	.	.	.	.	.	.	.
56	174.700	62.000	6.000	4.400	0.000	.	.	.	.	.	.	.	.
57	175.400	62.000	6.800	4.400	0.000	.	.	.	.	.	.	.	.
58	174.900	60.000	6.100	0.000	0.000	.	.	.	.	.	.	.	24.000
59	175.300	65.000	6.150	4.400	0.000	.	.	.	.	.	.	.	.
60	175.700	62.000	6.150	4.400	0.000	.	.	.	.	.	.	.	.
61	173.800	62.000	6.050	4.400	0.000	.	.	.	.	.	.	.	.
62	174.700	62.000	6.150	7.800	0.000	0.190	0.440	0.050	0.220	0.270	2.600	10.600	20.500
63	174.700	58.000	6.150	5.200	0.000	.	.	.	.	.	.	.	.
64	175.100	56.000	6.200	-0.100	0.000	.	.	.	.	.	.	.	.
65	176.200	58.000	6.000	2.100	0.000	.	.	.	.	.	.	.	.
66	176.000	52.000	6.500	2.100	0.000	.	.	.	.	.	.	.	.
67	174.600	50.000	6.550	4.200	5.800	.	.	.	.	.	.	.	.
68	177.100	50.000	6.250	-0.100	0.000	0.230	0.370	0.090	0.150	0.400	.	12.000	.
69	176.300	44.000	5.850	0.000	0.000	.	.	.	.	.	.	.	.
70	173.600	53.000	6.250	4.000	0.000	0.190	0.450	0.040	0.200	0.650	1.800	10.000	22.000
71	171.900	43.000	6.200	5.000	0.000	.	.	.	.	.	.	.	.
72	169.500	37.000	5.900	0.000	0.000	.	.	.	.	.	.	.	16.000
73	173.900	50.000	6.000	2.600	2.300	.	.	.	.	.	.	.	.
74	169.300	50.000	6.000	2.600	0.000	0.310	0.300	0.040	0.160	0.600	0.800	8.000	16.800
75	178.100	50.000	6.000	0.000	0.000	.	.	.	.	.	.	.	.
76	176.400	40.000	5.300	2.600	0.000	.	.	.	.	.	.	.	17.000
77	172.400	40.000	5.700	2.100	0.000	.	.	.	.	.	.	.	.
78	172.900	50.000	4.900	0.000	0.000	0.510	0.320	0.080	0.190	1.430	1.400	6.600	14.000
79	176.300	55.000	5.100	1.900	0.000	.	.	.	.	.	.	.	.
80	173.900	50.000	4.800	2.400	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.2. Drainage from 1:1 ratio of RK fines (Reactor 2).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	174.800	5000.000	12.400	1220.000	0.000	-0.100	-0.100	0.050	0.030	0.100	3.600	620.000	226.000
1	173.100	480.000	8.750	26.000	0.000	.	.	.	.	.	.	.	.
2	176.500	230.000	8.750	26.000	0.000	-0.100	0.100	0.030	0.020	-0.100	5.800	40.000	100.000
3	172.400	190.000	8.200	11.000	0.000	.	.	.	.	.	.	.	.
4	176.600	162.000	8.550	26.000	0.000	-0.100	-0.100	-0.010	0.010	-0.100	2.300	37.000	48.000
5	172.600	130.000	9.200	23.000	0.000	.	.	.	.	.	.	.	.
6	175.700	112.000	9.500	23.000	0.000	-0.100	0.010	-0.010	-0.010	-0.100	0.900	20.000	25.000
7	174.000	102.000	9.250	20.000	0.000	.	.	.	.	.	.	.	.
8	178.600	125.000	9.400	26.000	0.000	.	.	.	.	.	.	.	.
9	174.500	137.000	8.950	23.000	0.000	.	.	.	.	.	.	.	.
10	175.400	145.000	9.100	16.000	0.000	0.010	-0.100	0.020	-0.010	-0.100	1.200	24.000	39.000
11	176.700	155.000	8.900	20.000	0.000	.	.	.	.	.	.	.	.
12	171.400	128.000	9.050	24.000	0.000	0.010	-0.100	0.010	0.010	-0.100	1.600	26.000	38.000
13	175.600	122.000	8.600	27.000	0.000	.	.	.	.	.	.	.	.
14	170.700	76.000	9.500	22.000	0.000	0.020	0.100	0.020	0.010	-0.100	1.600	14.000	16.000
15	171.000	93.000	9.100	24.000	0.000	.	.	.	.	.	.	.	.
16	171.700	87.000	9.300	22.000	0.000	-0.010	-0.100	0.010	0.020	-0.100	7.400	16.000	17.400
17	177.300	78.000	9.400	16.000	0.000	.	.	.	.	.	.	.	.
18	174.600	91.000	8.900	22.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	3.400	14.000	19.000
19	171.000	78.000	9.000	24.000	0.000	.	.	.	.	.	.	.	.
20	175.400	92.000	9.200	16.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	4.400	12.000	22.800
21	174.400	90.000	9.150	19.000	0.000	.	.	.	.	.	.	.	.
22	170.200	105.000	8.750	16.000	0.000	.	.	.	.	.	.	.	26.000
23	172.700	95.000	9.300	22.000	0.000	.	.	.	.	.	.	.	26.000
24	171.200	98.000	9.150	22.000	0.000	.	.	.	.	.	.	.	.
25	170.400	110.000	8.650	22.000	0.000	.	.	.	.	.	.	.	.
26	172.300	110.000	9.000	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	20.000	33.000
27	175.700	102.000	8.900	16.000	0.000	.	.	.	.	.	.	.	.
28	176.600	98.000	9.200	20.000	0.000	.	.	.	.	.	.	.	29.000
29	172.300	80.000	9.200	19.000	0.000	.	.	.	.	.	.	.	.
30	173.800	90.000	9.200	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.200	22.000	23.000
31	171.300	78.000	9.300	24.000	0.000	.	.	.	.	.	.	.	.
32	185.900	82.000	9.200	22.000	0.000	.	.	.	.	.	.	.	21.000
33	174.400	88.000	8.950	22.600	0.000	.	.	.	.	.	.	.	.
34	173.300	88.000	8.900	22.000	0.000	.	.	.	.	.	.	.	19.000
35	174.800	85.000	8.950	22.000	0.000	.	.	.	.	.	.	.	.
36	171.700	82.000	9.350	22.000	0.000	0.020	-0.100	-0.010	-0.010	-0.100	0.600	12.000	19.000
37	171.400	80.000	9.200	22.000	0.000	.	.	.	.	.	.	.	.
38	189.100	68.000	8.550	22.000	0.000	.	.	.	.	.	.	.	12.000
39	180.000	50.000	9.300	20.000	0.000	.	.	.	.	.	.	.	.
40	172.200	63.000	8.450	21.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.2. Drainage from 1:1 ratio of RK fines (Reactor 2).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	174.200	75.000	8.950	19.000	0.000	.	.	.	.	.	.	.	.
42	171.100	92.000	8.900	20.000	0.000	.	.	.	.	.	.	.	.
43	171.700	92.000	9.300	17.000	0.000	.	.	.	.	.	.	.	.
44	171.100	92.000	8.750	19.000	0.000	.	.	.	.	.	.	.	.
45	179.900	104.000	8.950	15.000	0.000	.	.	.	.	.	.	.	.
46	176.900	101.000	8.800	20.500	0.000	0.010	-0.100	0.010	0.010	-0.100	0.100	22.000	33.000
47	171.000	95.000	8.800	16.000	0.000	.	.	.	.	.	.	.	.
48	180.300	99.000	8.950	15.000	0.000	.	.	.	.	.	.	.	.
49	172.600	89.000	8.850	16.000	0.000	.	.	.	.	.	.	.	.
50	170.600	107.000	8.850	16.000	0.000	.	.	.	.	.	.	.	28.000
51	171.700	118.000	8.600	18.000	0.000	.	.	.	.	.	.	.	.
52	171.600	83.000	8.800	18.000	0.000	.	.	.	.	.	.	.	.
53	171.100	105.000	8.400	18.000	0.000	.	.	.	.	.	.	.	.
54	171.000	95.000	8.550	18.000	0.000	0.010	0.020	0.010	0.020	-0.100	1.600	30.000	32.500
55	170.200	89.000	8.500	16.000	0.000	.	.	.	.	.	.	.	.
56	171.200	93.000	8.350	15.000	0.000	.	.	.	.	.	.	.	.
57	172.900	99.000	8.550	14.000	0.000	.	.	.	.	.	.	.	.
58	172.100	90.000	8.300	0.000	0.000	.	.	.	.	.	.	.	31.500
59	171.300	100.000	8.500	14.000	0.000	.	.	.	.	.	.	.	.
60	172.600	110.000	8.600	14.000	0.000	.	.	.	.	.	.	.	.
61	171.400	90.000	8.450	15.000	0.000	.	.	.	.	.	.	.	.
62	170.700	90.000	8.750	15.000	0.000	0.020	0.030	0.010	0.020	0.020	2.800	16.000	23.500
63	171.500	80.000	8.700	13.000	0.000	.	.	.	.	.	.	.	.
64	170.700	73.000	9.200	15.000	0.000	.	.	.	.	.	.	.	.
65	171.700	75.000	7.300	15.000	0.000	.	.	.	.	.	.	.	.
66	170.800	73.000	9.050	15.000	0.000	.	.	.	.	.	.	.	.
67	171.100	69.000	9.100	13.000	0.000	.	.	.	.	.	.	.	.
68	172.200	54.000	9.100	11.000	0.000	.	.	.	.	.	.	.	.
69	171.800	55.000	8.600	12.000	0.000	.	.	.	.	.	.	.	.
70	.	58.000	8.900	13.000	0.000	0.010	0.030	-0.010	0.020	0.030	1.800	10.000	16.500
71	170.600	54.000	8.900	10.500	0.000	.	.	.	.	.	.	.	.
72	171.300	43.000	7.300	0.000	0.000	.	.	.	.	.	.	.	9.000
73	171.500	52.000	9.300	10.000	0.000	.	.	.	.	.	.	.	.
74	174.400	50.000	9.100	10.500	0.000	0.020	0.030	0.010	0.010	0.010	0.600	10.400	5.200
75	169.100	40.000	8.500	7.300	0.000	.	.	.	.	.	.	.	.
76	173.400	50.000	8.500	10.500	0.000	.	.	.	.	.	.	.	18.000
77	170.400	47.000	8.700	9.500	0.000	.	.	.	.	.	.	.	.
78	168.000	39.000	7.000	9.500	0.000	0.010	0.040	0.010	0.010	0.010	1.200	8.600	4.800
79	169.300	55.000	8.700	9.000	0.000	.	.	.	.	.	.	.	.
80	168.930	50.000	9.000	11.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.3. Drainage from 1:1 ratio of RK fines (Reactor 3).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	173.800	5000.000	12.400	1223.000	0.000	0.100	0.100	0.050	0.070	0.100	0.600	620.000	224.000
1	172.200	510.000	9.050	44.000	0.000	.	.	.	.	.	.	.	.
2	174.600	234.000	8.800	31.000	0.000	-0.100	0.100	0.020	-0.010	-0.100	6.000	40.000	82.000
3	170.300	185.000	8.200	11.000	0.000	.	.	.	.	.	.	.	.
4	176.600	153.000	8.300	23.000	0.000	-0.100	0.030	-0.010	0.010	-0.100	2.610	26.000	49.000
5	175.000	116.000	9.300	22.000	0.000	.	.	.	.	.	.	.	.
6	174.500	108.000	9.450	21.000	0.000	-0.010	0.040	0.010	-0.010	-0.100	0.970	20.000	23.000
7	176.000	96.000	9.300	24.000	0.000	.	.	.	.	.	.	.	.
8	174.600	120.000	9.350	26.000	0.000	.	.	.	.	.	.	.	.
9	173.000	143.000	9.000	21.000	0.000	.	.	.	.	.	.	.	.
10	174.500	140.000	9.050	21.000	0.000	-0.010	-0.100	0.100	0.010	0.010	1.200	24.000	41.000
11	174.900	140.000	9.100	17.000	0.000	.	.	.	.	.	.	.	.
12	173.900	120.000	9.200	24.000	0.000	0.010	-0.100	-0.010	0.010	-0.100	1.800	22.000	41.000
13	174.100	108.000	9.200	22.000	0.000	.	.	.	.	.	.	.	.
14	172.800	90.000	9.200	22.000	0.000	0.020	-0.100	-0.010	0.010	-0.100	1.600	16.000	21.000
15	173.100	87.000	9.300	22.000	0.000	.	.	.	.	.	.	.	.
16	172.100	92.000	9.350	16.000	0.000	-0.010	-0.100	0.010	0.040	-0.100	6.800	18.000	17.800
17	176.100	82.000	9.400	22.000	0.000	.	.	.	.	.	.	.	.
18	173.400	77.000	9.050	19.000	0.000	-0.010	-0.100	-0.010	0.020	-0.100	3.200	14.000	13.000
19	173.900	80.000	9.050	32.000	0.000	.	.	.	.	.	.	.	.
20	173.300	90.000	9.100	24.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	4.600	12.000	19.400
21	177.000	80.000	9.200	20.000	0.000	.	.	.	.	.	.	.	.
22	176.200	85.000	9.100	19.000	0.000	.	.	.	.	.	.	.	21.000
23	175.200	78.000	9.400	24.000	0.000	.	.	.	.	.	.	.	.
24	175.400	85.000	9.250	22.000	0.000	.	.	.	.	.	.	.	21.000
25	170.600	100.000	9.200	19.000	0.000	.	.	.	.	.	.	.	.
26	174.200	88.000	9.200	16.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.000	16.000	23.000
27	177.400	77.000	9.050	16.000	0.000	.	.	.	.	.	.	.	.
28	174.200	70.000	9.350	20.000	0.000	.	.	.	.	.	.	.	17.000
29	175.000	70.000	9.300	16.000	0.000	.	.	.	.	.	.	.	.
30	172.500	90.000	9.250	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.400	20.000	23.000
31	176.400	66.000	9.300	22.000	0.000	.	.	.	.	.	.	.	.
32	173.600	67.000	9.200	20.000	0.000	.	.	.	.	.	.	.	23.000
33	174.500	92.000	9.150	20.400	0.000	.	.	.	.	.	.	.	.
34	173.500	72.000	9.150	22.000	0.000	.	.	.	.	.	.	.	16.000
35	173.700	82.000	9.150	20.000	0.000	.	.	.	.	.	.	.	.
36	171.600	70.000	9.300	20.000	0.000	-0.010	-0.100	-0.010	-0.010	0.100	0.600	14.000	16.000
37	174.800	62.000	9.300	20.000	0.000	.	.	.	.	.	.	.	.
38	175.500	82.000	9.050	22.000	0.000	.	.	.	.	.	.	.	19.000
39	173.300	65.000	9.250	21.000	0.000	.	.	.	.	.	.	.	.
40	172.700	76.000	9.100	22.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.3. Drainage from 1:1 ratio of RK fines (Reactor 3).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	171.900	89.000	9.000	21.000	0.000	.	.	.	.	.	.	.	.
42	175.600	74.000	9.250	18.000	0.000	.	.	.	.	.	.	.	.
43	171.200	70.000	9.450	18.000	0.000	.	.	.	.	.	.	.	.
44	173.700	66.000	9.100	18.000	0.000	.	.	.	.	.	.	.	.
45	174.800	62.000	9.050	17.000	0.000	.	.	.	.	.	.	.	.
46	173.500	65.000	9.160	16.000	0.000	0.010	-0.100	0.010	0.010	-0.100	0.800	16.000	10.500
47	174.900	60.000	9.200	18.000	0.000	.	.	.	.	.	.	.	.
48	175.400	63.000	9.200	18.000	0.000	.	.	.	.	.	.	.	.
49	174.100	65.000	9.100	16.000	0.000	.	.	.	.	.	.	.	.
50	175.000	60.000	9.200	17.000	0.000	.	.	.	.	.	.	.	9.000
51	174.000	62.000	9.000	15.000	0.000	.	.	.	.	.	.	.	.
52	173.100	52.000	9.050	18.000	0.000	.	.	.	.	.	.	.	.
53	173.700	52.000	9.050	18.000	0.000	.	.	.	.	.	.	.	.
54	173.500	46.000	9.050	17.000	0.000	-0.010	0.050	0.010	0.020	-0.100	1.200	18.000	6.000
55	175.100	50.000	9.000	16.000	0.000	.	.	.	.	.	.	.	.
56	174.200	46.000	8.900	15.000	0.000	.	.	.	.	.	.	.	.
57	173.700	50.000	9.000	15.000	0.000	.	.	.	.	.	.	.	.
58	174.100	50.000	8.850	0.000	0.000	.	.	.	.	.	.	.	9.000
59	169.200	55.000	8.800	22.000	0.000	.	.	.	.	.	.	.	.
60	173.900	65.000	8.750	15.000	0.000	.	.	.	.	.	.	.	.
61	169.700	73.000	8.750	16.000	0.000	.	.	.	.	.	.	.	.
62	176.000	65.000	9.000	16.000	0.000	0.020	0.020	-0.010	0.010	0.030	2.200	13.400	15.000
63	171.000	62.000	8.800	16.000	0.000	.	.	.	.	.	.	.	.
64	174.700	53.000	9.000	17.000	0.000	.	.	.	.	.	.	.	.
65	176.000	46.000	8.950	15.000	0.000	.	.	.	.	.	.	.	.
66	175.000	45.000	8.900	14.000	0.000	.	.	.	.	.	.	.	.
67	170.900	46.000	9.100	15.000	0.000	.	.	.	.	.	.	.	.
68	173.000	56.000	9.150	20.000	0.000	.	.	.	.	.	.	.	.
69	171.200	53.000	8.850	19.000	0.000	.	.	.	.	.	.	.	.
70	174.200	53.000	8.850	18.000	0.000	0.010	0.010	-0.010	0.010	0.050	2.200	12.000	7.500
71	173.800	53.000	9.100	16.000	0.000	.	.	.	.	.	.	.	.
72	167.600	39.000	9.100	0.000	0.000	.	.	.	.	.	.	.	4.000
73	171.200	47.000	9.400	15.000	0.000	.	.	.	.	.	.	.	.
74	174.400	48.000	9.200	16.000	0.000	0.010	0.020	0.010	0.010	0.010	0.400	10.200	4.000
75	167.200	40.000	8.900	10.500	0.000	.	.	.	.	.	.	.	.
76	176.300	50.000	9.100	10.500	0.000	.	.	.	.	.	.	.	16.800
77	168.500	49.000	8.400	13.000	0.000	.	.	.	.	.	.	.	.
78	171.800	49.000	8.900	14.000	0.000	0.010	0.010	0.020	-0.010	-0.010	1.200	10.200	6.000
79	168.800	50.000	9.000	9.000	0.000	.	.	.	.	.	.	.	.
80	172.400	55.000	9.000	12.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.4. Drainage from 3:1 ratio of RK fines (Reactor 5).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	168.400	5000.000	12.600	2204.000	0.000	-0.100	0.100	0.090	0.060	0.100	0.600	1220.000	650.000
1	163.300	1975.000	11.500	397.000	0.000	.	.	.	.	.	.	.	.
2	172.100	600.000	9.350	41.000	0.000	-0.100	0.100	-0.010	0.020	-0.100	10.600	120.000	258.000
3	168.600	385.000	8.200	15.000	0.000	.	.	.	.	.	.	.	.
4	172.000	325.000	8.550	30.000	0.000	-0.100	0.040	-0.010	0.010	-0.100	8.740	50.000	140.000
5	173.000	260.000	8.800	27.000	0.000	.	.	.	.	.	.	.	.
6	172.300	220.000	9.000	25.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	4.250	38.000	70.000
7	172.000	190.000	8.900	25.000	0.000	.	.	.	.	.	.	.	.
8	176.600	195.000	9.000	21.000	0.000	.	.	.	.	.	.	.	.
9	172.800	155.000	9.000	23.000	0.000	.	.	.	.	.	.	.	.
10	168.900	160.000	9.000	31.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	1.200	26.000	41.000
11	176.000	142.000	8.850	25.000	0.000	.	.	.	.	.	.	.	.
12	167.200	120.000	9.050	24.000	0.000	0.030	-0.100	-0.010	0.010	-0.100	2.200	20.000	34.000
13	169.800	120.000	9.100	27.000	0.000	.	.	.	.	.	.	.	.
14	128.000	114.000	8.900	27.000	0.000	0.010	-0.100	0.010	-0.010	-0.100	2.200	20.000	25.000
15	166.100	96.000	9.150	27.000	0.000	.	.	.	.	.	.	.	.
16	166.100	102.000	9.300	27.000	0.000	-0.010	0.010	-0.010	0.020	-0.100	6.200	16.000	18.000
17	165.200	96.000	9.200	27.000	0.000	.	.	.	.	.	.	.	.
18	165.000	98.000	8.900	22.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	5.200	16.000	17.400
19	168.700	85.000	9.000	27.000	0.000	.	.	.	.	.	.	.	.
20	172.100	84.000	9.100	27.000	0.000	0.010	-0.100	-0.010	-0.010	-0.100	4.600	12.000	14.600
21	165.300	81.000	9.100	27.000	0.000	.	.	.	.	.	.	.	.
22	152.700	100.000	8.950	30.000	0.000	.	.	.	.	.	.	.	18.000
23	167.900	75.000	9.250	27.000	0.000	.	.	.	.	.	.	.	.
24	166.400	75.000	9.200	27.000	0.000	.	.	.	.	.	.	.	12.000
25	164.300	76.000	9.250	27.000	0.000	.	.	.	.	.	.	.	.
26	165.800	70.000	9.200	27.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	10.000
27	173.300	65.000	9.050	27.000	0.000	.	.	.	.	.	.	.	.
28	177.000	60.000	9.300	27.000	0.000	.	.	.	.	.	.	.	12.000
29	174.700	57.000	9.250	27.000	0.000	.	.	.	.	.	.	.	.
30	170.000	72.000	9.100	27.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.400	18.000	5.000
31	175.000	57.000	9.250	27.000	0.000	.	.	.	.	.	.	.	.
32	174.300	60.000	9.150	27.000	0.000	.	.	.	.	.	.	.	3.000
33	175.900	72.000	9.000	28.000	0.000	.	.	.	.	.	.	.	.
34	174.700	73.000	9.000	30.000	0.000	.	.	.	.	.	.	.	2.000
35	174.500	70.000	9.050	27.000	0.000	.	.	.	.	.	.	.	.
36	170.900	62.000	9.250	27.000	0.000	0.010	-0.100	-0.010	-0.010	0.100	0.600	12.000	4.000
37	170.400	66.000	9.150	28.000	0.000	.	.	.	.	.	.	.	.
38	187.400	70.000	9.000	32.000	0.000	.	.	.	.	.	.	.	3.500
39	175.100	62.000	9.250	28.000	0.000	.	.	.	.	.	.	.	.
40	172.100	62.000	9.100	27.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.4. Drainage from 3:1 ratio of RK fines (Reactor 5).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	174.700	65.000	9.200	26.000	0.000	.	.	.	.	.	.	.	.
42	174.500	148.000	9.000	37.000	0.000	.	.	.	.	.	.	.	.
43	172.100	78.000	9.200	28.000	0.000	.	.	.	.	.	.	.	.
44	175.200	72.000	9.000	24.000	0.000	.	.	.	.	.	.	.	.
45	175.500	69.000	9.000	23.000	0.000	.	.	.	.	.	.	.	.
46	173.100	78.000	8.960	26.000	0.000	0.010	.	0.040	0.020	.	0.800	20.000	14.000
47	174.200	79.000	9.000	24.000	0.000	.	.	.	.	.	.	.	.
48	173.500	92.000	8.950	21.000	0.000	.	.	.	.	.	.	.	.
49	169.800	115.000	8.750	23.000	0.000	.	.	.	.	.	.	.	.
50	172.800	108.000	8.900	22.000	0.000	.	.	.	.	.	.	.	26.500
51	174.900	105.000	8.850	23.000	0.000	.	.	.	.	.	.	.	.
52	173.800	78.000	8.850	24.000	0.000	.	.	.	.	.	.	.	.
53	173.000	78.000	8.800	25.000	0.000	.	.	.	.	.	.	.	.
54	172.800	80.000	8.800	24.000	0.000	-0.010	0.060	0.010	0.020	-0.100	1.600	28.000	20.000
55	173.000	85.000	8.750	23.000	0.000	.	.	.	.	.	.	.	.
56	172.000	81.000	8.650	23.000	0.000	.	.	.	.	.	.	.	.
57	172.300	81.000	8.800	21.000	0.000	.	.	.	.	.	.	.	.
58	171.200	88.000	8.550	0.000	0.000	.	.	.	.	.	.	.	19.500
59	173.000	78.000	8.800	15.000	0.000	.	.	.	.	.	.	.	.
60	167.800	92.000	8.550	15.000	0.000	.	.	.	.	.	.	.	.
61	172.000	90.000	8.700	16.000	0.000	.	.	.	.	.	.	.	.
62	170.500	79.000	8.600	25.000	0.000	0.010	0.020	0.010	0.010	0.020	2.300	16.600	12.000
63	170.000	70.000	8.800	26.000	0.000	.	.	.	.	.	.	.	.
64	166.400	73.000	8.800	25.000	0.000	.	.	.	.	.	.	.	.
65	171.100	69.000	8.550	24.000	0.000	.	.	.	.	.	.	.	.
66	168.000	67.000	8.450	23.000	0.000	.	.	.	.	.	.	.	.
67	176.600	68.000	8.850	24.000	0.000	.	.	.	.	.	.	.	.
68	174.800	68.000	8.850	26.000	0.000	.	.	.	.	.	.	.	.
69	170.500	68.000	8.650	23.000	0.000	.	.	.	.	.	.	.	.
70	180.200	70.000	8.100	26.000	0.000	0.020	0.020	-0.010	-0.010	0.010	1.800	14.000	14.000
71	173.000	75.000	8.900	24.000	0.000	.	.	.	.	.	.	.	.
72	170.500	68.000	8.850	0.000	0.000	.	.	.	.	.	.	.	9.000
73	172.300	63.000	8.850	23.000	0.000	.	.	.	.	.	.	.	.
74	166.900	72.000	8.550	24.000	0.000	0.010	0.010	0.020	0.010	0.010	0.600	17.400	10.000
75	.	70.000	8.500	21.000	0.000	.	.	.	.	.	.	.	.
76	173.100	70.000	8.700	23.500	0.000	.	.	.	.	.	.	.	14.600
77	168.800	70.000	8.750	19.000	0.000	.	.	.	.	.	.	.	.
78	169.600	70.000	8.700	24.000	0.000	0.010	0.020	0.020	-0.010	-0.010	1.200	15.000	10.400
79	170.200	70.000	8.600	23.000	0.000	.	.	.	.	.	.	.	.
80	170.100	70.000	8.400	19.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.5. Drainage from 3:1 ratio of RK fines (Reactor 6).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	173.300	5000.000	12.600	2256.000	0.000	-0.100	-0.100	0.070	0.060	0.100	0.800	1240.000	540.000
1	169.500	2425.000	12.050	476.000	0.000	.	.	.	.	.	.	.	.
2	171.700	700.000	9.450	39.000	0.000	-0.100	0.100	0.020	0.020	-0.100	11.200	140.000	320.000
3	173.000	400.000	8.100	13.000	0.000	.	.	.	.	.	.	.	.
4	174.500	283.000	8.700	39.000	0.000	-0.100	0.050	-0.010	0.010	-0.100	7.670	88.000	130.000
5	177.100	235.000	8.850	25.000	0.000	.	.	.	.	.	.	.	.
6	172.100	196.000	9.150	26.000	0.000	-0.100	0.020	0.020	-0.010	-0.100	4.080	34.000	70.000
7	174.900	172.000	8.950	25.000	0.000	.	.	.	.	.	.	.	.
8	172.600	210.000	9.000	21.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	1.800	34.000	61.400
9	171.900	182.000	9.000	23.000	0.000	.	.	.	.	.	.	.	.
10	174.400	165.000	9.050	31.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	1.400	28.000	44.000
11	172.100	173.000	8.800	23.000	0.000	.	.	.	.	.	.	.	.
12	174.000	150.000	9.000	27.000	0.000	0.020	-0.100	-0.010	0.010	-0.100	2.400	30.000	50.000
13	176.100	138.000	9.000	27.000	0.000	.	.	.	.	.	.	.	.
14	174.500	100.000	9.300	22.000	0.000	0.020	-0.100	0.020	0.010	-0.100	1.800	18.000	26.000
15	173.400	108.000	9.150	24.000	0.000	.	.	.	.	.	.	.	.
16	176.200	110.000	9.250	22.000	0.000	0.010	-0.100	-0.010	0.020	-0.100	6.000	18.000	24.000
17	176.700	103.000	9.200	22.000	0.000	.	.	.	.	.	.	.	.
18	169.900	102.000	8.900	22.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	5.400	16.000	20.600
19	174.400	92.000	8.900	27.000	0.000	.	.	.	.	.	.	.	.
20	173.400	100.000	9.050	27.000	0.000	0.010	-0.100	-0.010	-0.010	-0.100	4.600	16.000	21.000
21	170.300	100.000	8.700	30.000	0.000	.	.	.	.	.	.	.	.
22	175.300	84.000	9.150	26.000	0.000	.	.	.	.	.	.	.	15.000
23	178.300	88.000	9.200	27.000	0.000	.	.	.	.	.	.	.	.
24	177.700	85.000	9.100	27.000	0.000	.	.	.	.	.	.	.	15.000
25	170.500	94.000	9.050	0.000	0.000	.	.	.	.	.	.	.	.
26	170.200	80.000	9.100	27.000	0.000	-0.010	-0.100	-0.010	-0.010	0.100	1.000	14.000	14.000
27	173.500	83.000	8.950	31.000	0.000	.	.	.	.	.	.	.	.
28	174.700	75.000	9.200	27.000	0.000	.	.	.	.	.	.	.	12.000
29	175.300	75.000	9.150	22.000	0.000	.	.	.	.	.	.	.	.
30	171.800	78.000	9.100	30.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.600	20.000	11.000
31	174.900	72.000	9.100	27.000	0.000	.	.	.	.	.	.	.	.
32	175.800	75.000	9.000	26.000	0.000	.	.	.	.	.	.	.	12.000
33	175.000	83.000	9.050	27.000	0.000	.	.	.	.	.	.	.	.
34	176.100	80.000	9.050	27.000	0.000	.	.	.	.	.	.	.	14.000
35	175.400	75.000	9.050	27.000	0.000	.	.	.	.	.	.	.	.
36	176.800	80.000	9.250	27.000	0.000	-0.010	-0.100	-0.010	0.020	-0.100	0.600	14.000	11.000
37	174.100	70.000	9.250	27.000	0.000	.	.	.	.	.	.	.	.
38	168.600	40.000	9.250	27.000	0.000	.	.	.	.	.	.	.	-1.000
39	173.300	70.000	9.200	28.000	0.000	.	.	.	.	.	.	.	.
40	174.200	63.000	9.150	27.000	0.000	.	.	.	.	.	.	.	.

