Chapter 4
Experimental Results: Surface Runoff

4.1 Prescreening Tests

The function of the prescreening tests was to determine the ranges of operational parameters to be utilized in the study for the control variables employed. As stated in Chapter 3, E-1 and E-2 represent aluminum sulfate and ferric chloride, respectively. Names and identifications of coagulant aids and MCs are indicated in Tables 3-4 and 3-8, respectively. A series of jar tests was performed with conditions stated in Table 3-7.

Rapid mixing. Based on the prescreening trials, two stages of rapid mixing were used in the MC weighted jar tests. In the first stage, a mixing rate of 150 rpm for 10 seconds was required to lift MCs from the bottom of the jar into suspension. In the second stage, a mixing rate of 100 rpm was required to keep the MC in suspension. It was observed that floc growth began 10 seconds from the beginning of the second rapid mixing stage. Floc shear would occur due to the rapid speed if the rapid mixing rate of 100 rpm were continued. Based on this observation, a 10-second duration was selected in the second stage of rapid mixing.

Slow mixing (flocculation). It was observed that both MC and flocs would settle without further flocculation if the slow mixing rate were lower than 60 rpm. 60 rpm was found to be an appropriate mixing rate to avoid floc shear but still keep MCs and flocs in suspension. A 10-second duration was found to be sufficient for the flocculation process.

In the MC weighted jar test, the total mixing time (approximately 30 seconds) is much shorter than those used in conventional jar tests. This indicates that MC might be an effective approach in reducing the treatment time and in turn, the treatment cost, compared to conventional coagulation processes. Due to the presence of MCs, however, both rapid and flocculation mixing rates of MC weighted jar tests were higher than those of conventional jar tests.

In addition, it was observed that the supernatant was rather clear after 3 minutes of settling. As a result, 3 and 8 minute sampling times were selected to study the settling kinetics.

Table 4-1 is a summary of experimental settings based on prescreening tests. These settings were used as operating conditions for both screening and confirmative tests.

Table 4-1. Summary of Experimental Settings

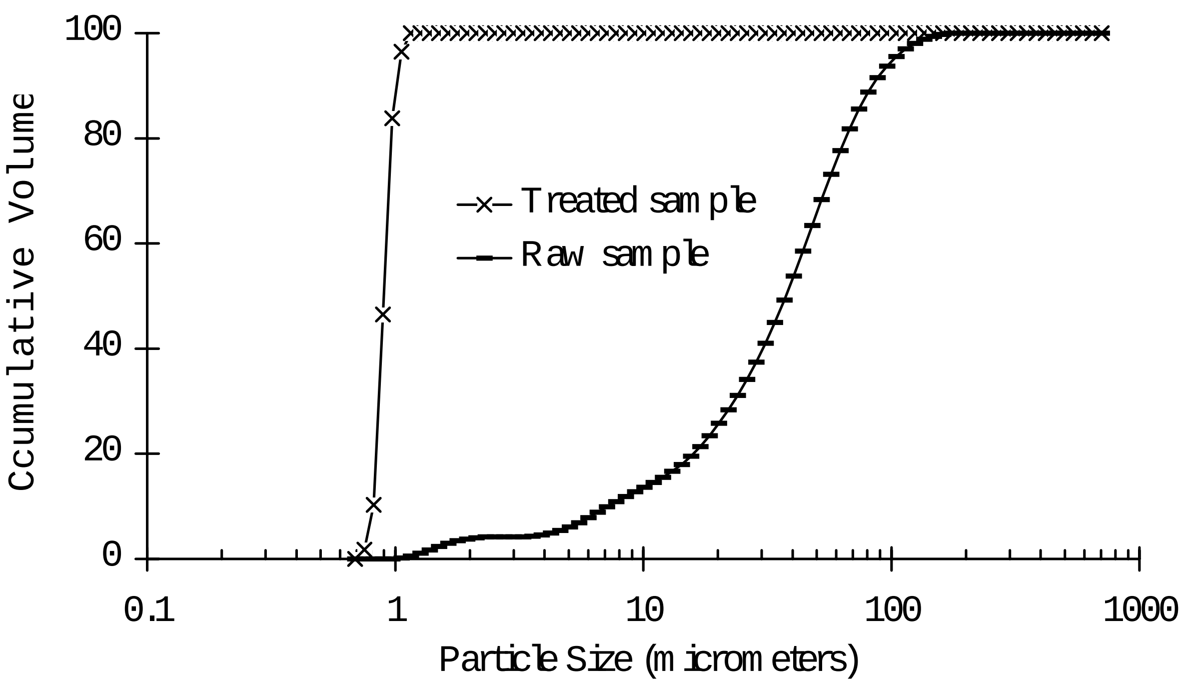
Parameter	Value
Rapid mixing rate -- stage-1	150 rpm
Rapid mixing duration -- stage-1	10 sec
Rapid mixing rate -- stage-2	100 rpm
Rapid mixing duration -- stage-2	10 sec
Slow mixing (Flocculation) rate	60 rpm
Slow mixing duration	10 sec
MC concentration -- 1	3 g/L
MC concentration -- 2	10 g/L
MC size -- 1	53—150 μm
MC size -- 2	150—250 μm
Settling time -- 1	3 min
Settling time -- 2	8 min
Coagulant concentration	10—80 mg/L
Coagulant aid concentration	0.3—1.5 mg/L

″

4.2 Effects of MC Coagulation

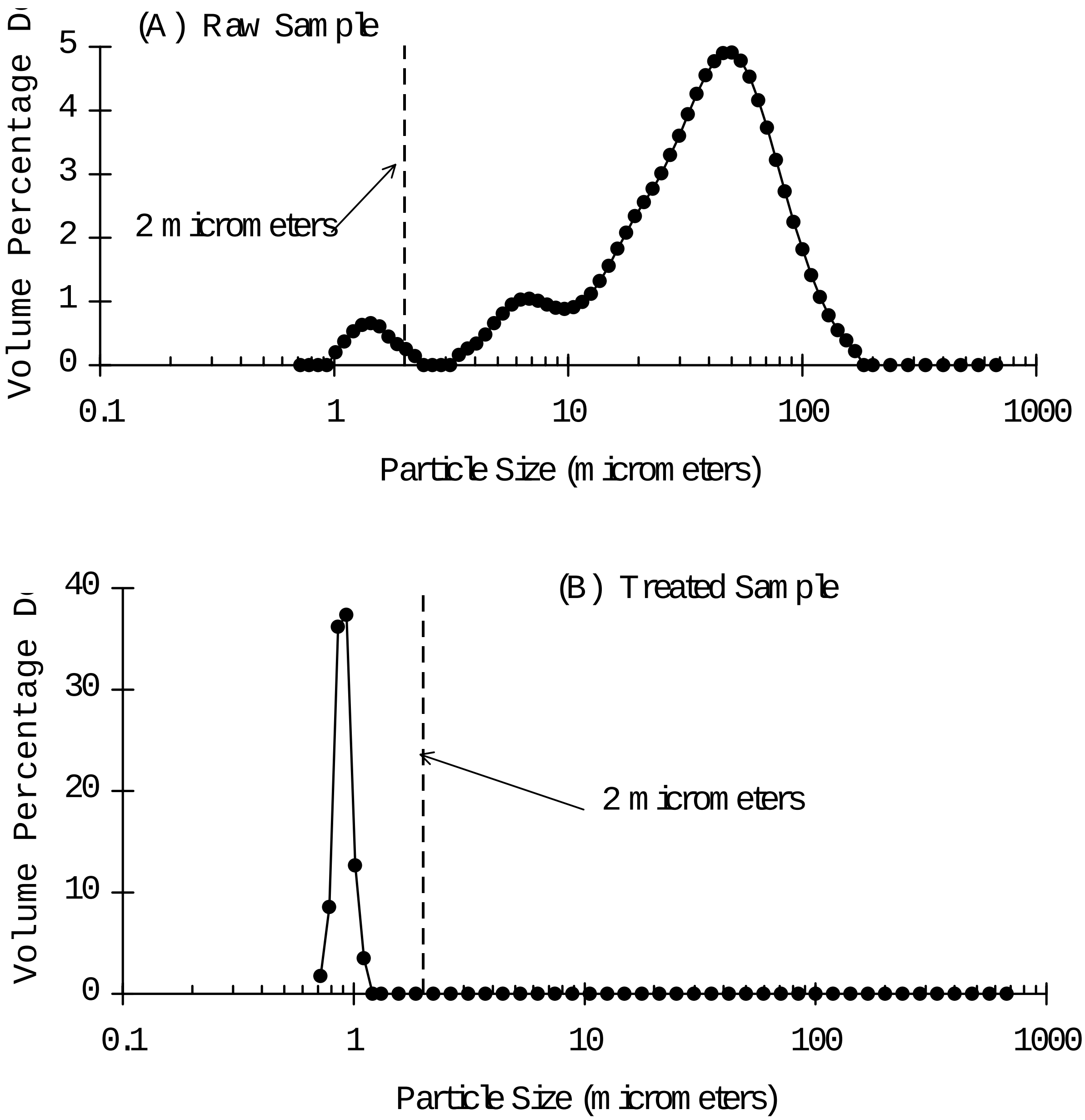
Figure 4-1 illustrates cumulative volume distributions versus particle size before and after the MC weighted coagulation. For the raw sample (before treatment), the measurable range of particle size is from 1 to 170 µm which consists of 81% from 10 to 100 µm and 14% smaller than 10 µm. After the MC coagulation, the particles in the supernatant of the jar were found to be < 2 µm, which indicated that all particles > 2 µm were removed.

Figures 4-2 (A) and (B) illustrate the particle size distribution characteristics of the raw sample and supernatant sample after treatment, respectively. For the raw sample, the distribution peak is at approximate 50 µm while the small particles (from 0.7 to 2 µm) were either undetectable or only a low percentage compared to the peak.



MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L
E-1: Aluminum Sulfate Concentration = 40 mg/L
PE-1: Polyelectrolyte POL-EZ-2466 Concentration = 1 mg/L

Figure 4-1. Particle Sizes of Raw and Treated Samples (Cumulative)



MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L
E-1: Aluminum Sulfate Concentration = 40 mg/L
PE-1: Polyelectrolyte POL-EZ-2466 Concentration = 1 mg/L

Figure 4-2. Particle Sizes of Raw and Treated Samples (Distributions)

After the treatment, only particles smaller than 2 µm were found to remain in the supernatant of the sample. Since the larger particles were all removed from the sample, the percentage of small particles increases. A summary of particle size distributions in different ranges is shown in Table 4-2. One can see that more than 96% (> 2 µm) of particles were removed from the raw sample. The removal efficiency for the 4% smaller particles (< 2 µm) was indicated by the particle count rate discussed below.

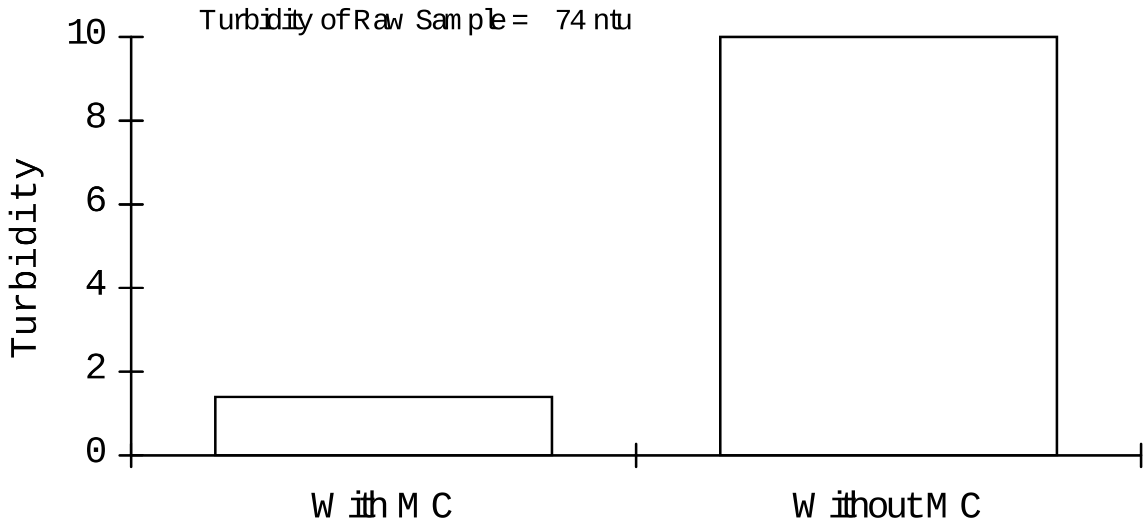
Figures 4-3 (A) and (B) present comparisons of turbidity and particle count rate (PCR) results with and without using an MC for different coagulant aids. Turbidity has been used extensively as a water quality indicator in water and wastewater treatment process analysis. The count rate, utilizing a unit of kilo-count per second, is directly related to the particle concentration in the solution; therefore, it is a good indicator for colloidal particles (containing particles smaller than 0.45 micrometer) for which TSS measurement is usually not applicable. Both turbidity and particle count rate of supernatant samples with MC are much lower than those without MC. It is apparent that the addition of MC improves the treatment process effectively.