-: less than

.: not analyzed

Table A1.5. Drainage from 3:1 ratio of RK fines (Reactor 6).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	174.300	63.000	9.200	25.000	0.000	.	.	.	.	.	.	.	.
42	173.100	68.000	9.250	26.000	0.000	.	.	.	.	.	.	.	.
43	174.000	68.000	9.300	24.000	0.000	.	.	.	.	.	.	.	.
44	173.300	70.000	9.000	25.000	0.000	.	.	.	.	.	.	.	.
45	170.500	80.000	8.900	24.000	0.000	.	.	.	.	.	.	.	.
46	173.800	108.000	8.770	26.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	1.200	30.000	31.000
47	174.400	105.000	8.850	21.000	0.000	.	.	.	.	.	.	.	.
48	174.500	145.000	8.750	22.000	0.000	.	.	.	.	.	.	.	.
49	174.500	140.000	8.800	20.000	0.000	.	.	.	.	.	.	.	.
50	172.300	120.000	8.850	25.000	0.000	.	.	.	.	.	.	.	31.000
51	172.500	130.000	8.700	23.000	0.000	.	.	.	.	.	.	.	.
52	175.200	82.000	8.850	23.000	0.000	.	.	.	.	.	.	.	.
53	173.500	113.000	8.700	22.000	0.000	.	.	.	.	.	.	.	.
54	169.800	125.000	8.500	22.000	0.000	0.010	0.050	0.010	0.030	-0.100	1.400	40.000	39.500
55	174.400	94.000	8.750	22.000	0.000	.	.	.	.	.	.	.	.
56	174.800	103.000	8.600	24.000	0.000	.	.	.	.	.	.	.	.
57	174.900	109.000	8.700	24.000	0.000	.	.	.	.	.	.	.	.
58	175.000	115.000	8.100	0.000	0.000	.	.	.	.	.	.	.	31.000
59	174.000	99.000	8.700	22.000	0.000	.	.	.	.	.	.	.	.
60	174.800	103.000	8.650	21.000	0.000	.	.	.	.	.	.	.	.
61	174.900	100.000	8.750	24.000	0.000	.	.	.	.	.	.	.	.
62	176.100	89.000	8.700	22.000	0.000	.	.	.	.	.	.	.	.
63	179.400	75.000	8.950	24.000	0.000	0.010	0.010	-0.010	-0.010	0.070	2.600	16.400	15.500
64	171.800	84.000	8.650	25.000	0.000	.	.	.	.	.	.	.	.
65	173.200	75.000	8.550	22.000	0.000	.	.	.	.	.	.	.	.
66	177.100	82.000	8.600	0.000	0.000	.	.	.	.	.	.	.	.
67	186.200	73.000	8.800	24.000	0.000	.	.	.	.	.	.	.	.
68	169.700	65.000	8.850	29.000	0.000	.	.	.	.	.	.	.	.
69	180.200	65.000	8.850	21.000	0.000	.	.	.	.	.	.	.	.
70	173.400	60.000	8.700	25.000	0.000	0.010	0.030	-0.010	-0.010	0.010	1.600	12.000	10.000
71	175.300	63.000	8.850	24.000	0.000	.	.	.	.	.	.	.	.
72	174.400	58.000	8.900	0.000	0.000	.	.	.	.	.	.	.	6.000
73	177.400	55.000	8.800	22.000	0.000	.	.	.	.	.	.	.	.
74	168.500	60.000	8.300	24.000	0.000	0.010	0.010	0.020	0.010	0.020	0.600	16.200	4.000
75	168.700	60.000	8.500	21.000	0.000	.	.	.	.	.	.	.	.
76	189.800	60.000	8.500	21.000	0.000	.	.	.	.	.	.	.	12.000
77	169.500	55.000	8.700	25.000	0.000	.	.	.	.	.	.	.	.
78	172.600	60.000	8.800	21.000	0.000	0.010	0.010	0.020	0.010	-0.010	1.000	13.800	5.600
79	167.700	70.000	7.800	21.000	0.000	.	.	.	.	.	.	.	.
80	173.200	60.000	8.900	14.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.6. Drainage from 5:1 ratio of RK fines (Reactor 7).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	170.400	5000.000	12.700	2730.000	0.000	-0.100	-0.100	0.070	0.090	0.100	0.600	1580.000	1000.000
1	179.100	5000.000	12.550	1380.000	0.000	.	.	.	.	.	.	.	.
2	173.800	2050.000	11.800	381.000	0.000	-0.100	0.100	0.010	-0.010	-0.100	3.400	360.000	380.000
3	167.500	900.000	8.200	22.000	0.000	.	.	.	.	.	.	.	.
4	167.900	550.000	8.350	48.000	0.000	-0.100	0.020	-0.010	0.010	-0.100	9.780	92.000	226.000
5	169.700	370.000	8.750	41.000	0.000	.	.	.	.	.	.	.	.
6	165.500	233.000	8.850	39.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	7.700	38.000	39.000
7	168.200	175.000	8.750	41.000	0.000	.	.	.	.	.	.	.	.
8	166.700	165.000	8.900	41.000	0.000	-0.010	-0.100	0.020	0.010	-0.100	2.600	26.000	38.000
9	166.000	139.000	8.850	41.000	0.000	.	.	.	.	.	.	.	.
10	170.200	105.000	9.100	31.000	0.000	0.010	-0.100	-0.010	0.020	-0.100	1.600	16.000	17.000
11	169.200	110.000	8.900	33.000	0.000	.	.	.	.	.	.	.	.
12	166.200	112.000	8.800	33.000	0.000	-0.100	-0.100	-0.010	-0.010	-0.100	2.400	18.000	24.000
13	169.800	112.000	8.800	33.000	0.000	.	.	.	.	.	.	.	.
14	165.300	102.000	9.000	32.000	0.000	0.020	-0.100	0.020	-0.010	-0.100	2.400	20.000	17.000
15	167.100	101.000	9.050	32.000	0.000	.	.	.	.	.	.	.	.
16	167.500	105.000	9.150	32.000	0.000	0.010	-0.100	-0.010	0.010	-0.100	5.400	18.000	17.000
17	165.500	102.000	9.000	32.000	0.000	.	.	.	.	.	.	.	.
18	166.300	108.000	8.900	30.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	5.400	18.000	21.000
19	168.200	108.000	8.900	30.000	0.000	.	.	.	.	.	.	.	.
20	167.400	115.000	8.800	30.000	0.000	0.010	-0.100	0.010	-0.010	-0.100	4.800	18.000	24.000
21	167.600	102.000	8.900	32.000	0.000	.	.	.	.	.	.	.	.
22	168.700	96.000	8.950	30.000	0.000	.	.	.	.	.	.	.	16.000
23	168.400	105.000	9.100	32.000	0.000	.	.	.	.	.	.	.	.
24	167.200	97.000	8.800	32.000	0.000	.	.	.	.	.	.	.	18.000
25	166.100	100.000	8.900	32.000	0.000	.	.	.	.	.	.	.	.
26	165.500	102.000	8.850	31.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.400	20.000	21.000
27	170.100	95.000	8.850	31.000	0.000	.	.	.	.	.	.	.	.
28	170.300	87.000	8.900	31.000	0.000	.	.	.	.	.	.	.	13.000
29	170.500	83.000	8.900	30.000	0.000	.	.	.	.	.	.	.	.
30	171.700	82.000	8.900	32.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.400	20.000	5.000
31	171.200	80.000	8.950	32.000	0.000	.	.	.	.	.	.	.	.
32	168.700	80.000	8.850	32.000	0.000	.	.	.	.	.	.	.	9.000
33	169.300	85.000	8.900	30.100	0.000	.	.	.	.	.	.	.	.
34	170.600	124.000	8.950	43.000	0.000	.	.	.	.	.	.	.	14.000
35	169.600	87.000	8.900	36.000	0.000	.	.	.	.	.	.	.	.
36	169.500	80.000	9.150	32.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.000	16.000	17.000
37	169.700	82.000	8.950	34.000	0.000	.	.	.	.	.	.	.	.
38	169.800	78.000	9.000	37.000	0.000	.	.	.	.	.	.	.	2.000
39	170.700	75.000	8.900	37.000	0.000	.	.	.	.	.	.	.	.
40	169.100	73.000	8.900	33.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.6. Drainage from 5:1 ratio of RK fines (Reactor 7).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	173.000	72.000	9.000	31.000	0.000	.	.	.	.	.	.	.	.
42	171.900	70.000	8.750	32.000	0.000	.	.	.	.	.	.	.	.
43	172.600	78.000	9.100	31.000	0.000	.	.	.	.	.	.	.	.
44	171.700	95.000	8.700	32.000	0.000	.	.	.	.	.	.	.	.
45	172.300	125.000	8.700	28.000	0.000	.	.	.	.	.	.	.	.
46	170.700	160.000	8.570	22.000	0.000	-0.010	-0.100	-0.010	0.020	-0.100	1.200	42.000	52.000
47	171.000	164.000	8.550	27.000	0.000	.	.	.	.	.	.	.	.
48	171.300	154.000	8.550	28.000	0.000	.	.	.	.	.	.	.	.
49	169.400	123.000	8.550	26.000	0.000	.	.	.	.	.	.	.	.
50	153.200	152.000	8.500	28.000	0.000	.	.	.	.	.	.	.	39.000
51	169.900	160.000	8.350	30.000	0.000	.	.	.	.	.	.	.	.
52	170.300	108.000	8.350	30.000	0.000	.	.	.	.	.	.	.	.
53	176.700	121.000	8.400	28.000	0.000	.	.	.	.	.	.	.	.
54	170.700	100.000	8.600	29.000	0.000	0.010	0.030	-0.010	0.020	-0.100	1.400	32.000	25.000
55	172.100	104.000	8.600	29.000	0.000	.	.	.	.	.	.	.	.
56	172.800	115.000	8.500	26.000	0.000	.	.	.	.	.	.	.	.
57	174.500	118.000	8.600	28.000	0.000	.	.	.	.	.	.	.	.
58	174.700	108.000	8.500	0.000	0.000	.	.	.	.	.	.	.	34.000
59	174.700	110.000	8.600	26.000	0.000	.	.	.	.	.	.	.	.
60	172.400	112.000	8.600	26.000	0.000	.	.	.	.	.	.	.	.
61	172.400	102.000	8.700	27.000	0.000	.	.	.	.	.	.	.	.
62	172.000	100.000	8.500	28.000	0.000	.	.	.	.	.	.	.	.
63	170.300	95.000	8.700	26.000	0.000	0.010	0.010	0.010	0.010	0.040	2.400	18.200	16.000
64	169.600	93.000	8.500	28.000	0.000	.	.	.	.	.	.	.	.
65	174.200	85.000	8.550	26.000	0.000	.	.	.	.	.	.	.	.
66	167.200	82.000	8.750	25.000	0.000	.	.	.	.	.	.	.	.
67	176.800	98.000	8.500	28.000	0.000	.	.	.	.	.	.	.	.
68	174.500	86.000	8.400	31.000	0.000	.	.	.	.	.	.	.	.
69	186.900	89.000	8.600	34.000	0.000	.	.	.	.	.	.	.	.
70	169.900	75.000	8.550	32.000	0.000	0.010	0.010	-0.010	-0.010	0.010	1.800	16.000	7.000
71	171.900	76.000	8.600	0.000	0.000	.	.	.	.	.	.	.	.
72	168.000	80.000	8.500	0.000	0.000	.	.	.	.	.	.	.	9.500
73	170.000	72.000	8.700	29.000	0.000	.	.	.	.	.	.	.	.
74	168.600	70.000	8.400	25.000	0.000	0.010	0.010	0.020	0.010	-0.010	0.600	18.400	4.600
75	169.500	60.5	8.100	24.000	0.000	.	.	.	.	.	.	.	.
76	170.400	70.000	8.300	18.000	0.000	.	.	.	.	.	.	.	15.200
77	170.100	70.000	8.600	29.000	0.000	.	.	.	.	.	.	.	.
78	170.300	70.000	8.650	28.000	0.000	0.010	0.010	0.010	0.010	-0.010	1.200	16.000	4.000
79	168.500	75.000	8.600	25.000	0.000	.	.	.	.	.	.	.	.
80	170.400	75.000	8.700	24.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.7. Drainage from 0.5:1 ratio of -10 mesh limestone (Reactor 8).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	174.800	200.000	7.800	26.000	6.000	-0.100	0.200	0.030	0.070	0.500	4.000	40.000	64.000
1	175.800	120.000	8.950	18.000	0.000	.	.	.	.	.	.	.	.
2	175.300	118.000	7.850	18.000	6.000	-0.100	0.100	-0.010	-0.010	-0.100	1.800	20.000	48.000
3	175.100	160.000	6.700	5.000	0.000	.	.	.	.	.	.	.	.
4	176.000	149.000	7.200	13.000	0.000	-0.100	0.020	-0.010	0.010	-0.100	0.720	26.000	44.000
5	174.300	133.000	7.900	13.000	0.000	.	.	.	.	.	.	.	.
6	174.100	120.000	7.850	13.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.400	22.000	73.000
7	173.500	108.000	7.750	14.000	0.000	.	.	.	.	.	.	.	.
8	175.400	110.000	8.300	10.000	0.000	-0.010	-0.100	0.010	0.020	-0.100	0.400	18.000	33.600
9	178.400	100.000	8.050	10.000	0.000	.	.	.	.	.	.	.	.
10	173.500	88.000	7.700	15.000	0.000	0.010	-0.100	-0.010	0.020	-0.100	1.000	14.000	24.000
11	176.200	98.000	8.100	10.000	0.000	.	.	.	.	.	.	.	.
12	176.100	85.000	8.300	11.000	0.000	0.010	-0.100	0.010	-0.010	-0.100	1.800	14.000	28.000
13	173.000	97.000	8.350	11.000	0.000	.	.	.	.	.	.	.	.
14	174.400	71.000	8.300	8.000	0.000	0.010	-0.100	0.010	0.010	-0.100	1.400	14.000	23.000
15	173.600	77.000	7.800	8.000	0.000	.	.	.	.	.	.	.	.
16	175.200	90.000	8.050	5.400	0.000	0.010	-0.100	0.010	0.010	-0.100	5.600	14.000	24.200
17	175.000	82.000	8.150	11.000	0.000	.	.	.	.	.	.	.	.
18	174.800	71.000	7.300	8.000	0.000	-0.010	-0.100	0.010	-0.010	-0.100	5.200	10.000	19.000
19	174.300	80.000	7.300	5.400	0.000	.	.	.	.	.	.	.	.
20	174.200	82.000	7.700	0.000	0.000	0.010	-0.100	-0.010	-0.010	-0.100	4.000	12.000	22.000
21	175.300	80.000	7.700	9.700	0.000	.	.	.	.	.	.	.	.
22	175.400	72.000	7.600	8.000	0.000	.	.	.	.	.	.	.	23.000
23	174.700	70.000	7.800	15.000	0.000	.	.	.	.	.	.	.	.
24	175.100	78.000	7.600	15.000	0.000	.	.	.	.	.	.	.	20.000
25	174.600	82.000	7.050	9.000	0.000	.	.	.	.	.	.	.	.
26	175.800	80.000	7.650	9.700	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	28.000
27	176.000	60.000	7.850	5.900	0.000	.	.	.	.	.	.	.	.
28	175.800	47.000	7.600	5.400	0.000	.	.	.	.	.	.	.	15.000
29	174.500	40.000	7.600	7.500	0.000	.	.	.	.	.	.	.	.
30	175.200	60.000	7.650	9.600	0.000	-0.010	-0.100	0.010	-0.010	-0.100	0.400	14.000	18.000
31	174.200	45.000	7.700	7.500	0.000	.	.	.	.	.	.	.	.
32	173.800	43.000	8.050	9.700	0.000	.	.	.	.	.	.	.	12.000
33	173.900	65.000	8.050	8.600	0.000	.	.	.	.	.	.	.	.
34	173.400	42.000	8.250	10.000	0.000	.	.	.	.	.	.	.	10.000
35	174.800	50.000	8.000	7.500	0.000	.	.	.	.	.	.	.	.
36	173.400	38.000	7.950	11.000	0.000	0.010	-0.100	-0.010	-0.010	-0.100	0.600	6.000	10.000
37	174.600	32.000	7.700	9.400	0.000	.	.	.	.	.	.	.	.
38	175.400	43.000	7.800	8.100	0.000	.	.	.	.	.	.	.	40.000
39	174.300	36.000	7.750	8.800	0.000	.	.	.	.	.	.	.	.
40	173.800	38.000	7.900	6.600	0.000	.	.	.	.	.	.	.	.

-: less than

.: not analyzed

Table A1.7. Drainage from 0.5:1 ratio of -10 mesh limestone (Reactor 8).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	173.600	45.000	8.000	7.700	0.000	.	.	.	.	.	.	.	.
42	174.100	39.000	8.350	6.600	0.000	.	.	.	.	.	.	.	.
43	174.000	60.000	7.400	6.600	0.000	.	.	.	.	.	.	.	.
44	174.000	50.000	7.500	6.600	0.000	.	.	.	.	.	.	.	.
45	175.400	55.000	7.150	7.000	0.000	.	.	.	.	.	.	.	.
46	175.300	72.000	7.090	7.000	0.000	0.010	-0.100	-0.010	0.020	-0.100	1.000	18.000	27.000
47	175.200	75.000	7.400	5.500	0.000	.	.	.	.	.	.	.	.
48	174.700	73.000	7.450	4.400	0.000	.	.	.	.	.	.	.	.
49	173.000	62.000	7.550	5.500	0.000	.	.	.	.	.	.	.	.
50	176.400	70.000	7.450	5.500	0.000	.	.	.	.	.	.	.	22.500
51	173.700	75.000	7.650	4.400	0.000	.	.	.	.	.	.	.	.
52	174.100	52.000	7.500	5.500	0.000	.	.	.	.	.	.	.	.
53	173.400	66.000	6.550	5.500	0.000	.	.	.	.	.	.	.	.
54	173.600	55.000	7.650	5.500	0.000	0.010	0.060	0.010	0.030	-0.100	1.400	18.000	23.500
55	175.100	60.000	7.750	5.500	0.000	.	.	.	.	.	.	.	.
56	174.700	67.000	7.850	4.400	0.000	.	.	.	.	.	.	.	.
57	172.900	75.000	7.300	4.400	0.000	.	.	.	.	.	.	.	.
58	174.100	75.000	7.800	0.000	0.000	.	.	.	.	.	.	.	29.000
59	174.800	82.000	6.500	6.600	0.000	.	.	.	.	.	.	.	.
60	173.900	78.000	6.300	6.000	0.000	.	.	.	.	.	.	.	.
61	172.300	75.000	7.750	6.600	0.000	.	.	.	.	.	.	.	.
62	174.600	70.000	6.650	6.600	0.000	.	.	.	.	.	.	.	.
63	173.900	65.000	7.750	7.900	0.000	0.020	0.060	-0.010	0.050	0.020	2.800	12.600	20.500
64	175.100	69.000	6.800	6.300	0.000	.	.	.	.	.	.	.	.
65	190.400	53.000	7.300	5.300	0.000	.	.	.	.	.	.	.	.
66	174.300	41.000	7.900	5.300	0.000	.	.	.	.	.	.	.	.
67	173.700	50.000	6.850	5.000	2.300	.	.	.	.	.	.	.	.
68	173.900	52.000	7.600	5.300	0.000	0.040	-0.010	-0.010	0.030	-0.100	-0.100	14.000	.
69	178.100	49.000	7.800	4.200	0.000	.	.	.	.	.	.	.	.
70	174.200	40.000	7.800	5.200	0.000	0.010	0.040	-0.010	0.010	0.010	2.400	10.000	13.000
71	173.700	42.000	7.750	5.200	0.000	.	.	.	.	.	.	.	.
72	174.400	37.000	7.750	0.000	0.000	.	.	.	.	.	.	.	11.000
73	187.900	45.000	7.500	4.200	0.000	.	.	.	.	.	.	.	.
74	168.900	37.000	6.700	5.200	0.000	0.020	0.030	0.010	0.020	-0.010	0.600	7.400	12.000
75	175.200	45.000	7.300	6.300	0.000	.	.	.	.	.	.	.	.
76	174.100	30.000	7.050	5.200	0.000	.	.	.	.	.	.	.	13.600
77	172.800	38.000	7.000	4.200	0.000	.	.	.	.	.	.	.	.
78	174.500	36.000	6.750	7.000	0.000	0.030	0.040	0.010	0.030	0.010	1.200	7.800	10.400
79	.	34.000	6.800	4.000	0.000	.	.	.	.	.	.	.	.
80	173.200	33.000	6.900	7.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.8. Drainage from 1:1 ratio of -10 mesh limestone (Reactor 9).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	133.800	246.000	7.550	30.000	0.000	-0.100	0.200	0.030	0.080	0.300	4.000	40.000	67.000
1	176.800	130.000	8.900	21.000	0.000	.	.	.	.	.	.	.	.
2	176.000	165.000	8.300	18.000	0.000	-0.100	0.100	-0.010	-0.010	-0.100	2.600	40.000	68.000
3	173.700	158.000	7.150	6.000	0.000	.	.	.	.	.	.	.	.
4	176.700	162.000	8.050	15.000	0.000	-0.100	0.020	-0.010	0.010	-0.100	0.830	30.000	52.000
5	176.900	139.000	8.800	17.000	0.000	.	.	.	.	.	.	.	.
6	176.300	125.000	9.000	16.000	0.000	-0.100	0.010	-0.010	-0.010	-0.100	0.420	176.000	44.000
7	174.400	120.000	8.400	14.000	0.000	.	.	.	.	.	.	.	.
8	173.900	130.000	8.910	5.000	0.000	-0.010	-0.100	0.030	0.020	-0.100	0.600	20.000	38.000
9	174.200	119.000	8.850	14.000	0.000	.	.	.	.	.	.	.	.
10	174.600	110.000	8.700	15.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.400	18.000	29.000
11	174.500	122.000	8.300	17.000	0.000	.	.	.	.	.	.	.	.
12	174.700	83.000	8.900	18.000	0.000	0.010	-0.100	0.020	-0.010	-0.100	1.600	14.000	23.000
13	175.100	104.000	8.950	14.000	0.000	.	.	.	.	.	.	.	.
14	179.100	70.000	9.100	14.000	0.000	0.010	-0.100	-0.010	0.010	0.100	2.600	14.000	23.000
15	174.900	71.000	9.100	15.000	0.000	.	.	.	.	.	.	.	.
16	171.700	80.000	9.100	16.000	0.000	0.060	-0.100	0.080	-0.010	5.900	3.400	12.000	18.000
17	179.100	75.000	9.050	16.000	0.000	.	.	.	.	.	.	.	.
18	175.000	68.000	9.000	16.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	5.400	12.000	14.000
19	172.500	72.000	8.900	16.000	0.000	.	.	.	.	.	.	.	.
20	172.900	95.000	8.600	13.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	4.200	14.000	24.000
21	174.800	70.000	8.800	13.000	0.000	.	.	.	.	.	.	.	.
22	177.000	80.000	8.700	13.000	0.000	.	.	.	.	.	.	.	20.000
23	175.400	70.000	8.800	15.000	0.000	.	.	.	.	.	.	.	.
24	176.900	73.000	7.350	9.700	0.000	.	.	.	.	.	.	.	27.000
25	173.000	75.000	8.850	11.000	0.000	.	.	.	.	.	.	.	.
26	175.500	75.000	8.900	16.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	22.000
27	174.600	50.000	8.950	11.000	0.000	.	.	.	.	.	.	.	.
28	173.100	55.000	9.000	16.000	0.000	.	.	.	.	.	.	.	11.000
29	175.100	45.000	8.900	16.000	0.000	.	.	.	.	.	.	.	.
30	174.400	58.000	8.750	13.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.400	14.000	13.000
31	177.100	49.000	8.350	16.000	0.000	.	.	.	.	.	.	.	.
32	174.200	44.000	8.400	15.000	0.000	.	.	.	.	.	.	.	6.000
33	175.100	56.000	8.900	16.100	0.000	.	.	.	.	.	.	.	.
34	175.000	55.000	8.550	13.000	0.000	.	.	.	.	.	.	.	12.000
35	174.500	52.000	8.450	14.000	0.000	.	.	.	.	.	.	.	.
36	174.300	52.000	8.900	14.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.600	12.000	19.000
37	175.400	45.000	8.850	14.000	0.000	.	.	.	.	.	.	.	.
38	174.900	63.000	7.900	11.000	0.000	.	.	.	.	.	.	.	15.500
39	173.400	45.000	7.650	13.000	0.000	.	.	.	.	.	.	.	.
40	173.100	39.000	7.500	7.100	0.000	.	.	.	.	.	.	.	.