Table 4-2. Particle Size Distribution of Raw and Treated Samples

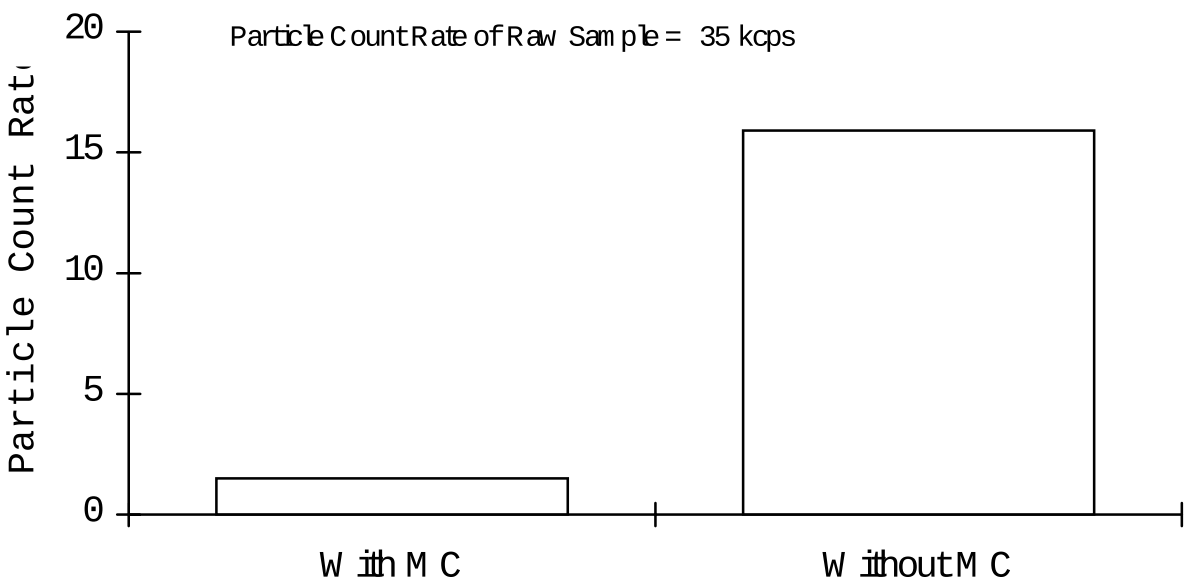
Size Range (µm)		0.69—1	1—2	2—10	10—100	100—170
Volume (%)	Raw	< 0.1	4	10	81	5
	Treated	84	16	< 0.1	< 0.1	< 0.1

″

″



(A) PE-4 (Anionic)



(B) PE-3 (Non-ionic)

MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L
E-1: Aluminum Sulfate Concentration = 40 mg/L
PE-3: Polyelectrolyte POL-EZ-2696 Concentration = 1 mg/L
PE-4: Polyelectrolyte POL-EZ-7736 Concentration = 1 mg/L

Figure 4-3. Effectiveness of the MC Process

4.3 Screening Tests

For each test set, supernatant samples were taken at 3 minute and 8 minute settling times, respectively. The time difference for sampling six jars was less than 15 seconds, which was negligible.

Screening tests include three levels of setup conditions that are summarized in Tables 3-10 through 3-12 (Section 3.3). Results of these three levels of tests are described in the following sections.

Level One

In this level, only an MC and a coagulant were used for the treatment process. The concentration of coagulant range from 0 to 80 mg/L (see Table 3-10).

pH

Figure 4-4 illustrates the relationship of pH and coagulant concentration. It is seen that pH decreases as coagulant concentration increases. All pH values are in the range of 6.5 to 7.5 except for jar number six with 80 mg/L coagulant. For coagulant concentration between 20 and 80 mg/L, pH values with 8 minute settling time are closer to neutral than those with 3 minute settling time. The changes of pH values may be due to that some of the immediate pH drop (as aluminum hydroxide is formed from alum) is counteracted by a slow loss of carbon dioxide to the atmosphere, raising the pH slowly.

Turbidity

Figure 4-5 shows the turbidity distribution versus coagulant concentration. Here the lowest turbidity for both 3 and 8 minute settling times was found at 60 mg/L. In addition, the 8-minute settling time yields better results (lower turbidity) than the 3 minute settling time.

Zeta Potential

Figure 4-6 illustrates zeta potential values versus coagulant concentrations. It can be seen that the zeta potential basically increases as coagulant concentration increases. At coagulant concentrations between 60 and 80 mg/L, the differential of zeta potential becomes greater between settling times of 3 minutes and 8 minutes.

Turbidity versus Zeta Potential

It is of interest to see the correlation between zeta potential and turbidity presented in Figure 4-7. The turbidity decreases for less charge in the zeta potential range of -10 to -25 mV. A log-linear regression was performed based on measurements within the negative zeta potential range. The straight line in the positive zeta potential side is the imaging line of the negative side. Since there is only one point on the positive side, regression at this side is impossible. Generally, organic colloids require zeta potentials near zero for optimal coagulation, while clay-related turbidity is best removed at slightly negative zeta potentials. In this case, the fact that the measured point is very close to the image line indicates that the zero potential is the image symmetrical point, and so, is the best for turbidity removal.

Particle Count Rate

The particle count rate for 60 mg/L coagulant was found to be 1.2 and 1.0 at settling times of 3 minutes and 8 minutes, respectively (see Figure 4-8). Results showed that approximately 50% of the small particles (< 5 μm) were removed from the raw sample in 3 minutes.

Level Two

Level two parameters include MC, coagulant, and four types of coagulant aids with a fixed concentration of 1 mg/L. For each coagulant aid, coagulant concentration was varied from 0 to 80 mg/L (see Table 3-11).

pH

Figure 4-9 shows a typical pH distribution versus coagulant concentration. It appears that the relationship between pH and coagulant for both level one and level two tests is similar. A summary of pH behavior for the four coagulant aids at two different settling times (3 and 8 minutes) is shown in Figure 4-10. pH values were found to be close to 7 when coagulant concentrations were in the range of 20 to 40 mg/L.

Turbidity

The lowest value of turbidity was obtained at 40 mg/L coagulant as shown in Figure 4-11. A plot of turbidity distributions (with 3 and 8 minute settling times) versus coagulant concentration with the four coagulant aids is illustrated in Figure 4-12. Based on the turbidity results, the optimal coagulant concentration for level two was 40 mg/L for all four coagulant aids. It was indicated that turbidity with 8 minute settling time is lower than that with 3 minute settling time. This is true because the longer the settling time, the more the particles will be removed.

Total Solids and Total Volatile Solids

Figure 4-13 and Figure 4-14 illustrate the total solids and total volatile solids distributions, respectively. It can be seen that 8 minutes settling time yields better results for both total solids and total volatile solids. The total solids results demonstrate that 40 mg/L was the optimal coagulant concentration.

For total volatile solids results, the optimal coagulant concentration was between 20 and 40 mg/L. Similar results were obtained for the total solids and total volatile solids removals.

Particle Count Rate

Figure 4-15 illustrates a comparison between particle count rate and turbidity. It can be seen that a similar trend indicates 40 mg/L of coagulant as the optimal concentration for turbidity and particle count rate removal.

Turbidity versus Zeta Potential

Figure 4-16 illustrates zeta potential distributions versus coagulant concentrations. Since anionic coagulant aid was added into the mixture, all supernatant samples, with the exception of 80 mg/L of coagulant samples, have larger negative charge than the raw sample. Figure 4-17 shows the correlation between turbidity and zeta potential by using a log-linear regression based on the negative zeta potential data. In addition, an image line was drawn for the positive zeta potential side with respect to the image centerline of - 10 mV zeta potential (Z). Similar to level one, it can be seen that turbidity decreases with lower zeta potential.

Level Three

In level three, four coagulant aids with concentration ranging from 0.3 to 1.5 mg/L were tested with MC-I and 40 mg/L coagulant which was determined in level two tests to be the optimal dosage for all four coagulant aids.

pH

Figure 4-18 shows the pH value versus coagulant aid concentration for the four coagulant aids at 3 and 8 minute settling times. Results indicate that coagulant aid concentration had no major influences on pH values.

Turbidity and/versus Zeta Potential

Based on the test results, the trends of turbidity removal are different for various types of coagulant aids. Figure 4-19 reveals that turbidity decreases as coagulant aid (POL-EZ-2696) concentration increases up to 1 mg/L, but varies between 1 mg/L to 1.5 mg/L. In this test set, 1 mg/L is considered as the best coagulant aid dosage. Similar observations can be found from zeta potential distributions (see Figure 4-20). By comparing the above two figures, one can see that there exists a mirror image phenomenon. As a result, a correlation between turbidity and zeta potential in the presence of coagulant aid can be established. Figure 4-21 shows the correlation of zeta potential with turbidity. The results show that the turbidity decreases for less negative charge in the range between -25 and -8 mV.

Figure 4-22 shows that turbidity decreases as coagulant aid (POL-EZ-2466) concentration increases up to 1.2 mg/L and reaches its lowest point between 0.7 and 1.2 mg/L. Figure 4-23 shows zeta potential distributions. Again, the mirror image phenomenon can be observed from these two figures. The correlation between zeta potential and turbidity is presented in Figure 4-24. It can be seen that in the zeta potential range of -3 to -15 mV, turbidity has no significant change while in the zeta potential range of -15 to -22 mV, turbidity decreases as zeta potential approach less negative charge. For other coagulant aids, the results are summarized in Table 4-3.

Particle Count Rate, Total Solids and Total Volatile Solids

Particle count rate distribution versus coagulant aid concentration is illustrated in Figure 4-25. At this point, no definite conclusion can be drawn as a result of the twin peaks. Similar trends were observed in total solids and total volatile solids versus coagulant aid concentration as shown in Figures 4-26 and 4-27, respectively. Therefore, there appears to be a functional relationship among particle count rate, total solids, and total volatile solids.

Summary

Based on the screening test results, the coagulant concentrations of 60 mg/L without coagulant aid and 40 mg/L with 1 mg/L of coagulant aid yielded better turbidity reduction efficiency. Relationships between turbidity and zeta potential under different conditions are listed in Table 4-3. For level one with coagulant in the absence of coagulant aid, the lowest turbidity point (symmetrical point) is at zero potential. For level two with additions of both coagulant (various concentrations) and coagulant aid (constant concentration), the lowest turbidity point shifted from zero potential to the range of -10 to +10 mV. For level three, for all four coagulant aids with various concentrations, the relationships between turbidity and zeta potential are either monotonously increasing (for anionic POL-EZ-7736) or decreasing (for cationic POL-EZ-2466, POL-EZ-3466 and non-ionic POL-EZ-2696).