-: less than

.: not analyzed

Table A1.8. Drainage from 1:1 ratio of -10 mesh limestone (Reactor 9).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	171.900	55.000	8.050	11.000	0.000	.	.	.	.	.	.	.	.
42	173.500	40.000	7.700	11.000	0.000	.	.	.	.	.	.	.	.
43	178.300	53.000	8.150	10.000	0.000	.	.	.	.	.	.	.	.
44	177.100	38.000	7.800	8.800	0.000	.	.	.	.	.	.	.	.
45	176.100	38.000	7.650	8.800	0.000	.	.	.	.	.	.	.	.
46	176.000	37.000	8.210	9.600	0.000	0.010	0.100	-0.010	-0.010	-0.100	0.800	12.000	8.000
47	180.300	35.000	8.000	9.900	0.000	.	.	.	.	.	.	.	.
48	178.700	35.000	7.950	8.800	0.000	.	.	.	.	.	.	.	.
49	179.000	30.000	8.000	9.200	0.000	.	.	.	.	.	.	.	.
50	178.900	38.000	8.050	11.000	0.000	.	.	.	.	.	.	.	3.500
51	177.800	31.000	7.050	8.800	0.000	.	.	.	.	.	.	.	.
52	177.700	32.000	8.150	11.000	0.000	.	.	.	.	.	.	.	.
53	177.600	32.000	7.200	11.000	0.000	.	.	.	.	.	.	.	.
54	178.200	40.000	7.950	11.000	0.000	0.010	0.050	0.010	0.020	-0.100	1.000	12.000	4.000
55	176.600	32.000	7.300	8.300	0.000	.	.	.	.	.	.	.	.
56	178.100	45.000	7.150	13.000	0.000	.	.	.	.	.	.	.	.
57	177.200	38.000	7.750	8.800	0.000	.	.	.	.	.	.	.	.
58	176.900	35.000	8.150	0.000	0.000	.	.	.	.	.	.	.	6.000
59	175.200	42.000	7.150	8.800	0.000	.	.	.	.	.	.	.	.
60	175.200	45.000	6.950	7.700	0.000	.	.	.	.	.	.	.	.
61	175.800	49.000	7.750	9.900	0.000	.	.	.	.	.	.	.	.
62	174.700	42.000	7.500	9.200	0.000	.	.	.	.	.	.	.	.
63	175.300	38.000	7.950	7.900	0.000	0.010	0.080	-0.010	0.020	0.030	2.000	10.200	4.500
64	171.200	49.000	7.750	10.500	0.000	.	.	.	.	.	.	.	.
65	175.800	38.000	7.050	10.500	0.000	.	.	.	.	.	.	.	.
66	175.900	35.000	8.200	9.500	0.000	.	.	.	.	.	.	.	.
67	178.400	35.000	7.700	7.400	1.200	.	.	.	.	.	.	.	.
68	176.300	33.000	8.500	12.000	0.000	.	.	.	.	.	.	.	.
69	174.400	29.000	8.600	8.400	0.000	.	.	.	.	.	.	.	.
70	176.000	28.000	8.100	10.500	0.000	0.010	0.010	0.010	-0.010	0.010	2.400	8.000	4.000
71	177.400	26.000	7.950	10.500	0.000	.	.	.	.	.	.	.	.
72	175.100	24.000	7.400	0.000	0.000	.	.	.	.	.	.	.	4.000
73	176.100	30.000	8.250	8.000	0.000	.	.	.	.	.	.	.	.
74	173.300	30.000	7.350	5.200	0.000	0.010	0.010	0.010	0.010	0.010	0.600	7.200	2.000
75	176.000	26.000	7.500	6.300	0.000	.	.	.	.	.	.	.	.
76	170.200	32.000	7.600	8.000	0.000	.	.	.	.	.	.	.	3.600
77	173.400	23.000	7.600	5.300	0.000	.	.	.	.	.	.	.	.
78	172.000	22.000	7.300	9.000	0.000	-0.010	0.010	0.010	0.010	-0.010	1.200	6.400	-1.000
79	172.100	24.000	7.100	7.600	0.000	.	.	.	.	.	.	.	.
80	172.700	25.000	7.300	5.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.9. Drainage from 1:1 ratio of -10 mesh limestone (Reactor 10).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	176.700	190.000	7.500	26.000	0.000	-0.100	0.200	0.030	0.060	0.200	4.000	40.000	67.000
1	177.400	130.000	8.750	23.000	0.000	.	.	.	.	.	.	.	.
2	177.500	142.000	8.300	18.000	0.000	-0.100	0.100	0.010	-0.010	-0.100	2.200	40.000	55.000
3	176.100	165.000	6.850	7.000	0.000	.	.	.	.	.	.	.	.
4	177.900	152.000	8.000	15.000	0.000	-0.100	0.010	-0.010	0.010	-0.100	0.780	24.000	53.000
5	175.000	152.000	8.550	16.000	0.000	.	.	.	.	.	.	.	.
6	177.600	120.000	8.800	16.000	0.000	-0.100	0.020	-0.010	0.010	-0.100	0.400	20.000	37.000
7	174.900	130.000	8.650	16.000	0.000	.	.	.	.	.	.	.	.
8	175.700	115.000	9.000	18.000	0.000	-0.010	-0.100	0.020	0.010	-0.100	0.600	20.000	30.000
9	175.100	107.000	8.850	14.000	0.000	.	.	.	.	.	.	.	.
10	174.200	115.000	8.550	15.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	1.000	20.000	30.600
11	175.100	123.000	8.450	12.000	0.000	.	.	.	.	.	.	.	.
12	175.100	110.000	8.700	19.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	1.600	18.000	35.000
13	173.500	100.000	8.900	15.000	0.000	.	.	.	.	.	.	.	.
14	175.700	83.000	9.050	14.000	0.000	0.010	-0.100	-0.010	0.020	0.100	1.400	16.000	24.000
15	174.100	80.000	8.950	13.000	0.000	.	.	.	.	.	.	.	.
16	172.600	100.000	8.950	11.000	0.000	.	-0.100	-0.010	-0.010	-0.100	4.800	18.000	27.400
17	172.700	85.000	8.900	16.000	0.000	.	.	.	.	.	.	.	.
18	176.500	99.000	8.800	19.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	5.200	16.000	27.400
19	175.800	88.000	8.650	16.000	0.000	.	.	.	.	.	.	.	.
20	175.300	108.000	8.200	13.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	4.200	16.000	30.600
21	177.000	88.000	8.450	16.000	0.000	.	.	.	.	.	.	.	.
22	176.800	72.000	8.800	16.000	0.000	.	.	.	.	.	.	.	22.000
23	176.900	78.000	8.700	16.000	0.000	.	.	.	.	.	.	.	.
24	174.700	75.000	8.100	11.000	0.000	.	.	.	.	.	.	.	24.000
25	173.600	75.000	8.200	11.000	0.000	.	.	.	.	.	.	.	.
26	175.500	80.000	8.450	11.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	27.000
27	175.300	72.000	8.500	15.000	0.000	.	.	.	.	.	.	.	.
28	175.500	70.000	8.300	14.000	0.000	.	.	.	.	.	.	.	21.000
29	175.000	64.000	8.200	11.000	0.000	.	.	.	.	.	.	.	.
30	173.600	73.000	8.200	16.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.600	16.000	20.000
31	175.300	57.000	8.200	11.000	0.000	.	.	.	.	.	.	.	.
32	176.300	53.000	8.150	15.000	0.000	.	.	.	.	.	.	.	13.000
33	173.600	63.000	8.600	16.100	0.000	.	.	.	.	.	.	.	.
34	175.500	61.000	8.350	16.000	0.000	.	.	.	.	.	.	.	18.000
35	174.300	58.000	8.250	15.000	0.000	.	.	.	.	.	.	.	.
36	173.700	70.000	8.650	12.000	0.000	-0.010	-0.100	-0.010	-0.010	0.100	8.000	12.000	21.000
37	175.700	49.000	8.100	15.000	0.000	.	.	.	.	.	.	.	.
38	170.500	55.000	8.250	11.000	0.000	.	.	.	.	.	.	.	4.000
39	178.000	75.000	8.200	13.000	0.000	.	.	.	.	.	.	.	.
40	174.800	44.000	7.700	11.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.9. Drainage from 1:1 ratio of -10 mesh limestone (Reactor 10).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	174.600	51.000	8.000	11.000	0.000	.	.	.	.	.	.	.	.
42	173.500	44.000	8.100	11.000	0.000	.	.	.	.	.	.	.	.
43	174.200	43.000	8.200	8.800	0.000	.	.	.	.	.	.	.	.
44	170.200	50.000	7.900	11.000	0.000	.	.	.	.	.	.	.	.
45	175.100	40.000	7.750	9.000	0.000	.	.	.	.	.	.	.	.
46	173.800	52.000	7.870	9.600	0.000	0.010	-0.100	-0.010	0.020	-0.100	1.000	14.000	14.000
47	173.300	55.000	7.550	9.900	0.000	.	.	.	.	.	.	.	.
48	173.200	53.000	7.100	8.800	0.000	.	.	.	.	.	.	.	.
49	170.500	79.000	7.750	8.800	0.000	.	.	.	.	.	.	.	.
50	172.900	76.000	7.650	9.300	0.000	.	.	.	.	.	.	.	22.000
51	173.600	76.000	7.200	7.600	0.000	.	.	.	.	.	.	.	.
52	172.900	66.000	7.750	11.000	0.000	.	.	.	.	.	.	.	.
53	175.000	53.000	7.050	8.800	0.000	.	.	.	.	.	.	.	.
54	169.300	66.000	7.600	10.000	0.000	-0.010	0.070	-0.010	0.020	-0.100	1.200	20.000	21.500
55	174.000	62.000	7.250	7.700	0.000	.	.	.	.	.	.	.	.
56	172.000	72.000	7.000	11.000	0.000	.	.	.	.	.	.	.	.
57	172.900	75.000	7.650	14.000	0.000	.	.	.	.	.	.	.	.
58	173.900	62.000	7.800	0.000	0.000	.	.	.	.	.	.	.	22.000
59	172.900	62.000	7.100	6.600	0.000	.	.	.	.	.	.	.	.
60	172.700	90.000	7.900	11.000	0.000	.	.	.	.	.	.	.	.
61	175.700	66.000	7.650	9.900	0.000	.	.	.	.	.	.	.	.
62	174.600	60.000	7.250	10.500	0.000	0.020	0.020	0.010	0.010	0.020	2.200	12.600	14.000
63	175.500	59.000	7.900	13.000	0.000	.	.	.	.	.	.	.	.
64	171.100	69.000	7.400	13.000	0.000	.	.	.	.	.	.	.	.
65	170.800	59.000	7.150	12.000	0.000	.	.	.	.	.	.	.	.
66	171.300	43.000	8.100	8.400	0.000	.	.	.	.	.	.	.	.
67	176.000	43.000	7.400	8.000	0.000	.	.	.	.	.	.	.	.
68	173.300	47.000	7.850	11.000	0.000	0.010	-0.010	-0.010	0.010	-0.100	0.100	14.000	.
69	168.000	55.000	8.350	12.000	0.000	.	.	.	.	.	.	.	.
70	175.900	46.000	7.350	9.000	0.000	0.010	0.010	0.010	0.010	0.010	2.000	10.000	13.000
71	170.700	52.000	7.750	7.000	0.000	.	.	.	.	.	.	.	.
72	170.200	58.000	7.800	0.000	0.000	.	.	.	.	.	.	.	14.000
73	174.100	52.000	7.700	8.400	0.000	.	.	.	.	.	.	.	.
74	168.800	43.000	7.100	10.500	0.000	0.020	0.010	0.020	0.010	0.010	0.400	9.200	9.000
75	176.200	50.000	7.650	10.500	0.000	.	.	.	.	.	.	.	.
76	175.400	45.000	7.350	5.200	0.000	.	.	.	.	.	.	.	10.000
77	171.600	36.000	7.300	5.200	0.000	.	.	.	.	.	.	.	.
78	167.500	48.000	7.250	7.000	0.000	0.010	0.020	0.010	0.010	0.010	1.000	10.400	10.400
79	173.000	49.000	7.000	5.700	0.000	.	.	.	.	.	.	.	.
80	169.500	47.000	7.700	9.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.10. Drainage from 2:1 ratio of -10 mesh limestone (Reactor 11).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	168.200	148.000	7.750	26.000	0.000	-0.100	0.100	0.020	0.030	0.100	3.400	40.000	50.000
1	163.500	117.000	8.850	15.000	0.000	.	.	.	.	.	.	.	.
2	165.500	107.000	8.500	21.000	0.000	-0.100	0.100	0.010	-0.010	-0.100	2.200	20.000	43.000
3	173.800	184.000	7.100	8.000	0.000	.	.	.	.	.	.	.	.
4	176.100	115.000	8.500	21.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.930	28.000	60.000
5	176.700	138.000	9.050	19.000	0.000	.	.	.	.	.	.	.	.
6	177.700	123.000	9.000	21.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.470	20.000	44.000
7	176.600	120.000	8.600	19.000	0.000	.	.	.	.	.	.	.	.
8	175.000	120.000	9.020	16.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	0.800	22.000	34.600
9	172.400	112.000	8.600	18.000	0.000	.	.	.	.	.	.	.	.
10	172.900	115.000	8.750	18.000	0.000	-0.010	-0.100	-0.010	-0.010	0.100	1.200	20.000	30.600
11	174.200	118.000	8.100	19.000	0.000	.	.	.	.	.	.	.	.
12	173.000	118.000	8.650	19.000	0.000	0.010	-0.100	0.020	0.010	-0.100	1.800	20.000	36.000
13	173.700	110.000	9.000	18.000	0.000	.	.	.	.	.	.	.	.
14	180.600	80.000	9.050	19.000	0.000	0.020	-0.100	-0.010	0.010	0.100	1.600	14.000	19.000
15	166.500	85.000	8.700	22.000	0.000	.	.	.	.	.	.	.	.
16	174.200	92.000	9.100	22.000	0.000	0.010	-0.100	-0.010	-0.010	-0.100	4.800	14.000	20.000
17	174.800	88.000	8.750	22.000	0.000	.	.	.	.	.	.	.	.
18	172.500	88.000	8.800	19.000	0.000	-0.010	-0.100	0.010	-0.010	-0.100	5.200	14.000	18.000
19	169.900	87.000	8.900	19.000	0.000	.	.	.	.	.	.	.	.
20	175.700	90.000	8.800	22.000	0.000	0.010	-0.100	-0.010	-0.010	-0.100	4.400	14.000	18.000
21	170.400	82.000	8.900	21.000	0.000	.	.	.	.	.	.	.	.
22	186.000	77.000	9.000	22.000	0.000	.	.	.	.	.	.	.	17.000
23	170.300	68.000	9.000	23.000	0.000	.	.	.	.	.	.	.	.
24	172.500	82.000	8.800	22.000	0.000	.	.	.	.	.	.	.	20.000
25	170.800	76.000	8.900	22.000	0.000	.	.	.	.	.	.	.	.
26	168.500	75.000	8.900	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	16.000
27	174.400	78.000	8.400	22.000	0.000	.	.	.	.	.	.	.	.
28	172.600	62.000	9.100	22.000	0.000	.	.	.	.	.	.	.	11.000
29	177.600	65.000	9.050	19.000	0.000	.	.	.	.	.	.	.	.
30	175.000	58.000	9.050	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.400	14.000	5.000
31	187.700	52.000	9.050	19.000	0.000	.	.	.	.	.	.	.	.
32	173.600	50.000	9.000	23.000	0.000	.	.	.	.	.	.	.	4.000
33	172.300	52.000	8.900	19.400	0.000	.	.	.	.	.	.	.	.
34	174.300	55.000	8.950	20.000	0.000	.	.	.	.	.	.	.	6.000
35	171.700	50.000	9.000	22.000	0.000	.	.	.	.	.	.	.	.
36	175.400	52.000	9.100	16.000	0.000	-0.010	-0.100	-0.010	-0.010	0.100	0.600	10.000	6.000
37	172.800	48.000	9.100	18.000	0.000	.	.	.	.	.	.	.	.
38	170.900	40.000	8.200	11.000	0.000	.	.	.	.	.	.	.	12.000
39	170.800	40.000	8.400	15.000	0.000	.	.	.	.	.	.	.	.
40	171.500	49.000	8.500	16.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.10. Drainage from 2:1 ratio of -10 mesh limestone (Reactor 11).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	172.300	59.000	8.700	15.000	0.000	.	.	.	.	.	.	.	.
42	171.600	62.000	8.800	14.000	0.000	.	.	.	.	.	.	.	.
43	172.800	76.000	8.750	14.000	0.000	.	.	.	.	.	.	.	.
44	170.500	78.000	8.550	14.000	0.000	.	.	.	.	.	.	.	.
45	168.400	103.000	8.350	13.000	0.000	.	.	.	.	.	.	.	.
46	177.900	118.000	8.520	11.000	0.000	-0.010	-0.100	0.020	0.020	-0.100	1.200	32.000	41.000
47	180.700	79.000	8.300	13.000	0.000	.	.	.	.	.	.	.	.
48	184.200	75.000	8.300	12.000	0.000	.	.	.	.	.	.	.	.
49	183.300	62.000	8.650	13.000	0.000	.	.	.	.	.	.	.	.
50	184.000	63.000	8.700	15.000	0.000	.	.	.	.	.	.	.	12.000
51	176.100	62.000	8.600	15.000	0.000	.	.	.	.	.	.	.	.
52	182.900	58.000	8.600	15.000	0.000	.	.	.	.	.	.	.	.
53	181.800	62.000	8.000	15.000	0.000	.	.	.	.	.	.	.	.
54	180.400	62.000	8.500	15.000	0.000	0.010	0.040	-0.010	0.020	-0.100	1.400	20.000	15.000
55	182.100	64.000	8.350	15.000	0.000	.	.	.	.	.	.	.	.
56	183.200	55.000	7.850	13.000	0.000	.	.	.	.	.	.	.	.
57	182.200	56.000	8.500	15.000	0.000	.	.	.	.	.	.	.	.
58	182.100	57.000	8.500	0.000	0.000	.	.	.	.	.	.	.	13.000
59	182.600	64.000	8.150	15.000	0.000	.	.	.	.	.	.	.	.
60	185.000	62.000	8.200	14.000	0.000	.	.	.	.	.	.	.	.
61	183.800	65.000	8.450	16.000	0.000	.	.	.	.	.	.	.	.
62	175.500	73.000	8.350	16.000	0.000	0.010	0.030	0.010	-0.010	0.020	2.200	14.800	12.000
63	175.200	65.000	8.750	14.000	0.000	.	.	.	.	.	.	.	.
64	163.400	92.000	8.100	15.000	0.000	.	.	.	.	.	.	.	.
65	185.000	73.000	8.100	15.000	0.000	.	.	.	.	.	.	.	.
66	170.600	59.000	8.700	16.000	0.000	.	.	.	.	.	.	.	.
67	178.800	76.000	8.550	17.000	0.000	.	.	.	.	.	.	.	.
68	176.100	69.000	8.600	16.000	0.000	.	.	.	.	.	.	.	.
69	174.900	54.000	8.650	11.000	0.000	.	.	.	.	.	.	.	.
70	174.000	60.000	8.400	16.000	0.000	0.010	0.010	0.020	0.010	0.010	1.400	12.000	16.000
71	177.900	53.000	8.550	10.500	0.000	.	.	.	.	.	.	.	.
72	172.900	45.000	8.750	0.000	0.000	.	.	.	.	.	.	.	16.000
73	174.000	53.000	8.200	14.000	0.000	.	.	.	.	.	.	.	.
74	174.300	50.000	7.400	18.000	0.000	0.010	0.010	0.020	0.010	0.010	0.800	12.600	7.400
75	183.100	50.000	7.900	12.600	0.000	.	.	.	.	.	.	.	.
76	173.200	48.000	8.000	13.000	0.000	.	.	.	.	.	.	.	6.000
77	.	50.000	7.900	10.500	0.000	.	.	.	.	.	.	.	.
78	174.300	46.000	8.400	12.000	0.000	0.010	0.010	0.010	0.010	0.010	1.200	10.800	5.200
79	173.300	40.000	7.800	10.000	0.000	.	.	.	.	.	.	.	.
80	171.900	55.000	7.600	16.500	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.11. Drainage from 3:1 ratio of -10 mesh limestone (Reactor 12).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	172.400	205.000	7.850	33.000	0.000	-0.100	0.100	0.010	0.040	0.200	4.600	40.000	67.000
1	171.300	128.000	8.800	21.000	0.000	.	.	.	.	.	.	.	.
2	171.600	162.000	8.150	21.000	0.000	-0.100	0.100	-0.010	0.010	-0.100	2.400	40.000	62.000
3	174.800	166.000	7.200	7.000	0.000	.	.	.	.	.	.	.	.
4	172.700	160.000	8.500	21.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.930	28.000	58.000
5	173.800	162.000	8.600	20.000	0.000	.	.	.	.	.	.	.	.
6	173.000	139.000	9.050	21.000	0.000	-0.100	0.010	-0.010	-0.010	-0.100	0.530	20.000	44.000
7	174.000	129.000	8.650	19.000	0.000	.	.	.	.	.	.	.	.
8	174.500	138.000	8.950	16.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	0.800	24.000	38.600
9	173.600	120.000	8.800	19.000	0.000	.	.	.	.	.	.	.	.
10	171.900	120.000	8.500	21.000	0.000	0.010	-0.100	0.020	0.010	-0.100	1.200	18.000	31.000
11	172.400	123.000	8.300	21.000	0.000	.	.	.	.	.	.	.	.
12	172.300	110.000	8.500	22.000	0.000	0.010	-0.100	0.030	0.010	-0.100	1.800	18.000	29.000
13	174.900	118.000	8.500	22.000	0.000	.	.	.	.	.	.	.	.
14	169.600	90.000	8.900	22.000	0.000	-0.100	-0.100	-0.010	-0.010	-0.100	1.400	16.000	22.000
15	169.000	95.000	9.000	22.000	0.000	.	.	.	.	.	.	.	.
16	172.000	98.000	9.150	19.000	0.000	0.020	0.100	-0.010	0.010	-0.100	4.600	16.000	22.600
17	171.500	95.000	9.000	22.000	0.000	.	.	.	.	.	.	.	.
18	169.800	99.000	8.900	19.000	0.000	-0.010	-0.100	0.010	-0.010	-0.100	5.200	18.000	22.600
19	172.500	99.000	8.950	16.000	0.000	.	.	.	.	.	.	.	.
20	170.600	98.000	8.650	24.000	0.000	0.010	0.100	0.010	-0.010	-0.100	4.200	16.000	19.000
21	169.900	88.000	8.850	22.000	0.000	.	.	.	.	.	.	.	.
22	171.000	85.000	9.000	22.000	0.000	.	.	.	.	.	.	.	21.000
23	171.200	80.000	9.000	22.000	0.000	.	.	.	.	.	.	.	.
24	169.900	87.000	8.950	20.000	0.000	.	.	.	.	.	.	.	20.000
25	168.000	78.000	9.000	19.000	0.000	.	.	.	.	.	.	.	.
26	172.800	80.000	8.900	23.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	17.000
27	172.100	70.000	9.000	16.000	0.000	.	.	.	.	.	.	.	.
28	175.600	65.000	9.100	21.000	0.000	.	.	.	.	.	.	.	11.000
29	174.500	55.000	8.950	24.000	0.000	.	.	.	.	.	.	.	.
30	174.600	65.000	8.800	22.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	0.600	16.000	13.000
31	173.100	56.000	9.000	17.000	0.000	.	.	.	.	.	.	.	.
32	172.700	56.000	9.100	19.000	0.000	.	.	.	.	.	.	.	7.000
33	172.400	67.000	8.900	19.400	0.000	.	.	.	.	.	.	.	.
34	173.200	62.000	9.000	19.000	0.000	.	.	.	.	.	.	.	9.000
35	173.400	60.000	9.000	19.000	0.000	.	.	.	.	.	.	.	.
36	174.100	62.000	9.200	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.600	12.000	7.000
37	173.800	55.000	8.200	19.000	0.000	.	.	.	.	.	.	.	.
38	172.700	60.000	9.100	19.000	0.000	.	.	.	.	.	.	.	6.000
39	171.600	56.000	8.850	20.000	0.000	.	.	.	.	.	.	.	.
40	173.300	70.000	8.800	16.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.11. Drainage from 3:1 ratio of -10 mesh limestone (Reactor 12).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	174.100	85.000	8.800	18.000	0.000	.	.	.	.	.	.	.	.
42	173.000	90.000	8.750	20.000	0.000	.	.	.	.	.	.	.	.
43	174.100	89.000	8.900	18.000	0.000	.	.	.	.	.	.	.	.
44	172.800	102.000	8.650	18.000	0.000	.	.	.	.	.	.	.	.
45	173.600	139.000	8.500	15.000	0.000	.	.	.	.	.	.	.	.
46	172.800	140.000	8.570	22.000	0.000	-0.010	0.100	0.020	0.040	0.200	1.400	44.000	48.000
47	173.300	102.000	8.500	18.000	0.000	.	.	.	.	.	.	.	.
48	170.400	100.000	8.550	19.000	0.000	.	.	.	.	.	.	.	.
49	172.400	95.000	8.450	16.000	0.000	.	.	.	.	.	.	.	.
50	169.500	90.000	8.650	22.000	0.000	.	.	.	.	.	.	.	23.000
51	172.600	93.000	8.650	18.000	0.000	.	.	.	.	.	.	.	.
52	173.200	72.000	8.450	18.000	0.000	.	.	.	.	.	.	.	.
53	171.600	85.000	8.200	18.000	0.000	.	.	.	.	.	.	.	.
54	173.000	68.000	8.600	18.000	0.000	0.010	0.060	-0.010	0.010	-0.100	1.800	22.000	17.500
55	173.500	80.000	8.450	18.000	0.000	.	.	.	.	.	.	.	.
56	172.000	85.000	7.950	18.000	0.000	.	.	.	.	.	.	.	.
57	172.200	96.000	8.450	15.000	0.000	.	.	.	.	.	.	.	.
58	174.400	82.000	8.550	0.000	0.000	.	.	.	.	.	.	.	27.000
59	172.200	93.000	8.350	15.000	0.000	.	.	.	.	.	.	.	.
60	168.600	110.000	8.150	21.000	0.000	.	.	.	.	.	.	.	.
61	172.100	80.000	8.550	23.000	0.000	.	.	.	.	.	.	.	.
62	174.000	80.000	8.550	18.000	0.000	0.010	0.020	0.020	0.020	0.030	2.400	16.200	20.000
63	171.800	75.000	8.650	16.000	0.000	.	.	.	.	.	.	.	.
64	172.200	89.000	8.600	15.000	0.000	.	.	.	.	.	.	.	.
65	171.500	80.000	8.350	16.000	0.000	.	.	.	.	.	.	.	.
66	188.000	70.000	8.800	16.000	0.000	.	.	.	.	.	.	.	.
67	167.500	72.000	8.600	16.000	0.000	.	.	.	.	.	.	.	.
68	174.100	96.000	8.450	16.000	0.000	.	.	.	.	.	.	.	.
69	174.300	73.000	8.650	15.000	0.000	.	.	.	.	.	.	.	.
70	173.400	63.000	8.500	18.000	0.000	0.010	0.010	0.020	-0.010	0.010	2.200	12.000	12.000
71	171.500	73.000	8.550	14.000	0.000	.	.	.	.	.	.	.	.
72	177.100	63.000	8.700	0.000	0.000	.	.	.	.	.	.	.	16.000
73	172.900	58.000	8.800	14.000	0.000	.	.	.	.	.	.	.	.
74	175.500	55.000	8.200	10.500	0.000	0.010	0.010	0.010	0.010	0.010	0.800	13.400	10.600
75	172.300	50.000	8.600	12.600	0.000	.	.	.	.	.	.	.	.
76	171.400	50.000	8.600	13.000	0.000	.	.	.	.	.	.	.	13.000
77	.	50.000	8.700	14.000	0.000	.	.	.	.	.	.	.	.
78	174.600	60.000	8.000	12.000	0.000	-0.010	0.010	-0.010	0.010	-0.010	1.200	12.400	6.400
79	172.800	60.000	8.200	11.000	0.000	.	.	.	.	.	.	.	.
80	171.300	60.000	8.500	9.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.12. **Drainage from 3:1 ratio of -10 mesh limestone (Reactor 13).**

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	173.900	208.000	8.150	28.000	0.000	-0.100	0.100	0.010	0.030	-0.100	4.000	40.000	70.000
1	174.900	115.000	8.850	18.000	0.000	.	.	.	.	.	.	.	.
2	173.700	167.000	8.450	18.000	0.000	-0.100	0.100	0.020	-0.010	-0.100	2.800	40.000	63.000
3	172.300	171.000	8.000	8.000	0.000	.	.	.	.	.	.	.	.
4	175.600	160.000	8.700	21.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.900	28.000	57.000
5	175.300	145.000	9.050	19.000	0.000	.	.	.	.	.	.	.	.
6	175.700	122.000	9.150	23.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.470	20.000	39.000
7	175.200	124.000	8.800	17.000	0.000	.	.	.	.	.	.	.	.
8	175.900	115.000	9.200	13.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	0.600	20.000	32.600
9	177.300	115.000	9.000	16.000	0.000	.	.	.	.	.	.	.	.
10	176.000	105.000	9.000	15.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.800	-1.000	26.000
11	173.300	118.000	8.850	14.000	0.000	.	.	.	.	.	.	.	.
12	172.700	100.000	8.800	22.000	0.000	-0.010	-0.100	0.010	-0.010	-0.100	1.800	16.000	29.000
13	175.900	108.000	9.150	17.000	0.000	.	.	.	.	.	.	.	.
14	173.400	79.000	9.300	16.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.400	14.000	20.000
15	172.600	81.000	9.300	16.000	0.000	.	.	.	.	.	.	.	.
16	174.500	80.000	9.500	16.000	0.000	0.010	-0.100	-0.010	0.010	-0.100	4.400	14.000	17.600
17	173.800	78.000	9.300	16.000	0.000	.	.	.	.	.	.	.	.
18	173.400	85.000	9.300	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	5.200	16.000	18.000
19	173.100	75.000	9.300	16.000	0.000	.	.	.	.	.	.	.	.
20	171.900	85.000	9.200	22.000	0.000	-0.010	-0.100	-0.010	0.020	-0.100	3.400	12.000	19.400
21	172.100	70.000	9.300	16.000	0.000	.	.	.	.	.	.	.	.
22	173.100	70.000	9.250	19.000	0.000	.	.	.	.	.	.	.	15.000
23	173.100	78.000	9.300	19.000	0.000	.	.	.	.	.	.	.	.
24	174.200	70.000	9.350	16.000	0.000	.	.	.	.	.	.	.	15.000
25	172.000	74.000	9.300	16.000	0.000	.	.	.	.	.	.	.	.
26	174.800	70.000	9.150	16.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	14.000	.
27	175.600	55.000	9.150	16.000	0.000	.	.	.	.	.	.	.	.
28	174.100	52.000	9.250	16.000	0.000	.	.	.	.	.	.	.	11.000
29	173.700	50.000	9.100	16.000	0.000	.	.	.	.	.	.	.	.
30	180.700	50.000	8.000	16.000	0.000	-0.010	-0.100	0.010	0.010	0.100	0.800	14.000	8.000
31	173.500	50.000	9.200	16.000	0.000	.	.	.	.	.	.	.	.
32	173.000	48.000	9.100	19.000	0.000	.	.	.	.	.	.	.	5.000
33	175.400	58.000	9.050	19.400	0.000	.	.	.	.	.	.	.	.
34	173.600	67.000	9.100	16.000	0.000	.	.	.	.	.	.	.	12.000
35	176.300	60.000	9.100	19.000	0.000	.	.	.	.	.	.	.	.
36	175.300	50.000	9.250	16.000	0.000	0.020	-0.100	-0.010	-0.010	-0.100	0.800	10.000	8.000
37	173.400	65.000	9.100	19.000	0.000	.	.	.	.	.	.	.	.
38	173.100	53.000	8.850	16.000	0.000	.	.	.	.	.	.	.	11.500
39	174.000	52.000	8.850	15.000	0.000	.	.	.	.	.	.	.	.
40	173.500	51.000	8.550	15.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.12. Drainage from 3:1 ratio of -10 mesh limestone (Reactor 13).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	175.000	66.000	8.850	15.000	0.000	.	.	.	.	.	.	.	.
42	174.000	63.000	9.000	15.000	0.000	.	.	.	.	.	.	.	.
43	174.400	72.000	9.000	14.000	0.000	.	.	.	.	.	.	.	.
44	173.700	68.000	8.850	14.000	0.000	.	.	.	.	.	.	.	.
45	175.500	94.000	8.550	15.000	0.000	.	.	.	.	.	.	.	.
46	173.700	102.000	8.590	14.000	0.000	-0.010	-0.100	0.020	0.020	-0.100	1.000	28.000	39.000
47	173.300	98.000	8.400	13.000	0.000	.	.	.	.	.	.	.	.
48	174.400	95.000	8.450	13.000	0.000	.	.	.	.	.	.	.	.
49	175.500	79.000	8.400	9.900	0.000	.	.	.	.	.	.	.	.
50	174.800	102.000	8.500	15.000	0.000	.	.	.	.	.	.	.	30.000
51	173.500	105.000	8.600	15.000	0.000	.	.	.	.	.	.	.	.
52	173.800	74.000	8.450	13.000	0.000	.	.	.	.	.	.	.	.
53	172.300	92.000	8.250	14.000	0.000	.	.	.	.	.	.	.	.
54	175.000	73.000	8.500	15.000	0.000	0.010	0.030	0.020	0.010	-0.100	1.800	22.000	22.000
55	173.300	76.000	8.450	15.000	0.000	.	.	.	.	.	.	.	.
56	173.100	70.000	8.050	13.000	0.000	.	.	.	.	.	.	.	.
57	173.600	87.000	8.400	16.000	0.000	.	.	.	.	.	.	.	.
58	174.700	92.000	8.350	0.000	0.000	.	.	.	.	.	.	.	33.500
59	173.300	83.000	8.150	14.000	0.000	.	.	.	.	.	.	.	.
60	174.300	94.000	8.350	14.000	0.000	.	.	.	.	.	.	.	.
61	173.700	89.000	8.500	15.000	0.000	.	.	.	.	.	.	.	.
62	174.800	75.000	8.350	16.000	0.000	-0.010	0.010	-0.010	0.020	0.020	2.600	15.600	17.000
63	173.300	70.000	8.700	14.000	0.000	.	.	.	.	.	.	.	.
64	174.200	75.000	8.650	15.000	0.000	.	.	.	.	.	.	.	.
65	175.000	65.000	8.400	15.000	0.000	.	.	.	.	.	.	.	.
66	173.000	65.000	8.300	15.000	0.000	.	.	.	.	.	.	.	.
67	174.700	70.000	8.700	14.000	0.000	.	.	.	.	.	.	.	.
68	175.100	70.000	8.700	16.000	0.000	.	.	.	.	.	.	.	.
69	175.200	70.000	7.850	19.000	0.000	.	.	.	.	.	.	.	.
70	172.600	60.000	8.650	16.000	0.000	0.010	0.010	0.020	-0.010	0.010	1.800	12.000	12.500
71	174.400	57.000	8.700	13.000	0.000	.	.	.	.	.	.	.	.
72	173.100	53.000	8.800	0.000	0.000	.	.	.	.	.	.	.	.
73	173.900	53.000	8.800	14.000	0.000	.	.	.	.	.	.	.	.
74	174.300	45.000	8.200	18.000	0.000	0.010	0.010	0.010	0.010	-0.010	0.800	10.400	8.800
75	175.600	40.000	8.600	14.000	0.000	.	.	.	.	.	.	.	.
76	175.600	50.000	8.600	10.000	0.000	.	.	.	.	.	.	.	12.000
77	166.500	40.000	8.500	14.000	0.000	.	.	.	.	.	.	.	.
78	169.400	50.000	8.300	12.000	0.000	0.010	0.010	-0.010	0.010	0.050	1.200	10.800	5.400
79	178.200	50.000	8.100	11.000	0.000	.	.	.	.	.	.	.	.
80	170.800	42.000	8.600	9.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.13. Drainage from 5:1 ratio of -10 mesh limestone (Reactor 14).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	172.300	230.000	8.000	31.000	6.000	-0.100	0.100	0.010	0.040	0.100	4.800	40.000	70.000
1	175.200	138.000	8.850	21.000	0.000	.	.	.	.	.	.	.	.
2	173.400	170.000	8.300	21.000	0.000	-0.100	0.100	0.010	0.010	.	2.800	40.000	62.000
3	175.800	187.000	8.000	9.000	0.000	.	.	.	.	.	.	.	.
4	172.200	169.000	8.550	21.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	1.080	38.000	58.000
5	176.100	140.000	9.000	21.000	0.000	.	.	.	.	.	.	.	.
6	174.300	128.000	9.050	21.000	0.000	-0.100	0.020	-0.010	-0.010	-0.100	0.580	22.000	39.000
7	173.000	132.000	8.800	19.000	0.000	.	.	.	.	.	.	.	.
8	175.700	125.000	9.100	21.000	0.000	-0.010	-0.100	0.010	0.010	-0.100	1.200	20.000	34.400
9	171.700	131.000	8.500	21.000	0.000	.	.	.	.	.	.	.	.
10	173.700	118.000	8.700	21.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	18.000	28.600
11	172.300	135.000	8.500	21.000	0.000	.	.	.	.	.	.	.	.
12	171.000	112.000	8.700	27.000	0.000	-0.010	-0.100	0.020	-0.010	-0.100	1.800	18.000	29.000
13	174.300	135.000	.	27.000	0.000	.	.	.	.	.	.	.	.
14	172.100	95.000	9.000	22.000	0.000	-0.010	-0.100	0.010	-0.010	-0.100	1.600	16.000	24.000
15	168.100	106.000	8.800	22.000	0.000	.	.	.	.	.	.	.	.
16	172.900	90.000	9.400	22.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	4.800	16.000	20.000
17	173.400	90.000	9.250	22.000	0.000	.	.	.	.	.	.	.	.
18	169.600	95.000	9.100	19.000	0.000	-0.010	-0.100	-0.010	0.010	-0.100	4.800	18.000	21.400
19	170.100	86.000	9.100	16.000	0.000	.	.	.	.	.	.	.	.
20	173.000	85.000	9.200	24.000	0.000	-0.010	-0.100	0.010	-0.010	-0.100	4.200	14.000	17.400
21	170.100	83.000	9.100	27.000	0.000	.	.	.	.	.	.	.	.
22	171.700	85.000	9.150	22.000	0.000	.	.	.	.	.	.	.	19.000
23	172.700	82.000	9.300	19.000	0.000	.	.	.	.	.	.	.	.
24	171.600	78.000	9.300	16.000	0.000	.	.	.	.	.	.	.	18.000
25	172.600	71.000	9.150	19.000	0.000	.	.	.	.	.	.	.	.
26	174.400	70.000	9.200	19.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	1.200	12.000	13.000
27	174.600	62.000	9.200	16.000	0.000	.	.	.	.	.	.	.	.
28	173.600	60.000	9.250	21.000	0.000	.	.	.	.	.	.	.	10.000
29	172.700	58.000	9.150	17.000	0.000	.	.	.	.	.	.	.	.
30	173.100	70.000	9.000	22.000	0.000	-0.010	-0.100	-0.010	-0.010	-0.100	0.600	16.000	4.000
31	171.400	66.000	9.100	22.000	0.000	.	.	.	.	.	.	.	.
32	169.800	63.000	9.000	22.000	0.000	.	.	.	.	.	.	.	9.000
33	174.500	59.000	9.100	21.500	0.000	.	.	.	.	.	.	.	.
34	173.500	70.000	9.200	22.000	0.000	.	.	.	.	.	.	.	19.000
35	174.300	65.000	9.150	22.000	0.000	.	.	.	.	.	.	.	.
36	174.500	66.000	9.200	16.000	0.000	0.010	-0.100	0.010	-0.010	-0.100	0.800	14.000	17.000
37	174.300	65.000	9.150	22.000	0.000	.	.	.	.	.	.	.	.
38	174.900	80.000	9.050	20.000	0.000	.	.	.	.	.	.	.	15.000
39	174.500	60.000	9.000	24.000	0.000	.	.	.	.	.	.	.	.
40	175.100	55.000	9.050	19.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.13. Drainage from 5:1 ratio of -10 mesh limestone (Reactor 14).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	173.000	60.000	9.100	20.000	0.000	.	.	.	.	.	.	.	.
42	174.000	58.000	9.150	20.000	0.000	.	.	.	.	.	.	.	.
43	173.000	58.000	9.250	20.000	0.000	.	.	.	.	.	.	.	.
44	173.300	60.000	9.000	20.000	0.000	.	.	.	.	.	.	.	.
45	173.400	55.000	8.950	22.000	0.000	.	.	.	.	.	.	.	.
46	173.200	64.000	8.910	21.000	0.000	-0.010	0.100	0.010	0.010	0.100	1.000	20.000	11.000
47	171.100	69.000	8.800	21.000	0.000	.	.	.	.	.	.	.	.
48	173.600	65.000	8.900	19.000	0.000	.	.	.	.	.	.	.	.
49	175.700	62.000	8.900	18.000	0.000	.	.	.	.	.	.	.	.
50	174.200	75.000	8.950	21.000	0.000	.	.	.	.	.	.	.	.
51	172.500	79.000	8.650	18.000	0.000	.	.	.	.	.	.	.	15.000
52	173.400	60.000	8.850	18.000	0.000	.	.	.	.	.	.	.	.
53	172.300	64.000	8.850	22.000	0.000	.	.	.	.	.	.	.	.
54	174.700	56.000	8.850	21.000	0.000	-0.010	0.020	0.010	0.010	-0.100	1.600	18.000	16.000
55	174.400	56.000	8.800	18.000	0.000	.	.	.	.	.	.	.	.
56	174.700	60.000	8.600	18.000	0.000	.	.	.	.	.	.	.	.
57	172.400	68.000	8.750	16.000	0.000	.	.	.	.	.	.	.	.
58	173.600	67.000	8.800	0.000	0.000	.	.	.	.	.	.	.	.
59	174.400	68.000	8.700	18.000	0.000	.	.	.	.	.	.	.	14.000
60	175.500	75.000	8.750	18.000	0.000	.	.	.	.	.	.	.	.
61	173.700	75.000	8.850	18.000	0.000	.	.	.	.	.	.	.	.
62	174.600	70.000	8.800	14.000	0.000	-0.010	0.010	0.010	-0.010	0.010	2.400	15.000	12.000
63	169.400	70.000	8.850	20.000	0.000	.	.	.	.	.	.	.	.
64	175.700	70.000	8.950	18.000	0.000	.	.	.	.	.	.	.	.
65	174.500	63.000	8.700	19.000	0.000	.	.	.	.	.	.	.	.
66	174.200	61.000	8.900	18.000	0.000	.	.	.	.	.	.	.	.
67	175.600	62.000	9.000	17.000	0.000	.	.	.	.	.	.	.	.
68	174.900	62.000	8.950	20.000	0.000	.	.	.	.	.	.	.	.
69	173.500	66.000	7.900	21.000	0.000	.	.	.	.	.	.	.	.
70	187.500	52.000	8.850	16.000	0.000	0.010	0.020	0.010	0.010	0.120	2.600	12.000	8.000
71	174.800	56.000	9.000	16.000	0.000	.	.	.	.	.	.	.	.
72	174.100	49.000	9.000	0.000	0.000	.	.	.	.	.	.	.	.
73	174.100	52.000	9.100	17.000	0.000	.	.	.	.	.	.	.	.
74	172.100	45.000	8.750	16.000	0.000	0.010	0.010	0.010	0.010	-0.010	1.000	10.600	5.600
75	171.600	40.000	8.900	19.000	0.000	.	.	.	.	.	.	.	.
76	170.600	50.000	8.700	16.000	0.000	.	.	.	.	.	.	.	9.000
77	173.300	45.000	8.900	13.000	0.000	.	.	.	.	.	.	.	.
78	172.600	49.000	8.700	14.000	0.000	0.010	0.010	-0.010	0.010	-0.010	1.400	11.400	-1.000
79	170.900	50.000	7.500	18.000	0.000	.	.	.	.	.	.	.	.
80	171.000	52.000	8.400	12.000	0.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.14. Drainage from 0.5:1 ratio of -0.25/+10 mesh limestone (Reactor 15).
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	163.600	170.000	6.400	10.300	6.000	-0.100	0.300	0.030	0.190	1.000	4.200	20.000	62.000
1	177.200	95.000	6.600	7.700	0.000	.	.	.	.	.	.	.	.
2	174.700	72.000	6.050	5.200	6.000	-0.100	0.100	-0.010	0.060	-0.100	2.600	20.000	28.000
3	178.500	75.000	.	0.000	0.000	.	.	.	.	.	.	.	.
4	176.200	103.000	5.800	7.700	6.000	-0.100	0.580	0.070	0.210	-0.100	1.970	18.000	38.000
5	176.100	100.000	5.300	4.100	0.000	.	.	.	.	.	.	.	.
6	176.000	100.000	4.950	7.700	6.000	0.100	1.270	0.180	0.950	1.000	2.220	10.000	37.000
7	176.200	96.000	4.700	2.100	0.000	.	.	.	.	.	.	.	.
8	173.700	115.000	4.600	5.200	23.900	0.110	1.500	0.200	1.460	5.100	2.400	8.000	36.000
9	175.200	105.000	4.700	4.100	0.000	.	.	.	.	.	.	.	.
10	176.400	105.000	4.500	0.000	17.900	0.100	0.800	0.070	0.750	6.900	1.400	20.000	32.600
11	173.600	128.000	4.500	0.000	36.000	.	.	.	.	.	.	.	.
12	175.600	178.000	4.300	0.000	78.000	-0.010	1.200	0.130	0.540	20.400	3.400	8.000	77.000
13	169.800	247.000	4.200	0.000	102.000	.	.	.	.	.	.	.	.
14	175.600	213.000	4.000	0.000	66.000	0.070	1.200	0.120	0.280	23.900	3.600	8.000	98.000
15	173.600	180.000	4.000	0.000	66.000	.	.	.	.	.	.	.	.
16	171.900	185.000	3.800	0.000	60.000	0.030	0.900	0.080	0.130	20.400	6.000	0.600	65.200
17	173.200	245.000	4.000	0.000	78.000	.	.	.	.	.	.	.	.
18	176.000	188.000	3.950	0.000	75.000	0.030	0.700	0.070	0.100	19.900	6.000	8.000	59.200
19	175.700	243.000	3.900	0.000	87.000	.	.	.	.	.	.	.	.
20	173.600	270.000	4.000	0.000	87.000	0.080	0.800	0.030	0.100	26.300	4.400	6.000	75.300
21	171.100	258.000	3.800	0.000	108.000	.	.	.	.	.	.	.	.
22	174.600	210.000	3.900	0.000	87.000	.	.	.	.	.	.	.	57.000
23	173.700	260.000	3.700	0.000	84.000	.	.	.	.	.	.	.	.
24	172.500	230.000	3.900	0.000	68.000	.	.	.	.	.	.	.	70.000
25	173.000	210.000	3.900	0.000	90.000	.	.	.	.	.	.	.	.
26	173.200	190.000	3.800	0.000	27.000	0.060	0.900	0.030	0.050	19.300	1.400	6.000	54.000
27	175.400	198.000	3.650	0.000	63.000	.	.	.	.	.	.	.	.
28	176.700	185.000	3.500	0.000	18.000	.	.	.	.	.	.	.	49.000
29	174.100	192.000	3.800	0.000	65.000	.	.	.	.	.	.	.	.
30	175.000	175.000	3.900	0.000	66.000	0.050	0.800	0.070	0.050	17.300	1.200	6.000	20.000
31	176.500	170.000	3.750	0.000	39.000	.	.	.	.	.	.	.	.
32	174.000	170.000	3.900	0.000	72.000	.	.	.	.	.	.	.	30.000
33	175.800	145.000	3.950	0.000	65.000	.	.	.	.	.	.	.	.
34	175.300	135.000	3.750	0.000	54.000	.	.	.	.	.	.	.	29.000
35	176.000	155.000	3.800	0.000	66.000	.	.	.	.	.	.	.	.
36	172.900	132.000	3.850	0.000	34.000	0.070	0.600	0.070	0.060	9.500	1.200	6.000	26.000
37	175.700	135.000	3.750	0.000	52.000	.	.	.	.	.	.	.	.
38	175.400	150.000	3.750	0.000	40.000	.	.	.	.	.	.	.	.
39	170.300	158.000	3.800	0.000	37.000	.	.	.	.	.	.	.	.
40	181.800	149.000	3.750	0.000	41.000	0.500	0.500	0.060	0.070	6.600	1.000	6.000	24.500
40	196.900	92.000	4.000	0.000	0.000	.	.	.	.	.	.	.	16.500
40	194.700	65.000	4.050	0.000	18.000	0.400	0.100	0.020	0.030	2.100	0.600	4.000	11.000
40	203.900	50.000	4.150	0.000	0.000	.	.	.	.	.	.	.	6.000
40	199.400	41.000	4.200	0.000	12.000	0.200	-0.100	0.010	0.020	0.700	0.400	2.000	5.000