Table 4-3. Relationship of Turbidity and Zeta Potential

Condition	Correlation Equation
Level 1	**Coagulant concentrations: 10—80 mg/L** **Without Coagulant aid**
	$\log T = -1 - 0.1\,Z\ (-25 < Z < 0)$ $\log T = -1 + 0.1\,Z\ (0 < Z < 15)$
Level 2	**Coagulant concentration: 10—80 mg/L** **Four coagulant aids (concentration = 1 mg/L)**
PE-1	$\log T = -0.87 - 0.08\ (-25 < Z < -6)$ $\log T = -0.38\ (-6 < Z < 15)$
PE-2	$\log T = 0.87 - 0.02\,Z\ (-25 < Z < 10)$ $\log T = 0.19 + 0.038\,Z\ (10 < Z < 15)$
PE-3	$\log T = -0.9 - 0.1(Z+7)\ (-25 < Z < -7)$ $\log T = -0.9 + 0.1(Z+7)\ (-7 < Z < 10)$
PE-4	$\log T = -0.5 - 0.08(Z+10)\ (-30 < Z < -10)$ $\log T = -0.5 + 0.08(Z+10)\ (-10 < Z < 10)$

Level 3	**Coagulant concentration = 40 mg/L** **Four coagulant aids (concentrations: 0.3——1.5 mg/L)**
PE-1	log T = 0.89 - 0.02 Z (-22 < Z < - 3)
PE-2	log T = 0.79 - 0.007 Z (-20 < Z < 30)
PE-3	log T = 0.33 - 0.02 Z (-25 < Z < - 8)
PE-4	log T = 1.5 + 0.05 Z (-25 < Z < -10)

Note:
T = Turbidity (ntu); Z = Zeta potential (mV)

4.4 Confirmative Tests

Based on the results from screening tests, confirmative tests were conducted to examine the influence of MC size and concentration on the MC process. Two MC size ranges,(53——150 μm defined as small MCs and 150——250 μm as large MCs) and two MC concentrations (3 g/L as low concentration and 10 g/L as high concentration) were tested. Coagulant and coagulant aid concentrations of 40 mg/L and 1 mg/L were used, respectively, for each jar test set.

MC-1 versus MC-3 and MC-2 versus MC-4

Figure 4-28 illustrates the turbidity distributions for small MCs with different MC concentrations. It is apparent that the high concentration yields lower turbidity than the low concentration for the four coagulant aids. Figure 4-29 shows the turbidity distributions for large MCs with different MC concentrations. The trend is similar with the small MC except for coagulant aid POL-EZ7736 (anionic). Comparing the above two figures, one can see that the influence of MC concentration is more pronounced in the smaller diameter range.

MC-1 versus MC-2 and MC-3 versus MC-4

Figure 4-30 compares the results of different MC sizes for low MC concentrations. Except for coagulant aid POL-EZ-2696 (non-ionic), large MCs yield lower turbidity. Figure 4-31 compares the results of different MC sizes for high MC concentrations. Unlike the situation for low MC concentration, the lower turbidity results were obtained from small MCs for all four coagulant aids. Figure 4-32 is a turbidity summary based on coagulant aid grouping.

Based on the turbidity analyses illustrated in Figure 4-33, MC-3, namely, 53——150 µm size range and 10 g/L dosage, yields the best results.

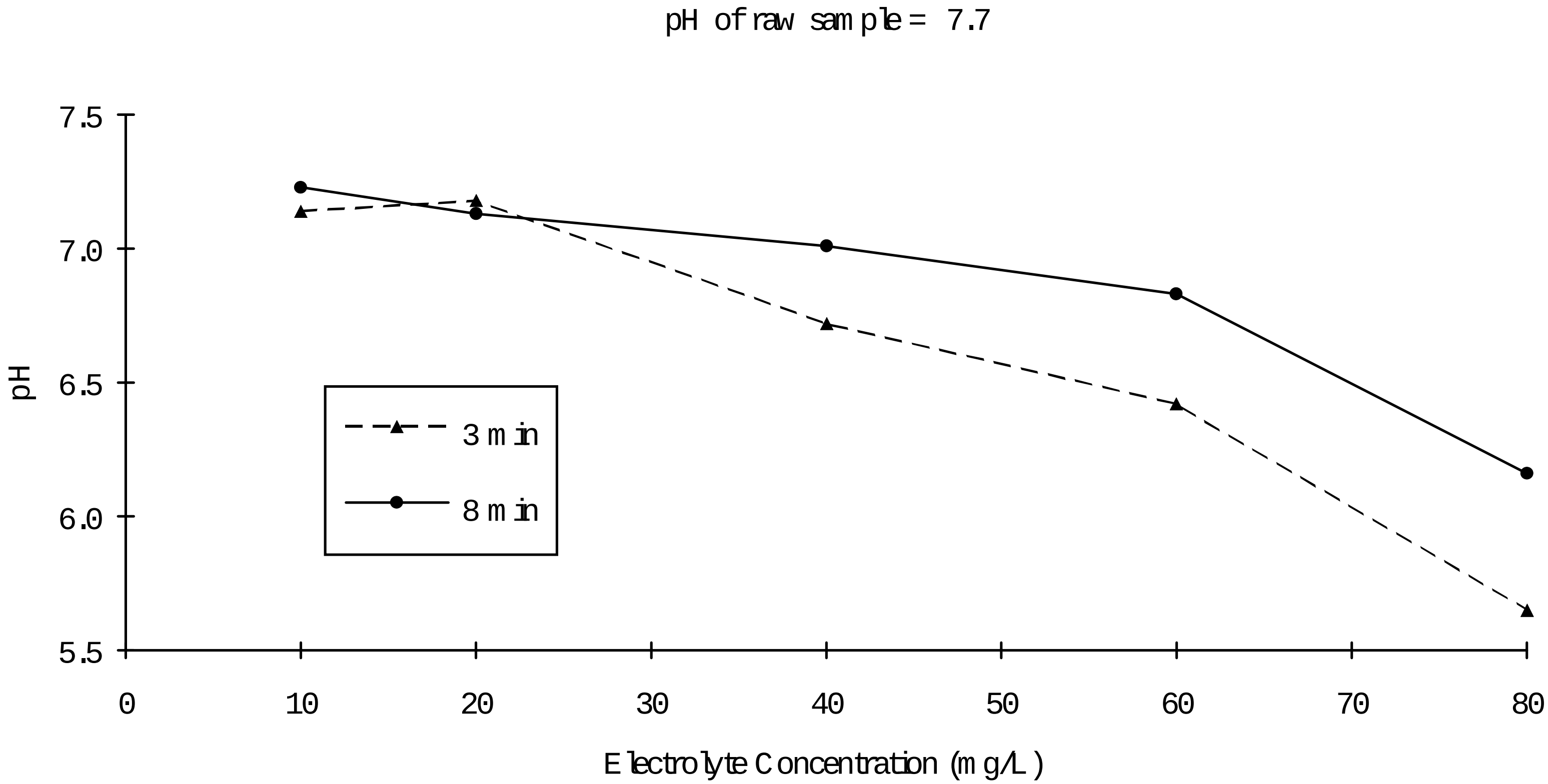
Turbidity versus Particle Count Rate

Figure 4-34 presents the correlation between particle count rate and turbidity. The correlation coefficient of turbidity and particle count rate was 0.5.

Figure 4-1. Particle size Distributions of raw and treated samples

Figure 4-2. Effectiveness of the MC process

Figure 4-3. Effectiveness of the MC process

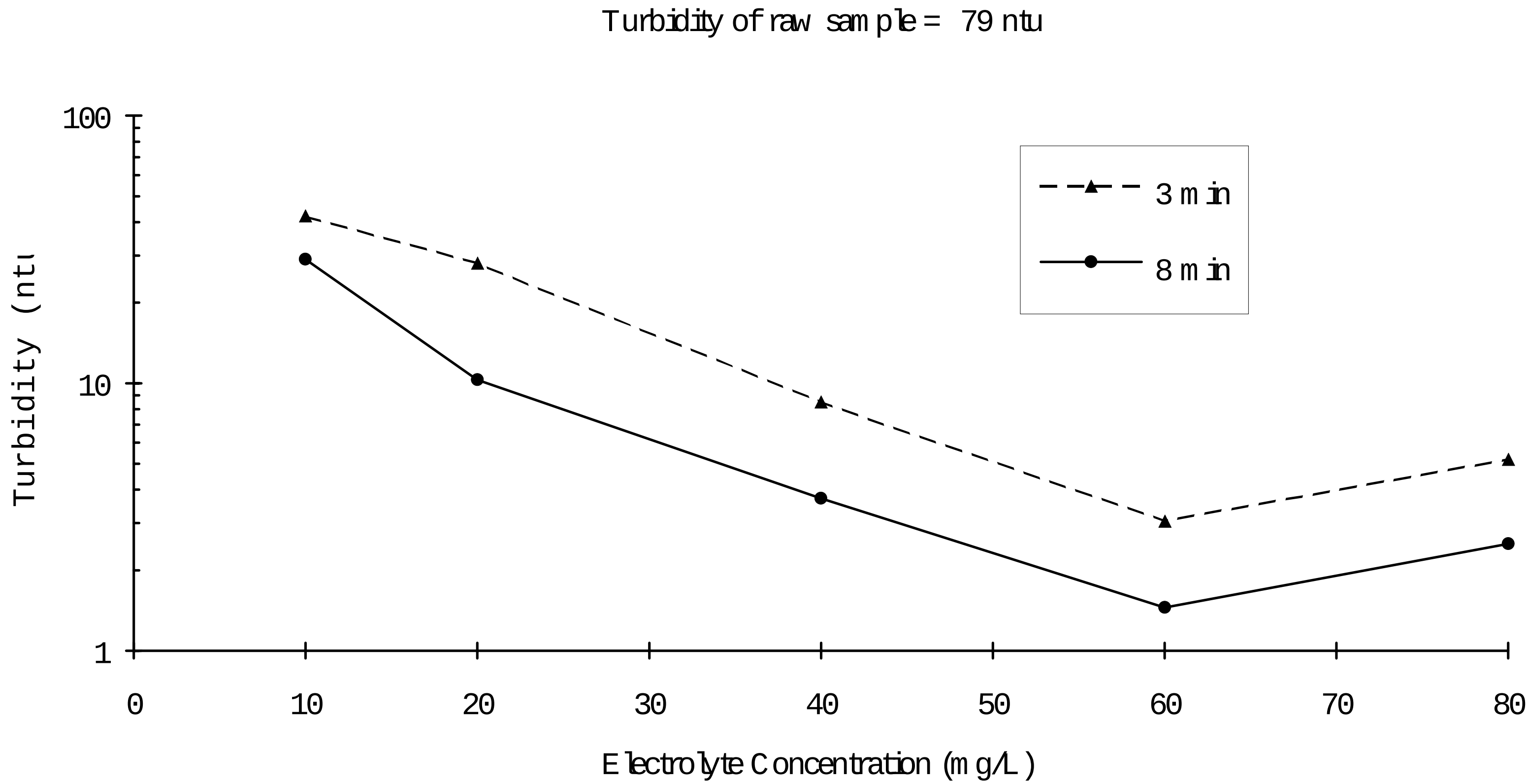


MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

Settling Time: 3 and 8 minutes; Without Polyelectrolyte

Figure 4-4. Typical pH Distributions (Level-1)