-: less than
.: not analyzed

Table A1.15. Drainage from 1:1 ratio of -0.25/+10 mesh limestone (Reactor 16).
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	173.200	147.000	6.450	10.300	6.000	-0.100	0.300	0.030	0.190	2.600	4.000	20.000	65.000
1	177.600	100.000	6.700	5.200	0.000	.	.	.	.	.	.	.	.
2	177.500	79.000	6.050	5.200	0.000	-0.100	0.100	-0.010	0.040	-0.100	2.600	20.000	41.000
3	178.800	85.000	5.800	2.500	0.000	.	.	.	.	.	.	.	.
4	174.500	119.000	5.800	5.200	4.500	-0.100	0.660	0.080	0.220	-0.100	2.300	22.000	47.000
5	178.200	102.000	5.350	4.100	0.000	.	.	.	.	.	.	.	.
6	177.200	80.000	5.150	5.200	0.000	0.100	0.890	0.120	0.530	0.400	1.440	8.000	27.000
7	172.800	75.000	4.950	3.100	0.000	.	.	.	.	.	.	.	.
8	180.300	80.000	4.890	7.700	12.000	0.090	1.100	0.150	0.860	1.400	1.800	8.000	30.000
9	176.500	70.000	4.900	4.100	0.000	.	.	.	.	.	.	.	.
10	175.400	70.000	4.600	0.000	12.000	0.130	0.600	0.050	0.650	1.800	2.400	6.000	20.600
11	175.000	80.000	4.600	0.000	20.000	.	.	.	.	.	.	.	.
12	175.300	68.000	4.500	0.000	15.000	0.060	0.600	0.090	0.510	2.400	2.400	6.000	23.000
13	185.000	104.000	4.350	0.000	24.000	.	.	.	.	.	.	.	.
14	186.300	64.000	4.350	0.000	12.000	0.130	0.400	0.060	0.290	3.100	2.000	4.000	23.000
15	174.000	70.000	4.300	0.000	12.000	.	.	.	.	.	.	.	.
16	184.500	105.000	4.050	0.000	27.000	0.110	0.600	0.070	0.390	8.100	5.200	6.000	30.000
17	177.300	95.000	4.300	0.000	24.000	.	.	.	.	.	.	.	.
18	184.400	92.000	4.200	0.000	27.000	0.110	0.400	0.080	0.230	6.400	5.400	0.800	27.600
19	175.600	88.000	4.200	0.000	24.000	.	.	.	.	.	.	.	.
20	177.700	105.000	4.300	0.000	0.000	0.160	0.400	0.040	0.240	8.100	4.600	4.000	30.000
21	185.400	120.000	4.000	0.000	39.000	.	.	.	.	.	.	.	.
22	182.400	90.000	4.150	0.000	24.000	.	.	.	.	.	.	.	29.000
23	184.700	90.000	4.100	0.000	27.000	.	.	.	.	.	.	.	.
24	180.200	90.000	4.200	0.000	18.000	.	.	.	.	.	.	.	25.000
25	171.500	100.000	4.100	0.000	24.000	.	.	.	.	.	.	.	.
26	176.800	115.000	4.050	0.000	36.000	0.150	0.400	0.030	0.170	7.500	1.600	4.000	33.000
27	178.700	110.000	3.950	0.000	42.000	.	.	.	.	.	.	.	.
28	174.700	105.000	3.750	0.000	36.000	.	.	.	.	.	.	.	30.000
29	174.200	125.000	4.050	0.000	43.000	.	.	.	.	.	.	.	.
30	174.200	150.000	3.950	0.000	58.000	0.160	0.400	0.020	0.170	12.500	1.000	6.000	22.000
31	177.100	145.000	3.850	0.000	48.000	.	.	.	.	.	.	.	.
32	174.600	146.000	4.000	0.000	54.000	.	.	.	.	.	.	.	39.000
33	177.900	164.000	3.950	0.000	50.000	.	.	.	.	.	.	.	.
34	171.600	172.000	3.800	0.000	72.000	.	.	.	.	.	.	.	53.000
35	173.400	165.000	3.800	0.000	66.000	.	.	.	.	.	.	.	.
36	174.300	172.000	3.850	0.000	49.000	0.220	0.400	0.050	0.160	14.400	1.200	6.000	53.000
37	177.700	162.000	3.800	0.000	60.000	.	.	.	.	.	.	.	.
38	174.300	167.000	3.800	0.000	46.000	.	.	.	.	.	.	.	.
39	175.500	185.000	3.800	0.000	46.000	.	.	.	.	.	.	.	.
40	175.700	187.000	3.750	0.000	61.000	.	.	.	.	.	.	.	.
40	200.500	83.000	4.050	0.000	0.000	.	.	.	.	.	.	.	.
40	198.100	55.000	4.200	0.000	12.000	.	.	.	.	.	.	.	.
40	200.800	41.000	4.300	0.000	0.000	.	.	.	.	.	.	.	.
40	173.100	80.000	3.900	0.000	15.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.16. **Drainage from 1:1 ratio of -0.25/+10 mesh limestone (Reactor 17).**
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	171.000	140.000	6.600	5.200	4.500	-0.100	0.300	0.030	0.170	1.400	4.000	20.000	56.000
1	173.000	98.000	6.700	5.200	0.000	.	.	.	.	.	.	.	.
2	175.100	78.000	7.100	5.200	0.000	-0.100	0.100	0.030	0.040	-0.100	2.600	20.000	31.000
3	176.700	103.000	6.200	2.000	0.000	.	.	.	.	.	.	.	.
4	173.500	125.000	5.500	5.200	0.000	-0.100	0.930	0.110	0.350	0.200	2.550	18.000	52.000
5	172.200	105.000	5.300	4.100	0.000	.	.	.	.	.	.	.	.
6	172.900	86.000	5.100	5.200	0.000	0.100	0.900	0.130	0.720	0.800	1.620	10.000	25.000
7	174.800	86.000	4.950	2.100	0.000	.	.	.	.	.	.	.	.
8	176.200	60.000	4.800	5.200	18.000	0.100	1.200	0.170	1.050	3.200	2.000	8.000	28.400
9	176.500	80.000	4.800	3.100	0.000	.	.	.	.	.	.	.	.
10	174.900	75.000	4.600	0.000	18.000	0.130	0.600	0.070	0.580	3.100	2.000	6.000	24.000
11	173.100	85.000	4.600	0.000	18.000	.	.	.	.	.	.	.	.
12	173.000	82.000	4.400	0.000	18.000	0.100	0.600	0.070	0.450	4.000	2.200	4.400	29.000
13	177.500	132.000	4.400	0.000	42.000	.	.	.	.	.	.	.	.
14	175.100	105.000	4.200	0.000	30.000	0.100	0.600	0.080	0.300	10.000	2.400	4.000	41.000
15	174.400	120.000	4.200	0.000	33.000	.	.	.	.	.	.	.	.
16	172.100	153.000	3.900	0.000	48.000	0.060	0.800	0.050	0.270	16.000	5.000	6.000	49.000
17	173.500	158.000	4.150	0.000	54.000	.	.	.	.	.	.	.	.
18	171.000	178.000	4.100	0.000	84.000	0.040	0.800	0.070	0.190	20.400	5.400	8.000	57.000
19	171.000	178.000	4.050	0.000	66.000	.	.	.	.	.	.	.	.
20	172.700	230.000	4.300	0.000	87.000	0.070	0.800	0.080	0.180	28.900	5.000	6.000	70.700
21	169.700	220.000	3.850	0.000	94.000	.	.	.	.	.	.	.	.
22	165.100	205.000	4.050	0.000	78.000	.	.	.	.	.	.	.	84.000
23	167.500	300.000	3.850	0.000	122.000	.	.	.	.	.	.	.	.
24	166.900	290.000	3.800	0.000	102.000	.	.	.	.	.	.	.	88.000
25	166.300	275.000	3.900	0.000	108.000	.	.	.	.	.	.	.	.
26	168.400	205.000	3.800	0.000	90.000	0.070	0.800	0.040	0.070	21.100	1.800	6.000	59.000
27	175.800	172.000	3.900	0.000	66.000	.	.	.	.	.	.	.	.
28	176.500	145.000	3.700	0.000	60.000	.	.	.	.	.	.	.	46.000
29	177.400	140.000	4.050	0.000	53.000	.	.	.	.	.	.	.	.
30	174.500	158.000	3.850	0.000	54.000	0.060	0.500	0.060	0.060	9.700	1.200	6.000	27.000
31	174.500	137.000	3.900	0.000	47.000	.	.	.	.	.	.	.	.
32	176.400	122.000	4.100	0.000	48.000	.	.	.	.	.	.	.	23.000
33	174.600	130.000	3.900	0.000	48.000	.	.	.	.	.	.	.	.
34	175.400	132.000	3.900	0.000	52.000	.	.	.	.	.	.	.	30.000
35	175.200	132.000	3.950	0.000	52.000	.	.	.	.	.	.	.	.
36	176.300	105.000	4.050	0.000	24.000	0.070	0.400	0.050	0.050	7.800	1.200	6.000	20.000
37	176.500	105.000	3.950	0.000	46.000	.	.	.	.	.	.	.	.
38	174.500	130.000	3.900	0.000	47.000	.	.	.	.	.	.	.	.
39	175.500	132.000	3.900	0.000	24.000	.	.	.	.	.	.	.	.
40	175.400	115.000	3.950	0.000	24.000	0.090	0.400	0.050	0.080	6.300	1.000	6.000	23.000
40	198.100	70.000	4.150	0.000	0.000	.	.	.	.	.	.	.	14.000
40	197.000	>1.000	4.250	0.000	11.000	0.050	0.100	0.020	0.020	2.000	.	4.000	7.000
40	203.600	41.000	4.300	0.000	0.000	.	.	.	.	.	.	.	4.000
40	200.300	52.000	4.100	0.000	12.000	0.020	-0.100	0.010	0.020	1.000	.	2.000	3.000

-: less than
.: not analyzed

Table A1.17. Drainage from 2:1 ratio of -0.25/+10 mesh limestone (Reactor 18).
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	172.700	145.000	6.600	5.200	0.000	-0.100	0.300	0.040	0.170	1.500	3.800	20.000	61.000
1	174.900	95.000	6.600	5.200	0.000	.	.	.	.	.	.	.	.
2	174.700	78.000	6.600	5.200	0.000	-0.100	0.100	-0.010	0.050	-0.100	2.200	20.000	41.000
3	175.300	82.000	6.300	2.000	0.000	.	.	.	.	.	.	.	.
4	175.200	126.000	5.600	5.200	0.000	-0.100	0.690	0.080	0.240	-0.100	2.530	20.000	54.000
5	175.500	95.000	5.350	4.100	0.000	.	.	.	.	.	.	.	.
6	174.100	93.000	5.100	5.200	0.000	0.100	0.900	0.130	0.610	0.700	1.830	10.000	28.000
7	175.300	86.000	4.950	3.100	0.000	.	.	.	.	.	.	.	.
8	174.600	95.000	4.690	5.200	14.000	0.090	1.100	0.160	0.830	2.400	2.000	10.000	29.000
9	175.300	94.000	4.850	3.100	0.000	.	.	.	.	.	.	.	.
10	176.800	80.000	4.650	0.000	18.000	0.100	0.500	0.060	0.510	3.000	1.800	6.000	25.000
11	177.000	93.000	4.600	0.000	24.000	.	.	.	.	.	.	.	.
12	174.600	102.000	4.400	0.000	24.000	0.100	0.800	0.080	0.480	6.700	2.600	6.000	45.000
13	173.400	188.000	4.300	0.000	66.000	.	.	.	.	.	.	.	.
14	175.900	188.000	4.200	0.000	60.000	0.090	1.000	0.070	0.320	19.700	3.200	12.000	85.000
15	175.200	182.000	4.100	0.000	60.000	.	.	.	.	.	.	.	.
16	177.000	245.000	3.850	0.000	81.000	0.040	1.100	0.080	0.250	25.600	5.600	10.000	74.800
17	174.200	228.000	4.050	0.000	78.000	.	.	.	.	.	.	.	.
18	176.500	272.000	4.000	0.000	114.000	0.030	1.000	0.060	0.210	30.000	6.200	10.000	96.000
19	174.900	240.000	3.950	0.000	84.000	.	.	.	.	.	.	.	.
20	175.500	310.000	4.100	0.000	96.000	0.070	1.000	0.060	0.150	28.100	5.200	10.000	96.000
21	177.000	270.000	3.800	0.000	101.000	.	.	.	.	.	.	.	.
22	173.200	255.000	3.850	0.000	90.000	.	.	.	.	.	.	.	97.000
23	172.700	320.000	3.700	0.000	120.000	.	.	.	.	.	.	.	.
24	174.600	255.000	3.850	0.000	84.000	.	.	.	.	.	.	.	94.000
25	172.700	260.000	4.000	0.000	90.000	.	.	.	.	.	.	.	.
26	175.200	205.000	3.900	0.000	72.000	0.050	0.800	0.040	0.050	20.400	1.600	10.000	69.000
27	175.800	190.000	3.800	0.000	54.000	.	.	.	.	.	.	.	.
28	174.200	170.000	3.650	0.000	60.000	.	.	.	.	.	.	.	49.000
29	173.700	162.000	3.900	0.000	60.000	.	.	.	.	.	.	.	.
30	173.900	180.000	3.800	0.000	57.000	0.050	0.600	0.040	0.040	10.600	1.000	12.000	43.000
31	174.400	182.000	3.750	0.000	54.000	.	.	.	.	.	.	.	.
32	173.800	170.000	3.950	0.000	54.000	.	.	.	.	.	.	.	43.000
33	171.400	175.000	3.900	0.000	60.000	.	.	.	.	.	.	.	.
34	173.700	155.000	3.850	0.000	48.000	.	.	.	.	.	.	.	34.000
35	173.300	170.000	3.850	0.000	54.000	.	.	.	.	.	.	.	.
36	175.400	128.000	3.950	0.000	27.000	0.040	0.500	0.060	0.030	6.000	1.000	8.000	40.000
37	173.800	155.000	3.850	0.000	36.000	.	.	.	.	.	.	.	.
38	171.400	170.000	3.900	0.000	40.000	.	.	.	.	.	.	.	.
39	175.300	172.000	3.800	0.000	28.000	.	.	.	.	.	.	.	.
40	175.400	145.000	3.800	0.000	35.000	.	.	.	.	.	.	.	.
40	199.300	102.000	4.000	0.000	0.000	.	.	.	.	.	.	.	.
40	199.300	78.000	4.150	0.000	12.000	.	.	.	.	.	.	.	.
40	199.900	61.000	4.200	0.000	0.000	.	.	.	.	.	.	.	.
40	200.400	68.000	4.150	0.000	12.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.18. Drainage from 3:1 ratio of -0.25/+10 mesh limestone (Reactor 19).
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	174.400	152.000	6.500	2.600	6.000	-0.100	0.300	0.030	0.190	1.700	4.000	20.000	57.000
1	174.600	105.000	6.500	5.200	0.000	.	.	.	.	.	.	.	.
2	174.900	82.000	6.400	5.200	0.000	-0.100	0.100	0.020	0.040	-0.100	2.400	20.000	41.000
3	175.500	73.000	5.850	2.000	0.000	.	.	.	.	.	.	.	.
4	176.400	77 000	5.900	5.200	0.000	-0.100	0.180	0.020	0.060	-0.100	1.130	16.000	25.000
5	176.600	70.000	5.850	5.200	0.000	.	.	.	.	.	.	.	.
6	175.200	72.000	5.750	5.200	0.000	0.100	0.400	0.060	0.190	0.200	0.930	10.000	25.000
7	175.500	90.000	5.350	4.100	0.000	.	.	.	.	.	.	.	.
8	177.400	140.000	4.500	0.000	18.000	0.660	1.600	0.240	1.300	1.000	2.400	14.000	43.000
9	177.800	127.000	4.600	2.100	0.000	.	.	.	.	.	.	.	.
10	176.700	110.000	4.400	0.000	18.000	0.300	0.800	0.140	0.750	2.200	2.000	10.000	32.600
11	173.700	132.000	4.400	0.000	24.000	.	.	.	.	.	.	.	.
12	175.000	110.000	4.300	0.000	18.000	0.180	0.700	0.100	0.400	3.300	3.000	10.000	42.000
13	176.400	122.000	4.200	0.000	24.000	.	.	.	.	.	.	.	.
14	174.000	113.000	4.150	0.000	24.000	0.130	0.600	0.050	0.300	6.100	2.600	8.000	44.000
15	174.500	139.000	4.100	0.000	36.000	.	.	.	.	.	.	.	.
16	175.000	155.000	3.900	0.000	42.000	0.080	0.700	0.040	0.230	11.900	5.600	0.800	46.000
17	174.500	168.000	4.100	0.000	48.000	.	.	.	.	.	.	.	.
18	185.400	163.000	4.050	0.000	68.000	0.040	0.600	0.040	0.180	11.400	4.800	0.600	47.000
19	174.800	153.000	4.000	0.000	36.000	.	.	.	.	.	.	.	.
20	176.700	195.000	4.200	0.000	48.000	0.100	0.600	0.060	0.200	14.800	5.200	10.000	55.000
21	174.300	190.000	3.900	0.000	60.000	.	.	.	.	.	.	.	.
22	174.100	200.000	4.000	0.000	84.000	.	.	.	.	.	.	.	67.000
23	172.800	223.000	3.750	0.000	66.000	.	.	.	.	.	.	.	.
24	170.700	190.000	4.050	0.000	48.000	.	.	.	.	.	.	.	66.000
25	172.500	225.000	4.100	0.000	72.000	.	.	.	.	.	.	.	.
26	174.100	220.000	3.850	0.000	60.000	0.120	0.500	0.030	0.090	15.800	2.000	12.000	71.000
27	172.600	210.000	3.700	0.000	54.000	.	.	.	.	.	.	.	.
28	172.500	190.000	3.600	0.000	60.000	.	.	.	.	.	.	.	70.000
29	172.700	183.000	3.750	0.000	54.000	.	.	.	.	.	.	.	.
30	174.500	200.000	3.900	0.000	59.000	0.090	0.400	0.040	0.080	12.800	1.000	14.000	55.000
31	171.800	203.000	3.700	0.000	57.000	.	.	.	.	.	.	.	.
32	173.500	175.000	3.950	0.000	52.000	.	.	.	.	.	.	.	41.000
33	174.500	178.000	3.950	0.000	48.000	.	.	.	.	.	.	.	.
34	175.500	160.000	3.800	0.000	48.000	.	.	.	.	.	.	.	40.000
35	174.800	175.000	3.850	0.000	52.000	.	.	.	.	.	.	.	.
36	171.200	153.000	3.850	0.000	30.000	0.090	0.400	0.050	0.060	6.700	1.000	10.000	43.000
37	172.500	153.000	3.850	0.000	32.000	.	.	.	.	.	.	.	.
38	174.700	160.000	3.800	0.000	35.000	.	.	.	.	.	.	.	.
39	174.400	177.000	3.750	0.000	27.000	.	.	.	.	.	.	.	.
40	174.000	155.000	3.750	0.000	34.000	0.080	0.300	0.050	0.090	3.900	.	8.000	27.500
40	199.800	94.000	4.050	0.000	0.000	.	.	.	.	.	.	.	21.000
40	200.300	64.000	4.150	0.000	12.000	0.060	0.100	0.020	0.030	1.500	.	4.000	13.000
40	201.200	50.000	4.200	0.000	0.000	.	.	.	.	.	.	.	7.000
40	198.600	53.000	4.150	0.000	13.000	0.030	-0.100	0.020	0.020	0.700	.	4.000	6.000

-: less than
.: not analyzed

Table A1.19. **Drainage from 3:1 ratio of -0.25 /+10 mesh limestone (Reactor 20).**
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	174.200	159.000	6.500	5.200	0.000	-0.100	0.200	0.030	0.130	0.600	4.000	40.000	61.000
1	175.000	100.000	6.650	5.200	0.000	.	.	.	.	.	.	.	.
2	176.100	76.000	6.650	5.200	0.000	-0.100	0.100	0.010	0.040	-0.100	2.200	20.000	27.000
3	179.200	87.000	6.050	2.000	0.000	.	.	.	.	.	.	.	.
4	175.800	90.000	6.150	5.200	0.000	-0.100	0.330	0.040	0.100	0.300	1.610	16.000	35.000
5	177.800	90.000	5.800	4.100	0.000	.	.	.	.	.	.	.	.
6	174.800	75.000	5.750	5.200	0.000	-0.100	0.560	0.080	0.260	0.200	0.980	10.000	20.000
7	174.800	70.000	5.500	3.100	0.000	.	.	.	.	.	.	.	.
8	175.700	80.000	5.150	7.700	6.000	0.060	0.700	0.070	0.400	0.400	1.600	10.000	25.000
9	176.700	67.000	5.200	4.100	0.000	.	.	.	.	.	.	.	.
10	175.700	65.000	4.900	0.000	12.000	0.080	0.400	0.060	0.390	0.700	2.200	8.000	20.000
11	177.200	75.000	4.900	0.000	19.000	.	.	.	.	.	.	.	.
12	174.500	80.000	4.700	0.000	12.000	0.140	0.600	0.100	0.500	1.700	2.400	8.000	30.000
13	178.700	95.000	4.550	0.000	18.000	.	.	.	.	.	.	.	.
14	175.600	68.000	4.550	0.000	15.000	0.200	0.400	0.060	0.400	3.200	2.400	9.600	23.000
15	177.500	76.000	4.500	0.000	9.000	.	.	.	.	.	.	.	.
16	178.800	75.000	4.200	0.000	18.000	0.140	0.500	0.080	0.300	2.300	4.200	6.000	22.600
17	176.000	88.000	4.450	0.000	18.000	.	.	.	.	.	.	.	.
18	180.200	90.000	4.400	0.000	18.000	0.160	0.400	0.040	0.320	2.900	4.800	4.000	24.600
19	177.800	80.000	4.400	0.000	18.000	.	.	.	.	.	.	.	.
20	178.600	85.000	4.600	0.000	12.000	0.210	0.400	0.040	0.220	2.800	3.800	6.000	23.000
21	177.900	85.000	4.250	0.000	29.000	.	.	.	.	.	.	.	.
22	178.800	82.000	4.400	0.000	27.000	.	.	.	.	.	.	.	24.000
23	179.300	85.000	4.150	0.000	24.000	.	.	.	.	.	.	.	.
24	178.400	87.000	4.250	0.000	24.000	.	.	.	.	.	.	.	25.000
25	175.700	90.000	4.500	0.000	24.000	.	.	.	.	.	.	.	.
26	176.400	100.000	4.150	0.000	24.000	0.250	0.300	0.030	0.180	3.600	1.600	6.000	28.000
27	177.100	100.000	4.100	0.000	21.000	.	.	.	.	.	.	.	.
28	177.700	94.000	3.900	0.000	30.000	.	.	.	.	.	.	.	29.000
29	178.900	100.000	4.100	0.000	25.000	.	.	.	.	.	.	.	.
30	175.100	120.000	4.150	0.000	33.000	0.210	0.300	0.040	0.140	4.200	0.600	8.000	30.000
31	179.100	112.000	3.950	0.000	30.000	.	.	.	.	.	.	.	.
32	179.500	101.000	4.100	0.000	32.000	.	.	.	.	.	.	.	26.000
33	177.000	105.000	4.100	0.000	31.000	.	.	.	.	.	.	.	.
34	175.800	108.000	4.000	0.000	36.000	.	.	.	.	.	.	.	30.000
35	177.500	110.000	4.100	0.000	33.000	.	.	.	.	.	.	.	.
36	175.400	118.000	4.000	0.000	29.000	0.210	0.300	0.060	0.130	5.100	0.800	6.000	33.000
37	175.900	110.000	4.100	0.000	33.000	.	.	.	.	.	.	.	.
38	176.700	120.000	4.000	0.000	37.000	.	.	.	.	.	.	.	.
39	175.500	148.000	3.900	0.000	27.000	.	.	.	.	.	.	.	.
40	175.100	148.000	3.800	0.000	31.000	.	.	.	.	.	.	.	.
40	202.300	69.000	4.150	0.000	0.000	.	.	.	.	.	.	.	.
40	200.000	45.000	4.300	0.000	9.800	.	.	.	.	.	.	.	.
40	201.600	32.000	4.400	0.000	0.000	.	.	.	.	.	.	.	.
40	198.800	33.000	4.400	0.000	6.100	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.20. Drainage from 5:1 ratio of -0.25/+10 mesh limestone (Reactor 21).
(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	175.200	165.000	6.750	9.000	0.000	-0.100	0.200	0.040	0.090	0.200	4.000	40.000	68.000
1	175.700	102.000	7.150	7.700	0.000	.	.	.	.	.	.	.	.
2	176.100	72.000	6.550	5.200	0.000	-0.100	0.100	-0.010	0.040	-0.100	2.400	20.000	38.000
3	178.200	82.000	6.500	2.000	0.000	.	.	.	.	.	.	.	.
4	175.900	104.000	6.350	5.200	0.000	-0.100	0.270	0.020	0.080	-0.100	1.590	20.000	43.000
5	179.000	75.000	6.300	8.200	0.000	.	.	.	.	.	.	.	.
6	178.200	75.000	6.650	5.200	0.000	-0.100	0.350	0.050	0.130	0.100	0.820	10.000	20.000
7	175.600	72.000	5.850	4.100	0.000	.	.	.	.	.	.	.	.
8	177.900	85.000	5.600	2.600	12.000	0.030	0.500	0.080	0.230	0.300	1.600	12.000	27.000
9	175.700	75.000	5.700	4.100	0.000	.	.	.	.	.	.	.	.
10	175.300	75.000	5.400	0.000	6.000	0.060	0.300	0.040	0.280	0.300	1.600	10.000	24.000
11	176.100	79.000	5.350	0.000	12.000	.	.	.	.	.	.	.	.
12	178.000	82.000	5.100	0.000	9.000	0.130	0.500	0.090	0.340	0.500	2.200	12.000	32.000
13	171.800	82.000	5.000	0.000	6.000	.	.	.	.	.	.	.	.
14	182.700	75.000	5.000	0.000	5.000	0.240	0.400	0.040	0.320	0.500	2.000	10.000	28.000
15	177.800	64.000	4.800	0.000	5.000	.	.	.	.	.	.	.	.
16	175.900	70.000	4.500	0.000	15.000	0.220	0.500	0.030	0.380	0.700	3.600	8.000	22.000
17	175.800	82.000	4.700	0.000	12.000	.	.	.	.	.	.	.	.
18	180.500	80.000	4.700	0.000	12.000	0.260	0.400	0.070	0.410	0.900	4.800	0.800	27.600
19	176.700	63.000	4.650	0.000	15.000	.	.	.	.	.	.	.	.
20	176.200	75.000	5.000	0.000	15.000	0.310	0.400	0.070	0.350	1.000	4.600	8.000	21.000
21	174.800	67.000	4.500	0.000	12.000	.	.	.	.	.	.	.	.
22	175.800	80.000	4.700	0.000	15.000	.	.	.	.	.	.	.	24.000
23	175.000	80.000	4.450	0.000	18.000	.	.	.	.	.	.	.	.
24	175.000	85.000	4.400	0.000	17.000	.	.	.	.	.	.	.	28.000
25	173.600	92.000	4.500	0.000	15.000	.	.	.	.	.	.	.	.
26	176.200	97.000	4.350	0.000	21.000	0.310	0.300	0.020	0.230	2.200	1.400	8.000	32.000
27	172.500	90.000	4.300	0.000	17.000	.	.	.	.	.	.	.	.
28	174.600	80.000	4.200	0.000	21.000	.	.	.	.	.	.	.	25.000
29	175.100	82.000	4.400	0.000	18.000	.	.	.	.	.	.	.	.
30	174.400	98.000	4.350	0.000	18.000	0.210	0.300	0.040	0.130	1.700	0.800	10.000	27.000
31	175.200	85.000	4.250	0.000	18.000	.	.	.	.	.	.	.	.
32	174.200	85.000	4.350	0.000	23.000	.	.	.	.	.	.	.	24.000
33	174.100	90.000	4.250	0.000	22.000	.	.	.	.	.	.	.	.
34	165.800	85.000	4.250	0.000	24.000	.	.	.	.	.	.	.	25.000
35	174.800	83.000	4.200	0.000	22.000	.	.	.	.	.	.	.	.
36	174.100	95.000	4.200	0.000	18.000	0.250	0.200	0.050	0.120	2.300	1.000	10.000	37.000
37	174.500	92.000	4.200	0.000	21.000	.	.	.	.	.	.	.	.
38	175.200	90.000	4.150	0.000	23.000	.	.	.	.	.	.	.	.
39	173.700	122.000	4.100	0.000	19.000	.	.	.	.	.	.	.	.
40	171.700	128.000	4.050	0.000	29.000	0.270	0.300	0.050	0.160	3.000	.	10.000	36.500
40	204.500	59.000	4.350	0.000	0.000	.	.	.	.	.	.	.	14.000
40	198.800	40.000	4.500	0.000	11.000	0.060	0.100	0.010	0.040	0.700	.	4.000	7.000
40	200.100	28.000	4.600	0.000	0.000	.	.	.	.	.	.	.	3.000
40	163.800	37.000	4.400	0.000	6.100	0.030	-0.100	0.010	0.030	0.300	.	4.000	4.000