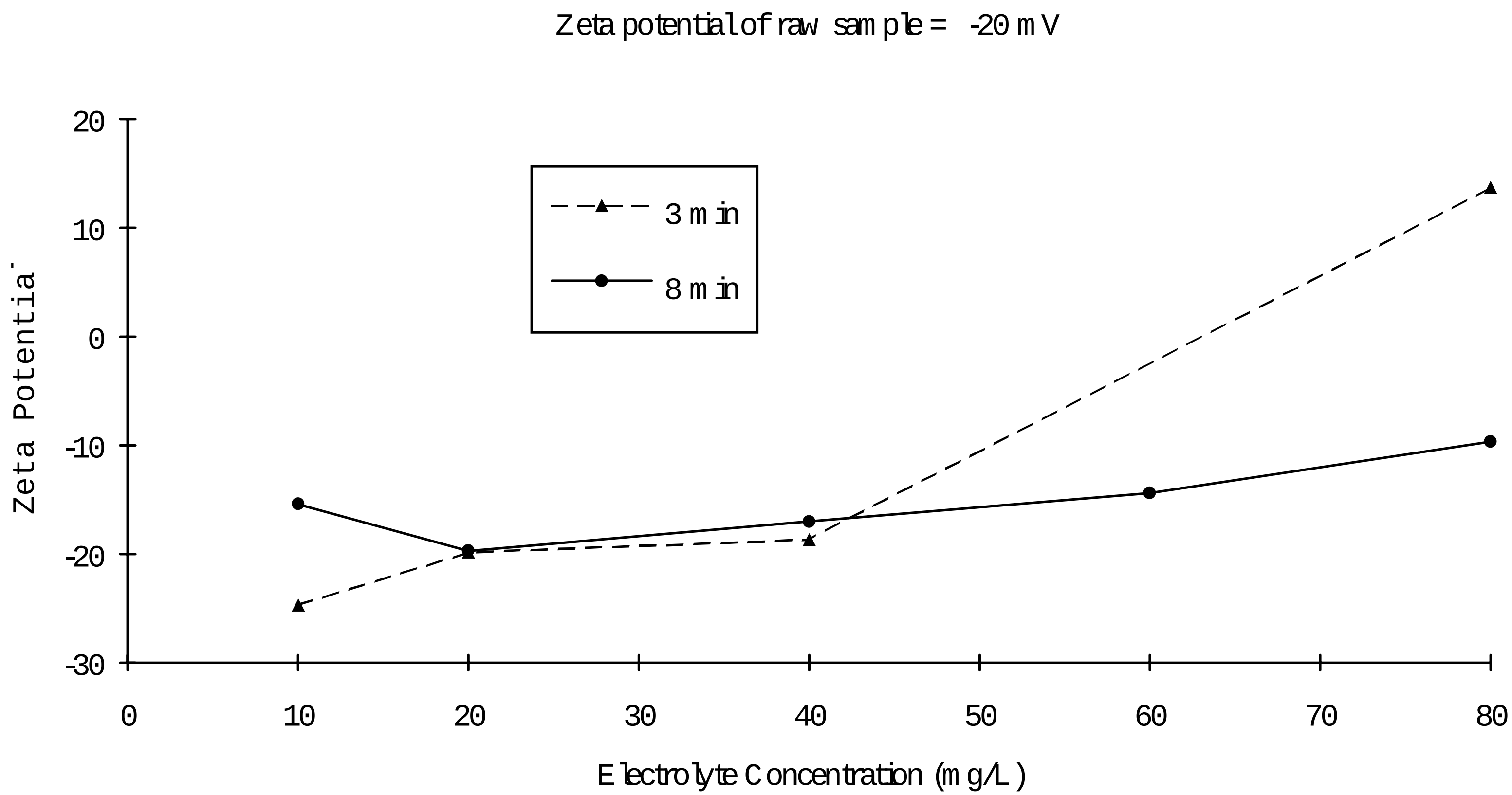


MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

Settling Time: 3 and 8 minutes; Without Polyelectrolyte

Figure 4-5. Turbidity Versus Coagulant Concentration (Level-1)

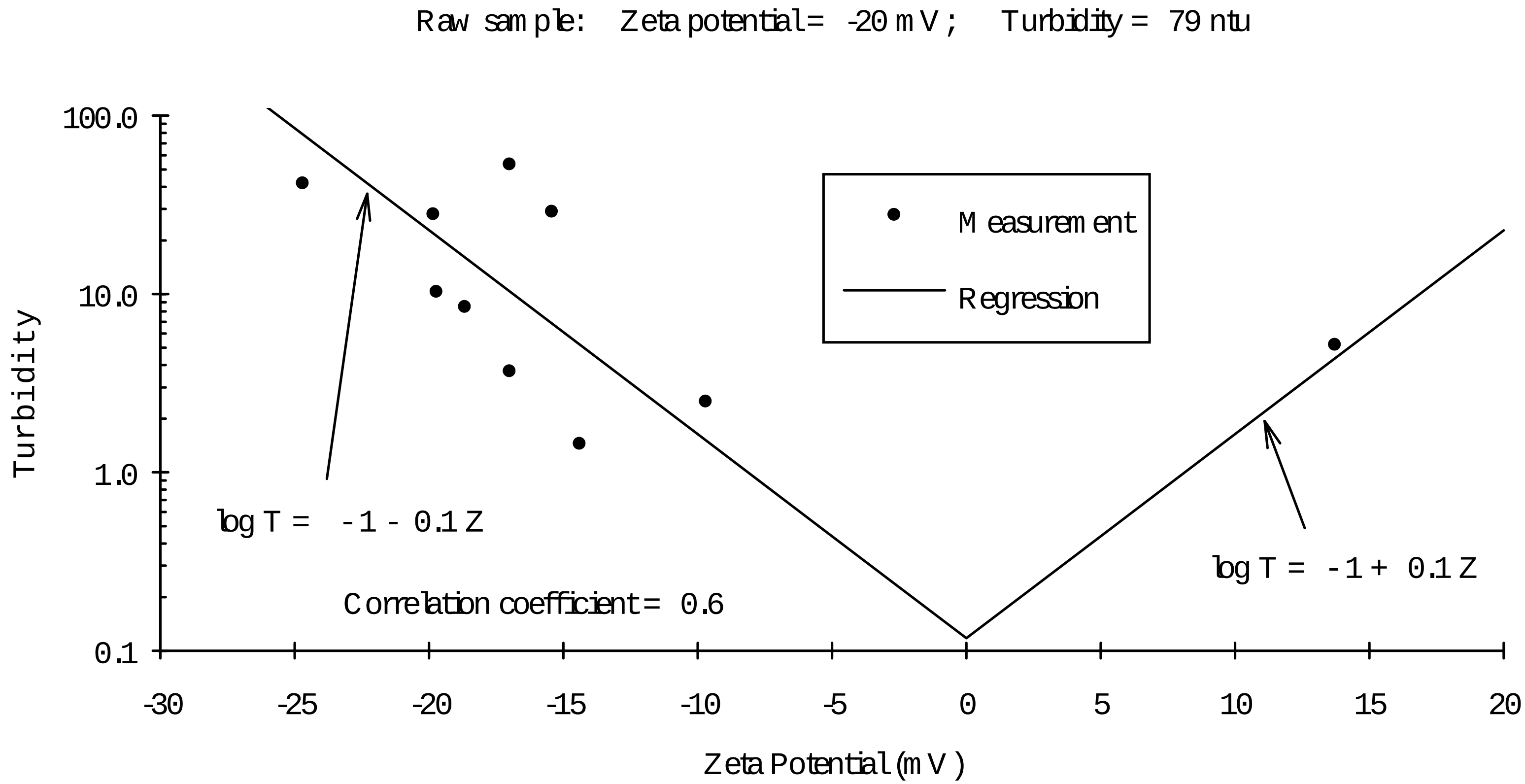


MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

Without Polyelectrolyte

Figure 4-6. Zeta Potential Distributions (Level-1)

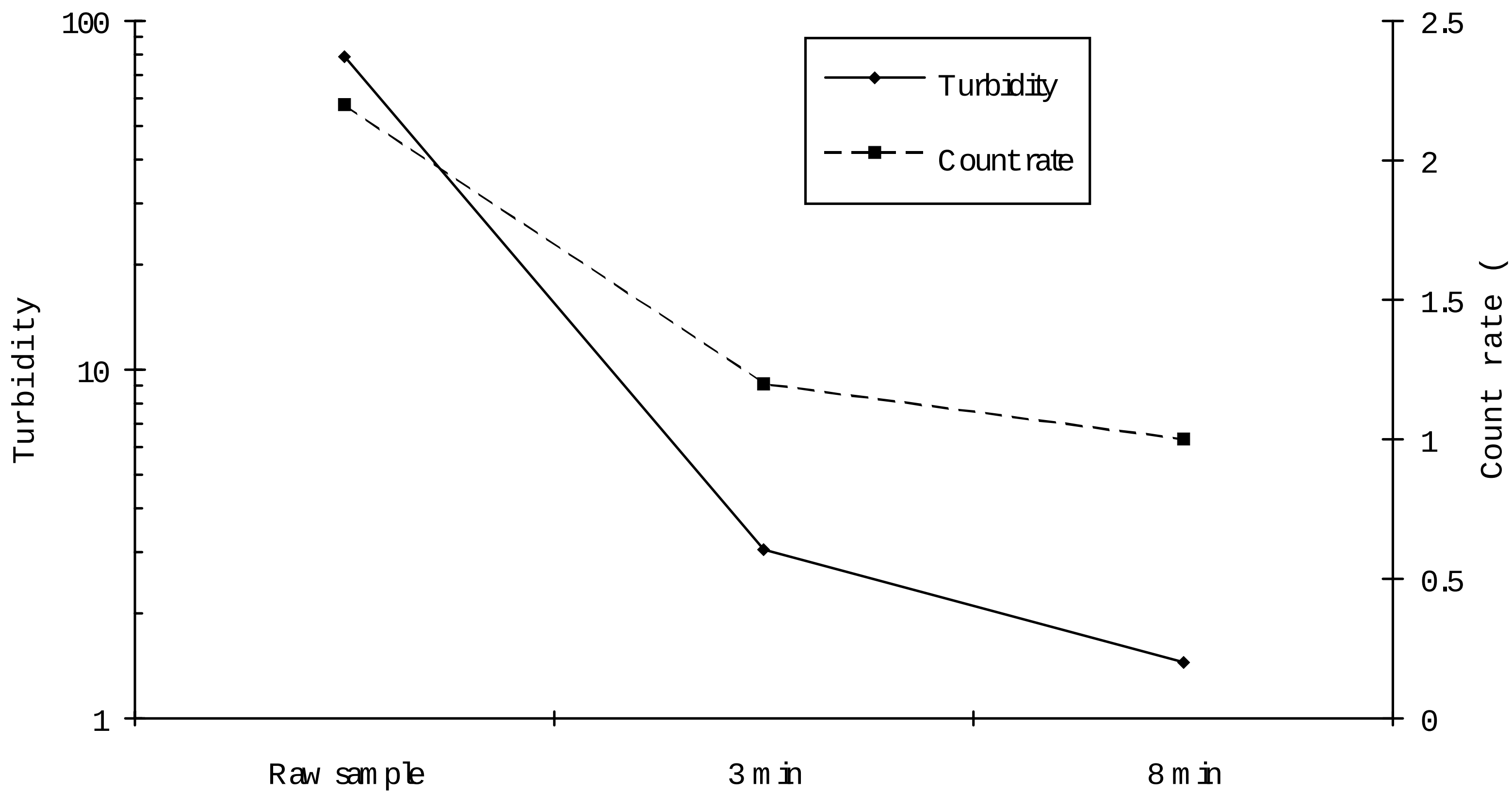


MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

Without Polyelectrolyte

Figure 4-7. Correlation of Zeta Potential and Turbidity (Level-1)

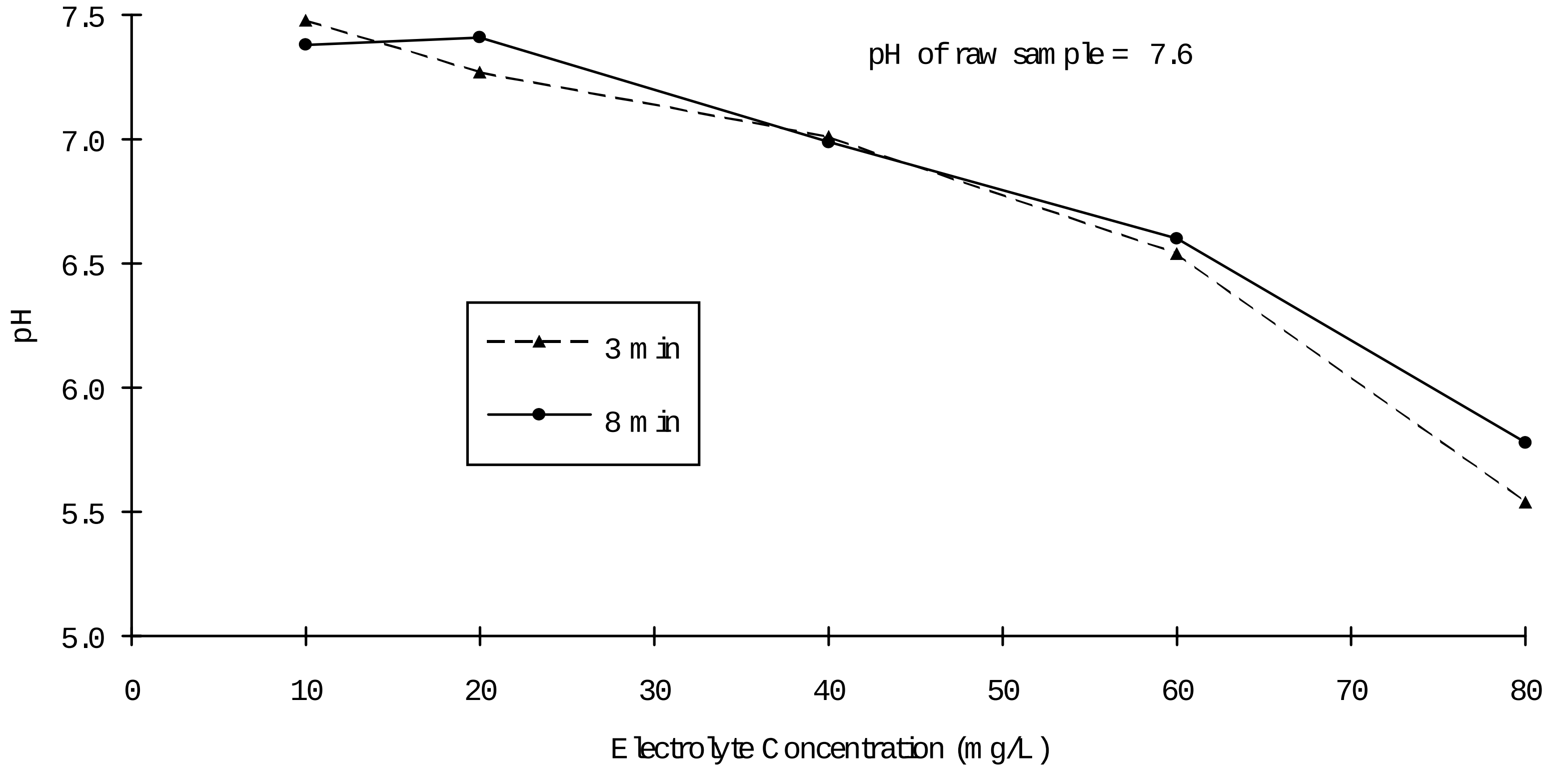


MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 60 mg/L

Settling Time: 3 and 8 minutes; Without Polyelectrolyte

Figure 4-8. Particle Count Rate for the Best Coagulant Concentration (Level-1)



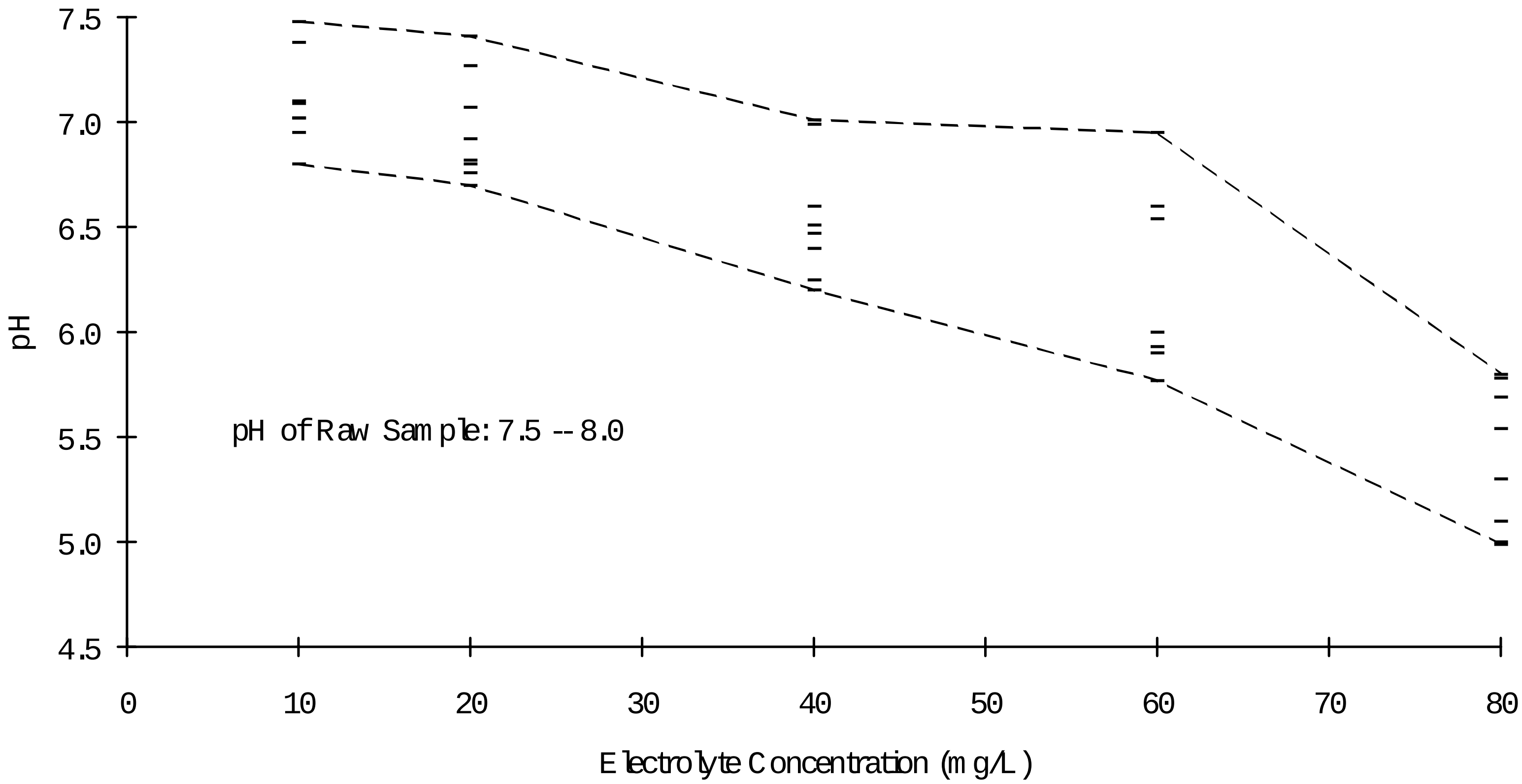
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-3: Polyelectrolyte POL-EZ-2696 Concentration = 1 mg/L

Settling Time: 3 and 8 minutes

Figure 4-9. Typical pH Distributions (Level-2)



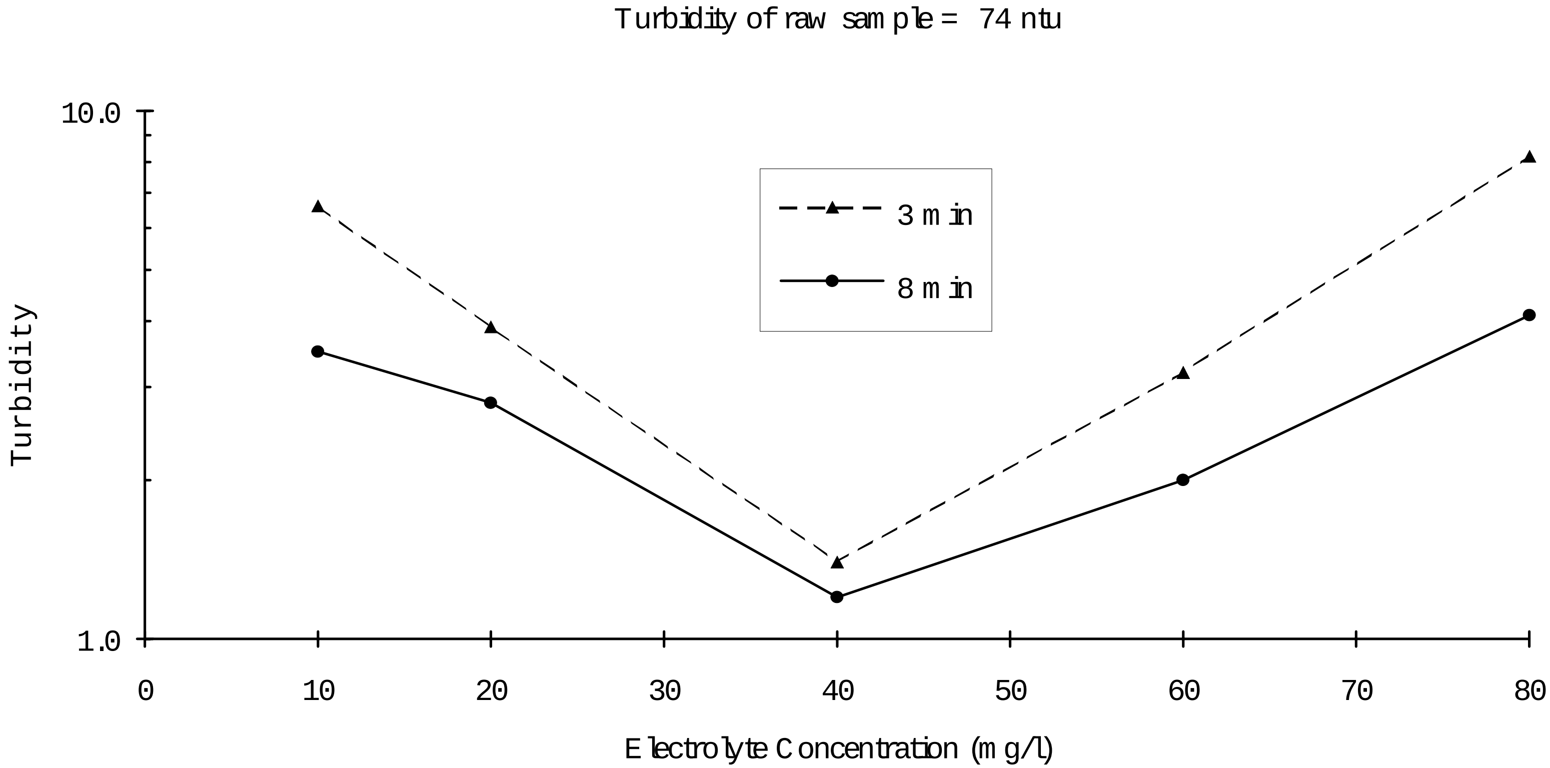
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-1: POL-EZ-2466; PE-2: POL-EZ-3466; PE-3: POL-EZ-2696; PE-4: POL-EZ-7736

Polyelectrolyte Concentration = 1 mg/L; Settling Time: 3 and 8 minutes

Figure 4-10. Summary of pH Distributions (Level-2)



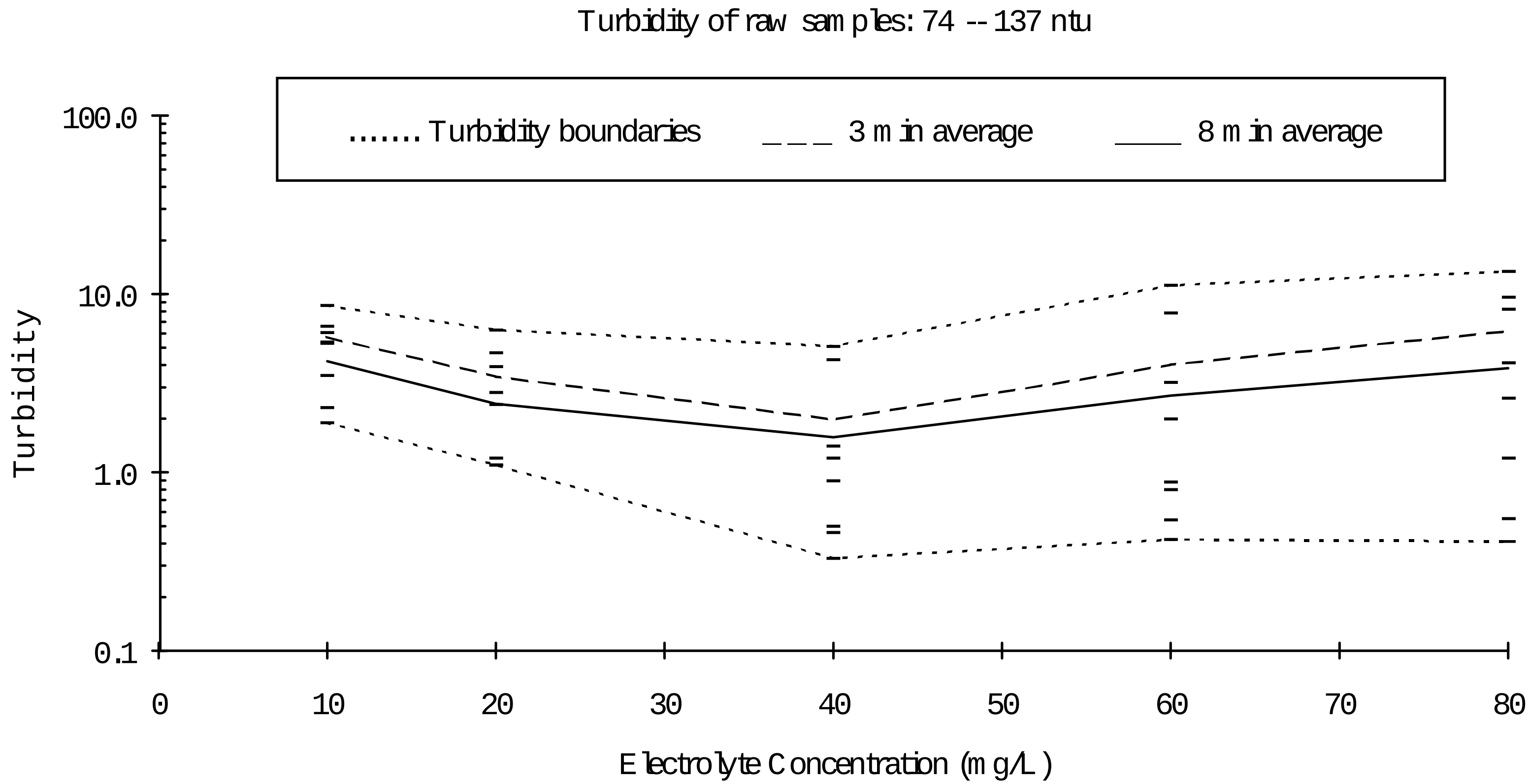
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-4: Polyelectrolyte POL-EZ-7736 Concentration = 1 mg/L