-: less than
.: not analyzed

Table A1.21. Drainage from control (Reactor 22).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	175.000	149.000	6.600	7.700	0.000	-0.100	0.200	0.040	0.110	0.700	3.800	20.000	59.000
1	176.700	92.000	6.800	5.200	0.000	.	.	.	.	.	.	.	.
2	179.800	62.000	6.250	5.200	0.000	-0.100	0.100	-0.010	0.030	-0.100	2.000	20.000	33.000
3	177.600	56.000	6.200	2.000	0.000	.	.	.	.	.	.	.	.
4	174.800	55.000	6.400	5.200	0.000	-0.100	0.140	-0.010	0.050	-0.100	0.800	6.000	21.000
5	179.000	61.000	6.250	7.200	0.000	.	.	.	.	.	.	.	.
6	177.200	62.000	5.750	5.200	0.000	-0.100	0.500	0.070	0.210	0.200	1.050	8.000	18.000
7	174.500	78.000	5.500	4.100	0.000	.	.	.	.	.	.	.	.
8	178.300	125.000	4.620	2.600	24.000	0.150	2.100	0.270	2.170	3.000	2.800	12.000	40.000
9	179.600	105.000	4.700	2.100	0.000	.	.	.	.	.	.	.	.
10	178.100	85.000	4.500	0.000	24.000	0.130	0.800	0.100	1.100	4.000	2.000	6.000	26.000
11	175.100	92.000	4.450	0.000	30.000	.	.	.	.	.	.	.	.
12	177.900	118.000	4.300	0.000	39.000	0.140	1.300	0.150	1.050	10.500	3.400	4.000	43.000
13	175.100	105.000	4.200	0.000	36.000	.	.	.	.	.	.	.	.
14	177.100	119.000	4.200	0.000	42.000	0.100	0.700	0.070	0.510	13.500	2.400	4.000	43.000
15	186.900	150.000	4.050	0.000	60.000	.	.	.	.	.	.	.	.
16	177.000	125.000	3.850	0.000	51.000	0.050	0.600	0.050	0.280	13.900	4.200	4.000	36.400
17	176.100	145.000	4.100	0.000	60.000	.	.	.	.	.	.	.	.
18	175.500	155.000	4.100	0.000	66.000	0.060	0.700	0.040	0.240	19.700	4.000	2.000	51.000
19	174.500	200.000	4.000	0.000	84.000	.	.	.	.	.	.	.	.
20	174.800	185.000	4.200	0.000	51.000	0.060	0.700	0.050	0.170	21.600	5.000	4.000	52.000
21	173.300	195.000	3.850	0.000	81.000	.	.	.	.	.	.	.	.
22	175.200	192.000	4.000	0.000	69.000	.	.	.	.	.	.	.	61.000
23	175.200	240.000	3.400	0.000	99.000	.	.	.	.	.	.	.	.
24	173.400	225.000	3.850	0.000	96.000	.	.	.	.	.	.	.	73.000
25	174.600	225.000	4.000	0.000	102.000	.	.	.	.	.	.	.	.
26	176.800	213.000	3.850	0.000	105.000	0.070	0.700	0.030	0.080	26.700	1.600	2.000	72.000
27	175.200	170.000	3.800	0.000	66.000	.	.	.	.	.	.	.	.
28	174.100	160.000	3.600	0.000	75.000	.	.	.	.	.	.	.	49.000
29	173.400	160.000	3.850	0.000	66.000	.	.	.	.	.	.	.	.
30	174.300	195.000	3.850	0.000	72.000	0.070	0.600	0.070	0.070	18.400	0.600	4.000	41.000
31	175.100	146.000	3.750	0.000	57.000	.	.	.	.	.	.	.	.
32	175.000	140.000	3.900	0.000	60.000	.	.	.	.	.	.	.	29.000
33	176.300	142.000	3.900	0.000	65.000	.	.	.	.	.	.	.	.
34	172.000	135.000	3.900	0.000	54.000	.	.	.	.	.	.	.	33.000
35	175.400	152.000	3.900	0.000	66.000	.	.	.	.	.	.	.	.
36	175.200	115.000	3.900	0.000	36.000	0.100	0.400	0.060	0.050	10.900	1.000	2.000	39.000
37	176.000	122.000	3.900	0.000	54.000	.	.	.	.	.	.	.	.
38	175.600	141.000	3.900	0.000	66.000	.	.	.	.	.	.	.	.
39	182.800	140.000	3.850	0.000	34.000	.	.	.	.	.	.	.	.
40	177.900	103.000	3.900	0.000	37.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.21. Drainage from control (Reactor 22).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	175.400	120.000	4.000	0.000	32.000	.	.	.	.	.	.	.	.
42	175.800	122.000	3.900	0.000	27.000	.	.	.	.	.	.	.	.
43	175.400	137.000	4.000	0.000	41.000	.	.	.	.	.	.	.	.
44	174.700	137.000	3.900	0.000	22.000	.	.	.	.	.	.	.	.
45	176.500	140.000	4.000	0.000	51.000	.	.	.	.	.	.	.	.
46	174.900	150.000	3.960	0.000	49.000	0.080	0.600	0.080	0.140	17.600	1.600	6.000	46.000
47	177.000	167.000	3.900	0.000	56.000	.	.	.	.	.	.	.	.
48	175.400	200.000	3.900	0.000	72.000	.	.	.	.	.	.	.	.
49	175.700	205.000	3.900	0.000	107.000	.	.	.	.	.	.	.	.
50	175.700	208.000	3.900	0.000	79.000	.	.	.	.	.	.	.	76.000
51	174.800	210.000	3.850	0.000	85.000	.	.	.	.	.	.	.	.
52	176.100	145.000	3.850	0.000	57.000	.	.	.	.	.	.	.	.
53	175.600	271.000	3.950	0.000	170.000	.	.	.	.	.	.	.	.
54	175.100	248.000	3.850	0.000	70.000	0.030	0.610	0.070	0.100	37.200	2.200	6.000	107.500
55	175.100	255.000	3.850	0.000	124.000	.	.	.	.	.	.	.	.
56	174.800	230.000	3.850	0.000	112.000	.	.	.	.	.	.	.	.
57	174.600	210.000	3.850	0.000	110.000	.	.	.	.	.	.	.	.
58	175.000	250.000	3.800	0.000	0.000	.	.	.	.	.	.	.	118.000
59	173.900	260.000	3.800	0.000	120.000	.	.	.	.	.	.	.	.
60	175.100	270.000	3.800	0.000	151.000	.	.	.	.	.	.	.	.
61	168.900	275.000	3.750	0.000	146.000	.	.	.	.	.	.	.	.
62	174.400	300.000	3.750	0.000	160.000	0.030	0.720	0.090	0.100	24.200	3.600	7.400	155.000
63	175.300	285.000	3.800	0.000	140.000	.	.	.	.	.	.	.	.
64	174.100	300.000	3.650	0.000	115.000	.	.	.	.	.	.	.	.
65	175.400	260.000	3.750	0.000	104.000	.	.	.	.	.	.	.	.
66	176.200	233.000	3.750	0.000	104.000	.	.	.	.	.	.	.	.
67	176.000	287.000	3.950	0.000	129.000	.	.	.	.	.	.	.	.
68	174.300	189.000	3.750	0.000	86.000	.	.	.	.	.	.	.	.
69	174.200	205.000	3.800	0.000	64.000	.	.	.	.	.	.	.	.
70	173.900	150.000	3.850	0.000	75.000	0.040	0.560	0.040	0.060	17.500	2.800	6.000	56.000
71	175.400	175.000	3.700	0.000	0.000	.	.	.	.	.	.	.	.
72	175.000	200.000	3.650	0.000	0.000	.	.	.	.	.	.	.	.
73	175.800	180.000	3.650	0.000	64.000	.	.	.	.	.	.	.	.
74	174.900	220.000	3.700	0.000	75.000	0.060	0.810	0.090	0.070	26.000	1.600	5.200	69.600
75	176.000	240.000	3.900	0.000	0.000	.	.	.	.	.	.	.	.
76	168.500	160.000	3.700	0.000	58.000	.	.	.	.	.	.	.	50.000
77	173.300	190.000	3.700	0.000	71.000	.	.	.	.	.	.	.	.
78	175.800	165.000	3.700	0.000	60.000	0.060	0.570	0.050	0.080	19.640	2.000	5.600	50.000
79	172.900	185.000	3.700	0.000	62.000	.	.	.	.	.	.	.	.
80	174.800	210.000	3.700	0.000	66.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.22. Drainage from control (Reactor 23).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
0	160.000	128.000	6.450	5.200	6.000	-0.100	0.300	0.050	0.160	1.500	3.400	20.000	48.000
1	174.600	92.000	6.700	5.200	0.000	.	.	.	.	.	.	.	.
2	172.000	72.000	6.400	5.200	0.000	-0.100	0.100	0.010	0.040	-0.100	2.000	20.000	30.000
3	174.400	60.000	6.200	2.000	0.000	.	.	.	.	.	.	.	.
4	173.200	59.000	6.250	5.200	0.000	-0.100	0.150	-0.010	0.050	-0.100	0.850	6.000	25.000
5	174.800	52.000	6.250	7.200	0.000	.	.	.	.	.	.	.	.
6	172.400	48.000	6.200	5.200	0.000	-0.100	0.210	0.030	0.060	0.100	0.660	6.000	12.000
7	171.600	42.000	6.050	5.200	0.000	.	.	.	.	.	.	.	.
8	171.900	90.000	4.890	2.600	12.000	0.150	1.300	0.200	0.780	0.500	2.000	10.000	28.000
9	170.800	110.000	4.750	3.100	0.000	.	.	.	.	.	.	.	.
10	171.700	100.000	4.450	0.000	24.000	0.300	1.100	0.160	1.480	3.100	2.000	8.000	30.600
11	168.100	102.000	4.350	0.000	31.000	.	.	.	.	.	.	.	.
12	168.200	100.000	4.300	0.000	33.000	0.250	1.100	0.130	0.890	6.500	3.000	4.000	39.000
13	171.300	122.000	4.100	0.000	42.000	.	.	.	.	.	.	.	.
14	167.600	108.000	4.100	0.000	33.000	0.200	0.600	0.070	0.450	8.700	2.400	4.000	36.000
15	167.500	115.000	4.100	0.000	40.000	.	.	.	.	.	.	.	.
16	166.800	170.000	3.800	0.000	66.000	0.090	0.900	0.080	0.350	20.800	5.000	2.000	51.600
17	167.100	150.000	4.100	0.000	66.000	.	.	.	.	.	.	.	.
18	167.800	142.000	4.100	0.000	54.000	0.080	0.600	0.040	0.180	16.400	5.200	2.000	40.000
19	168.700	220.000	3.950	0.000	90.000	.	.	.	.	.	.	.	.
20	154.000	215.000	4.150	0.000	78.000	0.100	0.700	0.050	0.160	24.300	4.200	4.000	60.000
21	165.200	193.000	3.850	0.000	87.000	.	.	.	.	.	.	.	.
22	161.000	190.000	4.050	0.000	75.000	.	.	.	.	.	.	.	60.000
23	161.800	180.000	3.900	0.000	75.000	.	.	.	.	.	.	.	.
24	163.200	175.000	4.050	0.000	71.000	.	.	.	.	.	.	.	71.000
25	160.600	199.000	4.050	0.000	78.000	.	.	.	.	.	.	.	.
26	176.000	215.000	3.900	0.000	98.000	0.080	0.400	0.040	0.070	27.500	1.600	2.000	75.000
27	172.800	195.000	3.750	0.000	76.000	.	.	.	.	.	.	.	.
28	173.000	190.000	3.550	0.000	88.000	.	.	.	.	.	.	.	69.000
29	173.100	190.000	3.750	0.000	76.000	.	.	.	.	.	.	.	.
30	172.700	190.000	3.800	0.000	90.000	0.100	0.500	0.040	0.100	22.800	1.000	4.000	58.000
31	172.000	202.000	3.650	0.000	60.000	.	.	.	.	.	.	.	.
32	172.600	180.000	3.800	0.000	75.000	.	.	.	.	.	.	.	46.000
33	169.200	172.000	3.900	0.000	78.000	.	.	.	.	.	.	.	.
34	170.300	152.000	3.800	0.000	60.000	.	.	.	.	.	.	.	39.000
35	171.700	188.000	3.800	0.000	75.000	.	.	.	.	.	.	.	.
36	169.300	125.000	3.850	0.000	39.000	0.080	0.300	0.060	0.060	10.300	1.000	2.000	32.000
37	169.200	140.000	3.800	0.000	41.000	.	.	.	.	.	.	.	.
38	169.300	140.000	3.750	0.000	61.000	.	.	.	.	.	.	.	.
39	166.400	143.000	3.800	0.000	31.000	.	.	.	.	.	.	.	.
40	164.800	123.000	3.700	0.000	34.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

Table A1.22. Drainage from control (Reactor 23).

(all values mg/L unless noted otherwise)

Time (weeks)	Volume (L)	S.C. (uS/cm)	pH	Alk.	Acy.	Cu	Ni	Co	Zn	Fe	Mg	Ca	Sulfate
41	166.400	113.000	4.000	0.000	32.000	.	.	.	.	.	.	.	.
42	175.300	117.000	3.900	0.000	32.000	.	.	.	.	.	.	.	.
43	175.300	108.000	4.050	0.000	31.000	.	.	.	.	.	.	.	.
44	162.500	120.000	3.950	0.000	34.000	.	.	.	.	.	.	.	.
45	174.700	131.000	4.000	0.000	49.000	.	.	.	.	.	.	.	.
46	175.100	155.000	3.930	0.000	55.000	0.050	0.600	0.080	0.150	17.400	1.600	6.000	51.000
47	176.000	179.000	3.900	0.000	68.000	.	.	.	.	.	.	.	.
48	174.700	250.000	3.850	0.000	110.000	.	.	.	.	.	.	.	.
49	175.900	295.000	4.000	0.000	155.000	.	.	.	.	.	.	.	.
50	173.200	278.000	3.800	0.000	128.000	.	.	.	.	.	.	.	104.000
51	177.100	255.000	3.800	0.000	110.000	.	.	.	.	.	.	.	.
52	174.500	210.000	3.800	0.000	93.000	.	.	.	.	.	.	.	.
53	174.700	247.000	3.900	0.000	132.000	.	.	.	.	.	.	.	.
54	171.900	325.000	3.800	0.000	177.000	0.010	0.740	0.080	0.090	47.200	2.600	8.000	153.000
55	173.000	330.000	3.850	0.000	183.000	.	.	.	.	.	.	.	.
56	172.500	300.000	3.800	0.000	156.000	.	.	.	.	.	.	.	.
57	173.400	328.000	3.800	0.000	140.000	.	.	.	.	.	.	.	.
58	173.800	280.000	3.750	0.000	0.000	.	.	.	.	.	.	.	140.000
59	173.200	395.000	3.650	0.000	206.000	.	.	.	.	.	.	.	.
60	172.000	450.000	3.600	0.000	243.000	.	.	.	.	.	.	.	.
61	172.800	390.000	3.650	0.000	224.000	.	.	.	.	.	.	.	.
62	170.300	380.000	3.700	0.000	160.000	0.020	0.800	0.080	0.170	26.400	4.000	7.800	170.000
63	173.600	270.000	3.750	0.000	116.000	.	.	.	.	.	.	.	.
64	172.200	282.000	3.700	0.000	108.000	.	.	.	.	.	.	.	.
65	172.700	248.000	3.850	0.000	97.000	.	.	.	.	.	.	.	.
66	172.800	205.000	3.800	0.000	81.000	.	.	.	.	.	.	.	.
67	178.000	220.000	4.000	0.000	99.000	.	.	.	.	.	.	.	.
68	180.900	169.000	4.000	0.000	92.000	.	.	.	.	.	.	.	.
69	171.500	163.000	4.000	0.000	87.000	.	.	.	.	.	.	.	.
70	175.200	160.000	4.000	0.000	78.000	0.030	0.660	0.090	0.090	24.300	3.200	6.000	68.500
71	170.000	163.000	3.750	0.000	72.000	.	.	.	.	.	.	.	.
72	171.400	150.000	3.700	0.000	0.000	.	.	.	.	.	.	.	.
73	171.300	180.000	3.700	0.000	67.000	.	.	.	.	.	.	.	.
74	181.200	190.000	3.800	0.000	63.000	0.050	0.730	0.080	0.100	23.000	1.600	5.400	62.800
75	177.000	190.000	3.900	0.000	69.000	.	.	.	.	.	.	.	.
76	169.400	170.000	3.700	0.000	60.000	.	.	.	.	.	.	.	44.000
77	176.100	187.000	3.700	0.000	64.000	.	.	.	.	.	.	.	.
78	175.700	160.000	3.800	0.000	51.000	0.120	0.660	0.070	0.110	17.540	2.000	6.000	48.800
79	175.800	155.000	3.700	0.000	48.000	.	.	.	.	.	.	.	.
80	179.000	150.000	3.700	0.000	66.000	.	.	.	.	.	.	.	.

-: less than
.: not analyzed

APPENDIX 2

Alkaline Addition Reactor Test

Timeline through November 1989

Table A2.1. Alkaline Addition Reactor Test Timeline Through November, 1989.

Reactor 1

2-22-89	used a 5.0 micron filter instead of a 0.45 on reactors 1-14, 22 & 23
3- 8-89	heavily disturbed - (mice)
8-23-89	large 1/8" crater hole formed thru solids after filtration. (possible flow path)

Reactor 2

7-20-88	no metals or SO_4 samples were taken
6-28-89	no alkalinity taken (forgotten)
7-12-89	pores formed at reactor - solids interface
9-20-89	didn't weigh the receiving flask plus water.
10- 4-89	forgot to take alkalinity

Reactor 3

7-20-88	no metals or SO_4 samples were taken
3- 1-89	reactor leaked
5-17-89	leak in reactor
7-12-89	pores formed at reactor - solids interface
7-19-89	reactor leaks
8- 9-89	solids cracked and swelling up probably gas action
10- 4-89	forgot alkalinity

Reactor 5

5-17-88	a few mls of H_2O was spilled before filtration, there was some precipitate in the sample. No SO_4 or metals sampled.
5-25-88	leak in the reactor, some H_2O was lost
6- 1-88	small leak in the reactor, forgot the .45 filter, the sample was filtered after pH was read.
7-20-88	no metals or SO_4 samples were taken
8-24-88	leaky reactor
8-31-88	leaky reactor
9- 7-88	leaky reactor
11-18-88	repaired leak in reactor
2-13-89	replaced solids filter, damaged by mice
3- 8-89	probably mice disturbance got higher s.c. and alkalinity than normal
7-12-89	large pores formed in solids, visible thru reactor when dry
10-4-89	no alkalinity taken

Table A2.1. Alkaline Addition Timeline (continued).

Reactor 6

5-17-88	precipitate in sample
5-25-88	leak in reactor, small amount of H_2O was lost
11- 9-88	no alkalinity taken
2- 8-89	solids filter broke - solids lost - rodent damage, millipore filter broke also
2-13-89	replaced solids filter, damaged by mice, much rodent wastes found, removed as much as possible
6-28-89	no alkalinity taken
7-12-89	pores formed at interface of solids & reactor when dry
8- 9-89	molding started on surface of solids same as #3
10- 4-89	no alkalinity taken

Reactor 7

5-17-88	precipitate in sample
5-17-88	very slow filtration, there must be a bad seal between the reactor and the perforated base, may have to fix reactor.
5-25-88	very slow filtration, there must be a bad seal between the reactor and the perforated base, may have to fix reactor.
6- 1-88	very slow filtration, there must be a bad seal between the reactor and the perforated base, may have to fix reactor.
6- 8-88	removed solids from reactor and re-glued the perforated base, re-mixed the solids and put back in reactor.
6-29-88	some H_2O was spilled from reactor
7-27-88	replaced the reactor with a new one
9- 7-88	reactor leaked
10-26-88	reactor leaked
11-18-88	repaired leak in reactor
5-24-89	filter .45 was cracked after filtering
6-28-89	no alkalinity taken
7-26-89	no SO_4 or metals samples
8-9-89	molding on surface solids - much cracking & swelling of solids
8-30-89	reactor was one of few that were still damp.
9-27-89	no alkalinity taken
10-4-89	no alkalinity taken
11-29-89	lost 0.15 g of solids on filter

Reactor 8

7-12-89	large pores noticed when dry at reactor - solids interface
8- 9-89	lots of crusting, swelling cracking
8-16-89	ran without filter
10- 4-89	no alkalinity taken

Table A2.1. Alkaline Addition Timeline (continued).

Reactor 9

5-17-88	the buret wasn't full of water so less than 200 mls was added, there is no way of telling how much.
2- 1-89	solids filter broke, a good amount of solids were lost.
2- 8-89	replaced solids filter
3-13-89	repaired leak on perf. base, replaced solids filter - no loss of solids
5-10-89	forgot to put filter in resulting in a quick water filling flask & lower pH
10- 4-89	no alkalinity taken

Reactor 10

2- 1-89	reactor leaked
2- 8-89	reactor leaked
2-13-89	replaced solids filter, damaged by mice - rodent wastes removed.
2-13-89	repair reactor leak
6-28-89	no alkalinity taken
8- 9-89	showed signs of trapped gas
10- 4-89	no alkalinity taken

Reactor 11

5-17-88	forgot the .45 filter, the sample was filtered after the pH was read
5-25-88	leak in the reactor, lost some H_2O
6- 1-88	leak in the reactor, lost some H_2O
8-31-88	very slow filtration, small leak in reactor
10-19-88	reactor leaked
11-18-88	repaired leak in reactor
11-30-88	reactor leaked
3- 1-89	repaired
3-22-89	repaired
3-29-89	repaired
4- 3-89	repaired leak w/vulcum cement - added approximately 2 gr. to reactor wt, completed and dry, 2.9 gr were added - wet wt.
8- 9-89	slow filtering, slight cracking, swelling
8-16-89	not completely dry
8-30-89	didn't dry well
10- 4-89	no alkalinity taken

Reactor 12

8-31-88	small leak in reactor
11-18-88	repaired leak in reactor
8- 9-89	showed signs of trapped gas

Table A2.1. Alkaline Addition Timeline (continued).

Reactor 13

11-16-88	no SO_4 sample
12-14-88	no .45 filter - filtered the sample before metals sample was taken
3-13-89	repaired leak around standpipe
6-28-89	no alkalinity taken
8-23-89	starting to swell (solids)

Reactor 14

5-17-88	a small volume of H_2O leaked from the reactor
2- 1-89	solids filter broke, a good amount of solids were on .45 filter
2- 8-89	replaced solids filter

Reactor 22

6- 1-88	there was a hole in the .45 filter, the sample was filtered after pH was read.
6-28-89	no acidity taken
8-31-89	forgot filter
10-25-89	no acidity taken

Reactor 23

5-17-88	leak in reactor, some H_2O was lost
7-20-88	leaky reactor
8- 3-88	leaky reactor
8-10-88	leaky reactor
8-31-88	leaky reactor
9- 7-88	leaky reactor
10- 5-88	leaky reactor
10-12-88	leaky reactor
10-19-88	leaky reactor
10-26-88	leaky reactor
11- 8-88	leaky reactor
11-15-88	reactor repaired
2-15-89	leaky reactor
2-22-89	leaky reactor
3- 7-89	repair leak on reactor, lost 1.1 gr of solids. Repair was made with vulcum cement this time as base of reactor was cracked almost in half. Weight added to reactor by vulcum after one day drying was .6 gr.
6-21-89	solids filter bad - solids lost
6-28-89	new solids filter - some solids lost
8-30-89	didn't dry well.