Settling Time: 3 and 8 minutes

Figure 4-11. Typical Turbidity Distributions (Level-2)



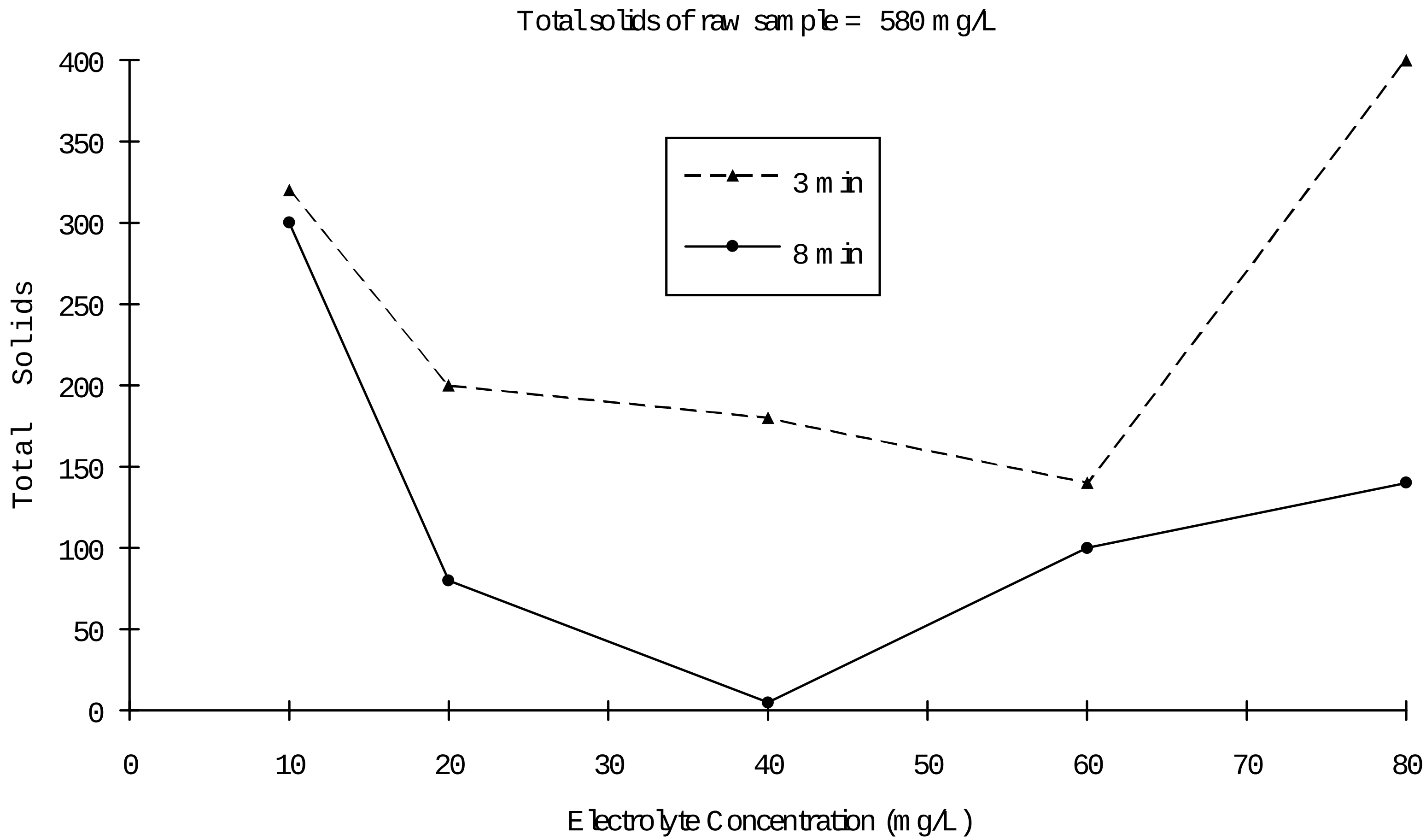
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-1: POL-EZ-2466; PE-2: POL-EZ-3466; PE-3: POL-EZ-2696; PE-4: POL-EZ-7736

Polyelectrolyte Concentration = 1 mg/L; Settling Time: 3 and 8

Figure 4-12. Summary of Turbidity Distributions (Level-2)

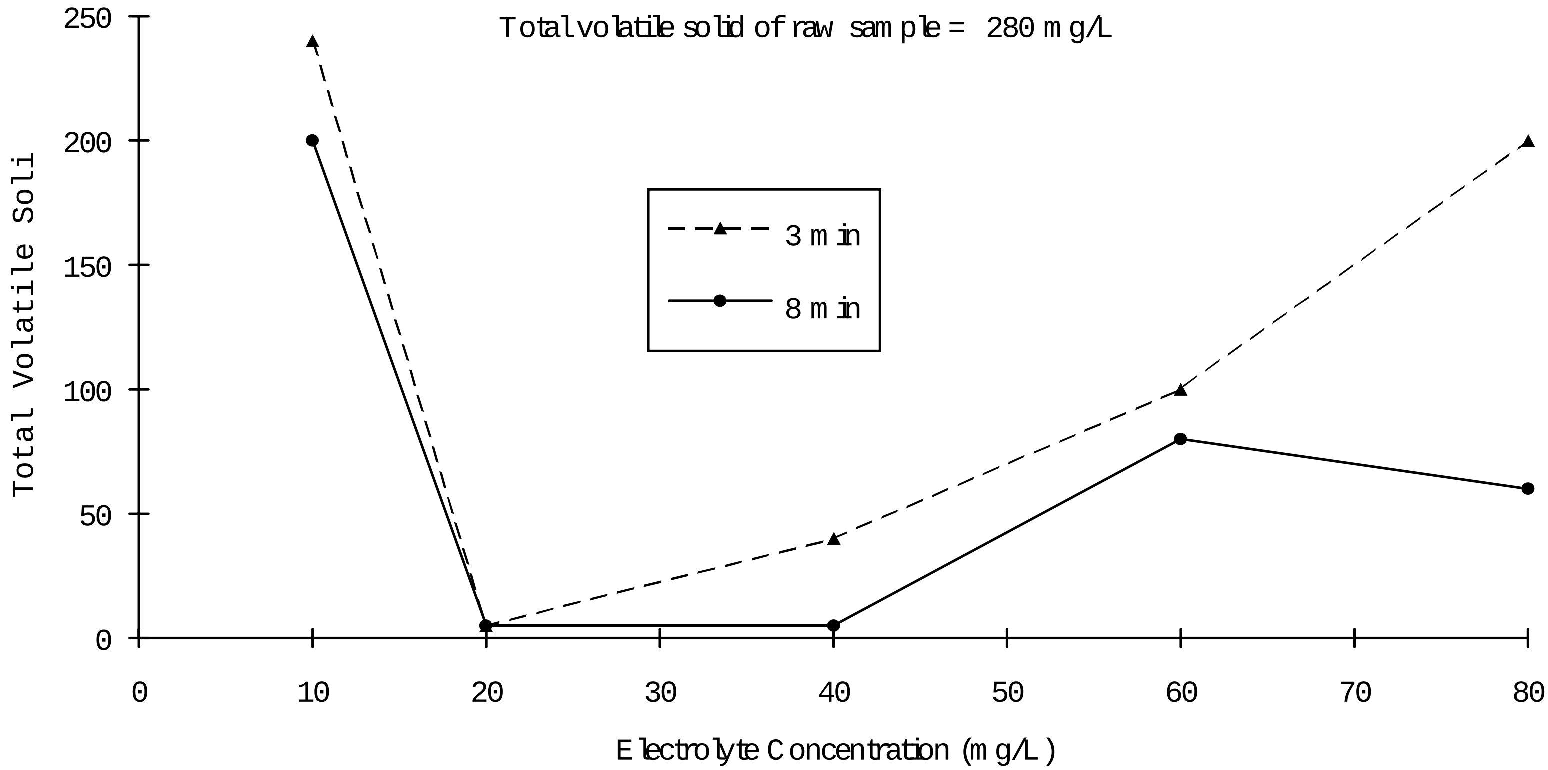


MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-3: Polyelectrolyte POL-EZ-2696 Concentration = 1

Figure 4-13. Total Solids Distributions (Level-2)



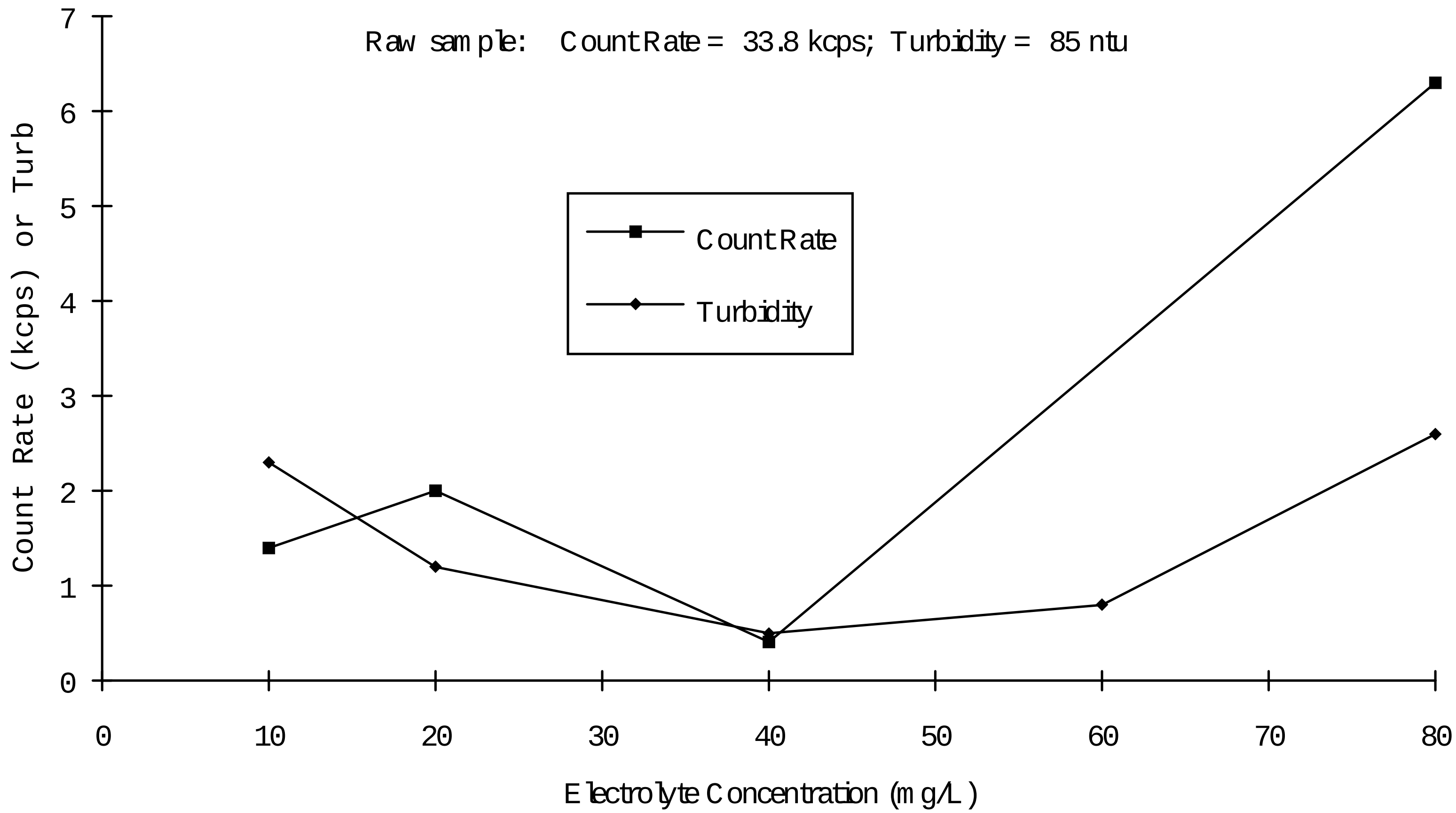
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-3: Polyelectrolyte POL-EZ-2696 Concentration = 1 mg/L

Settling Time: 3 and 8 minutes

Figure 4-14. Total Volatile Solids Distributions (Level-2)

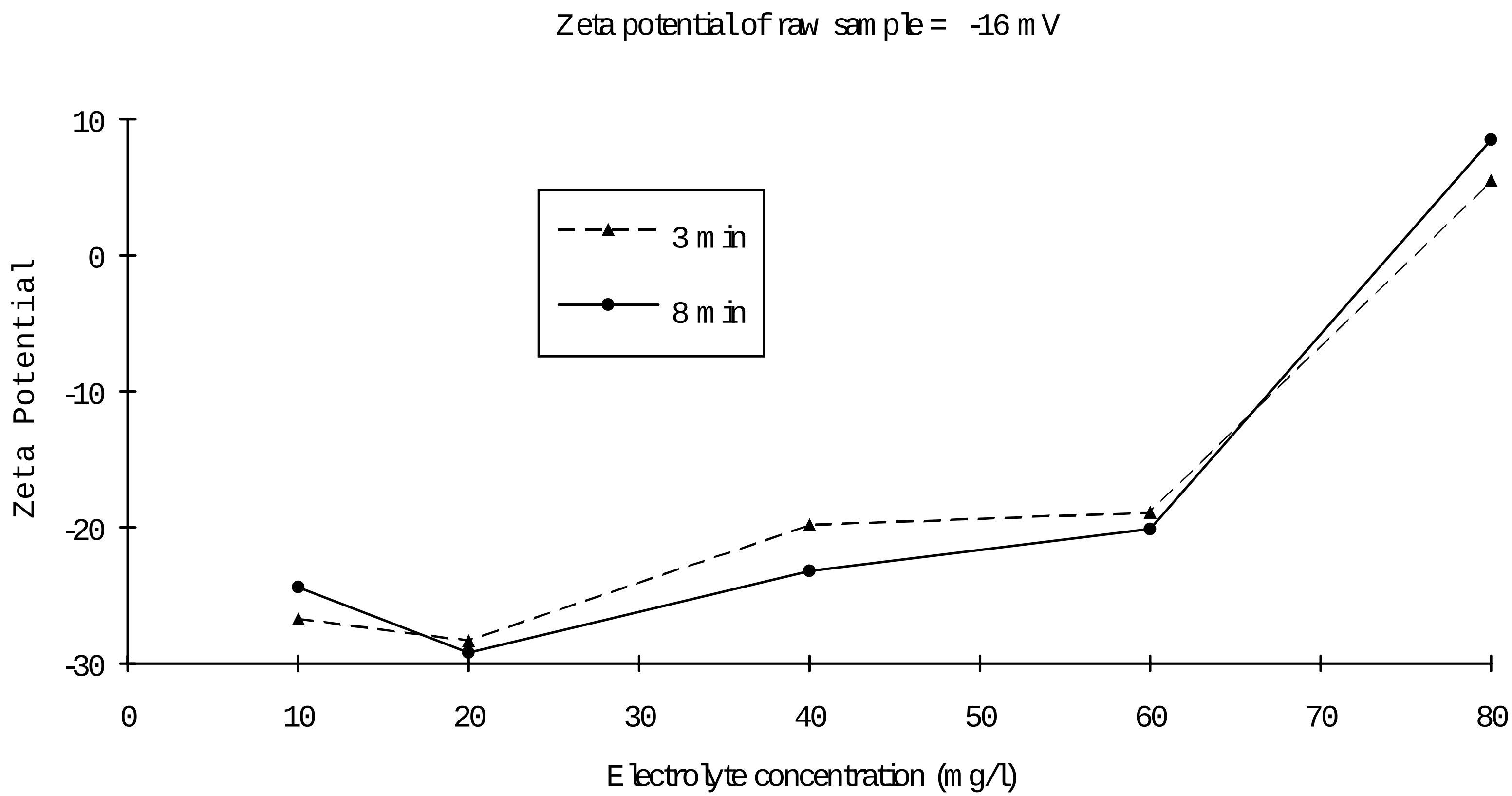


MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-3: Polyelectrolyte POL-EZ-2696 Concentration = 1

Figure 4-15. A Comparison of Turbidity and Particle Count Rate (Level-2)



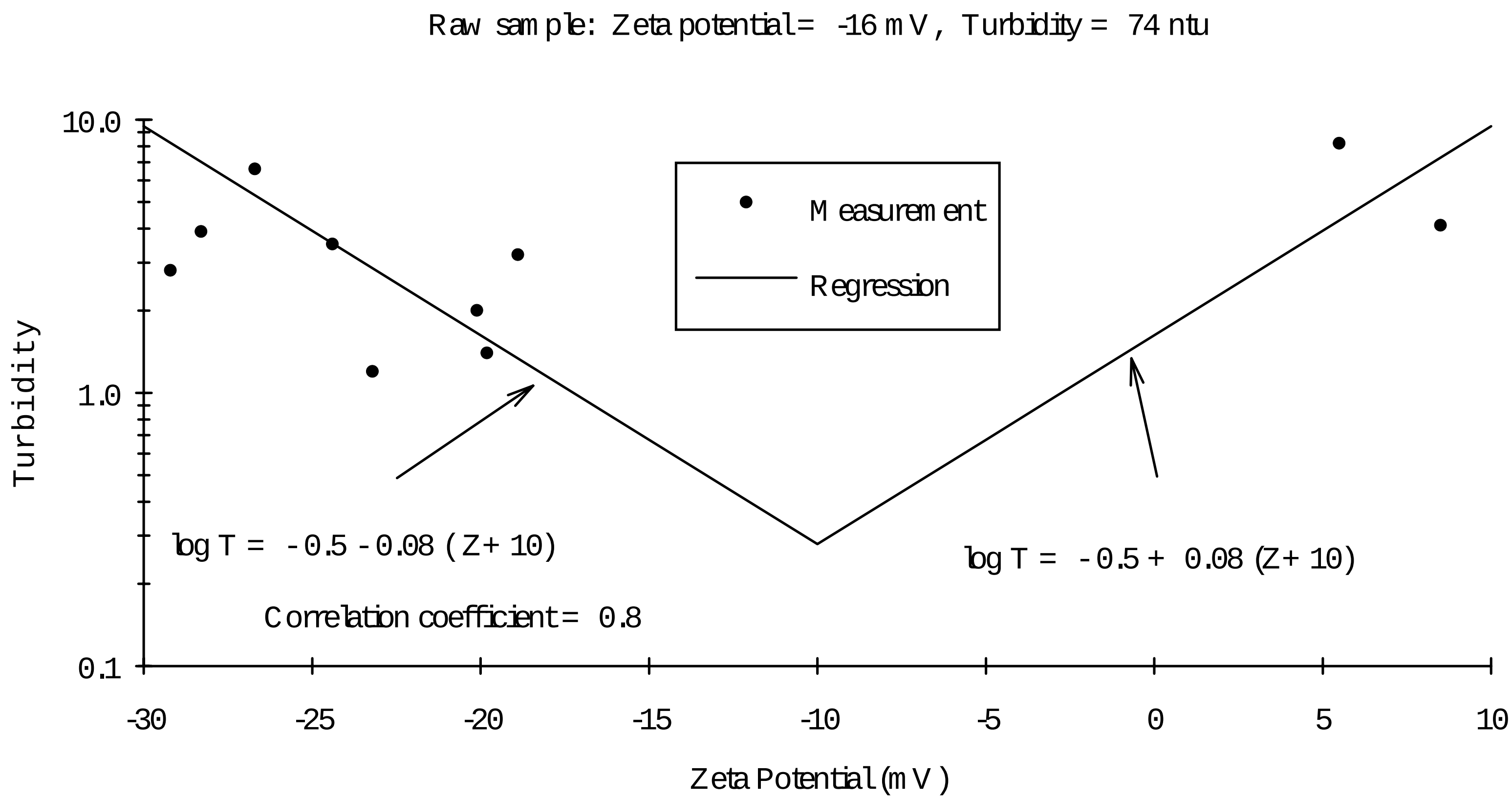
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-4: Polyelectrolyte POL-EZ-7736 Concentration = 1 mg/L

Settling Time: 3 and 8 minutes

Figure 4-16. Zeta Potential Distributions (Level-2)

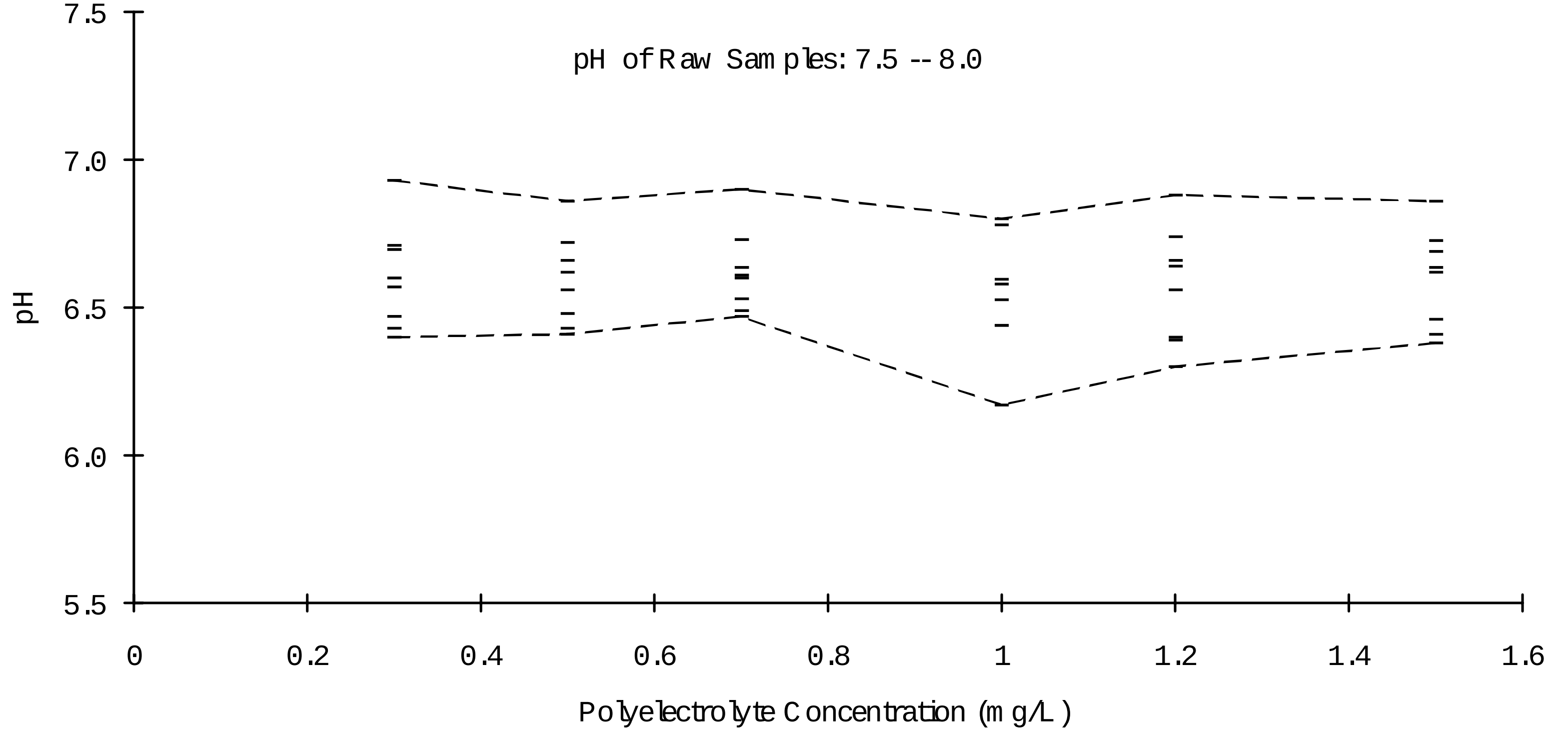


MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 10—80 mg/L

PE-4: Polyelectrolyte POL-EZ-7736 Concentration = 1

Figure 4-17. Correlation of Zeta Potential and Turbidity (Level-2)



MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

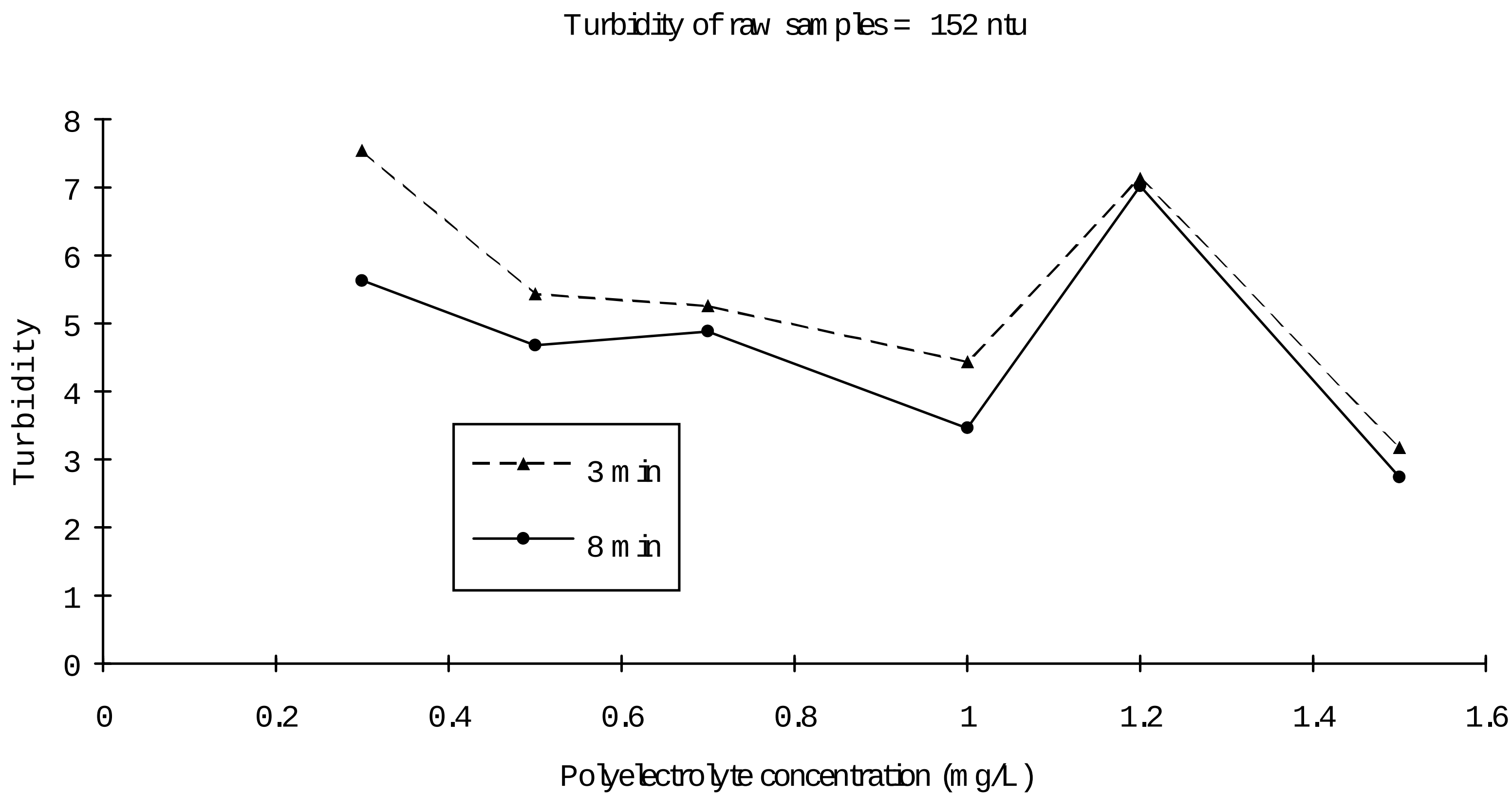
Polyelectrolyte: PE-1: POL-EZ-2466; PE-2: POL-EZ-3466;

PE-3: POL-EZ-2696; PE-4: POL-EZ-7736

Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 and 8 minutes

Figure 4-18. Summary of pH Distributions (Level-3)



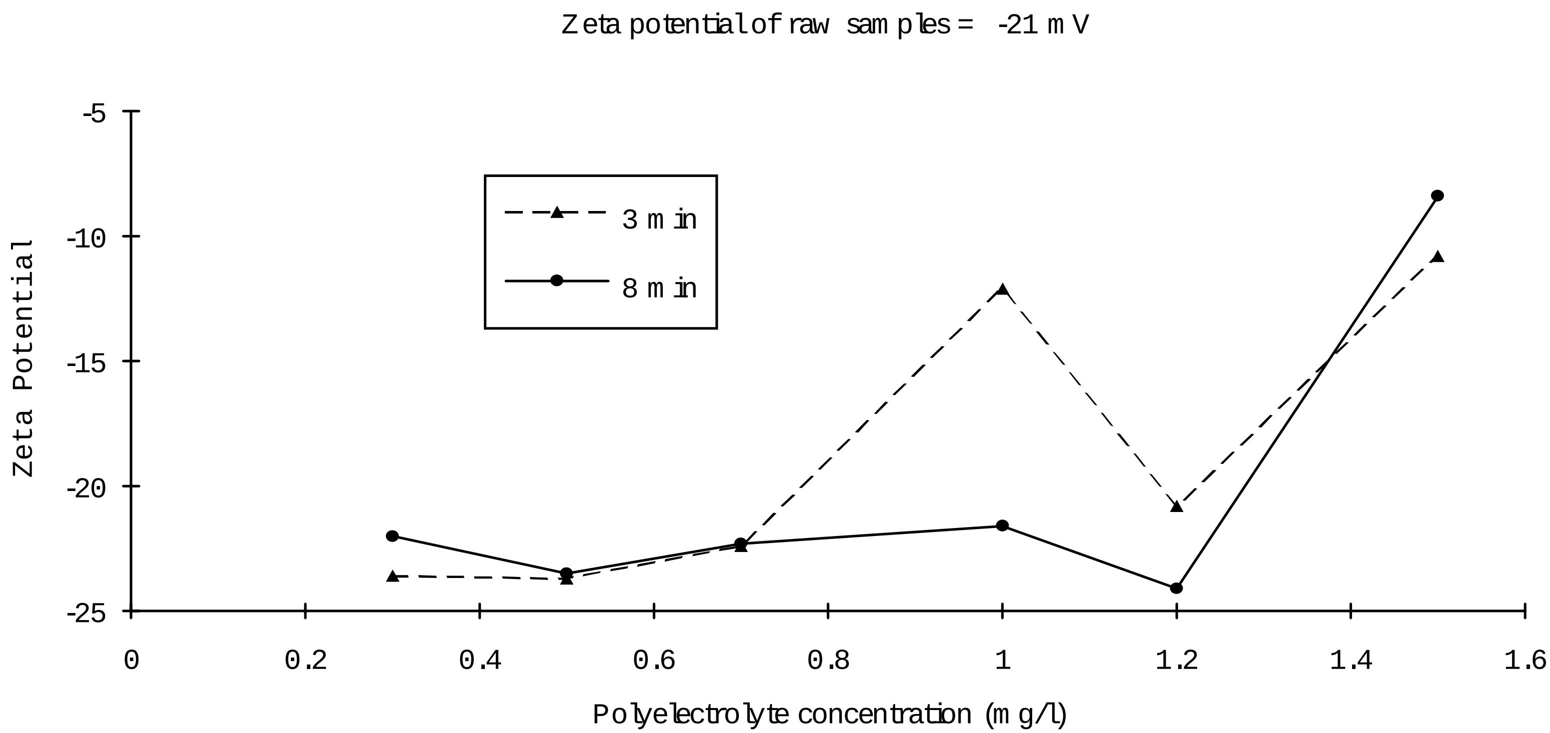
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-3: POL-EZ-2696; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 and 8 minutes

Figure 4-19. Turbidity Distributions (Level-3; POL-EZ-2696)



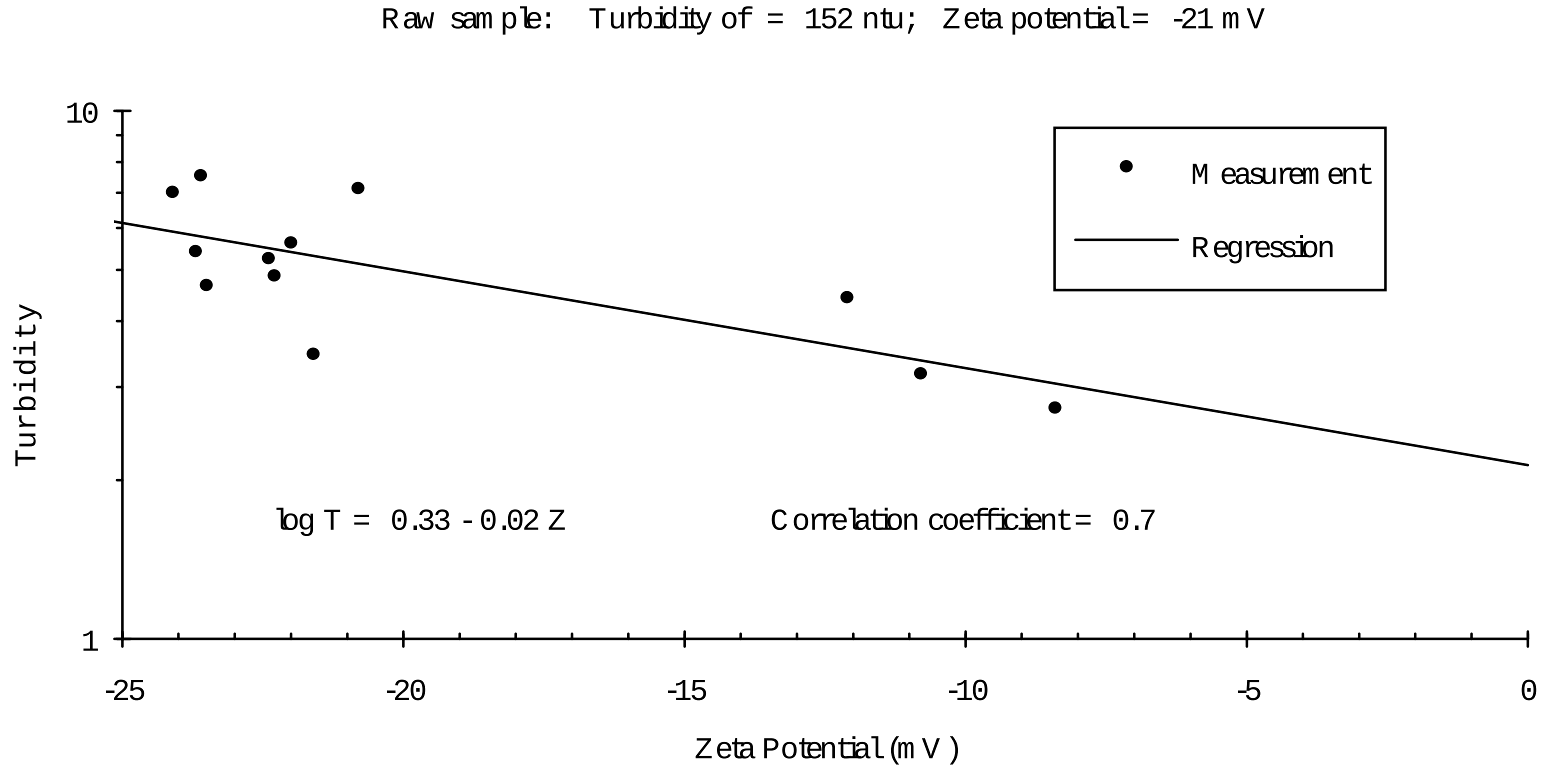
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-3: POL-EZ-2696; Polyelectrolyte Concentration = 0.3—1.5 mg/L

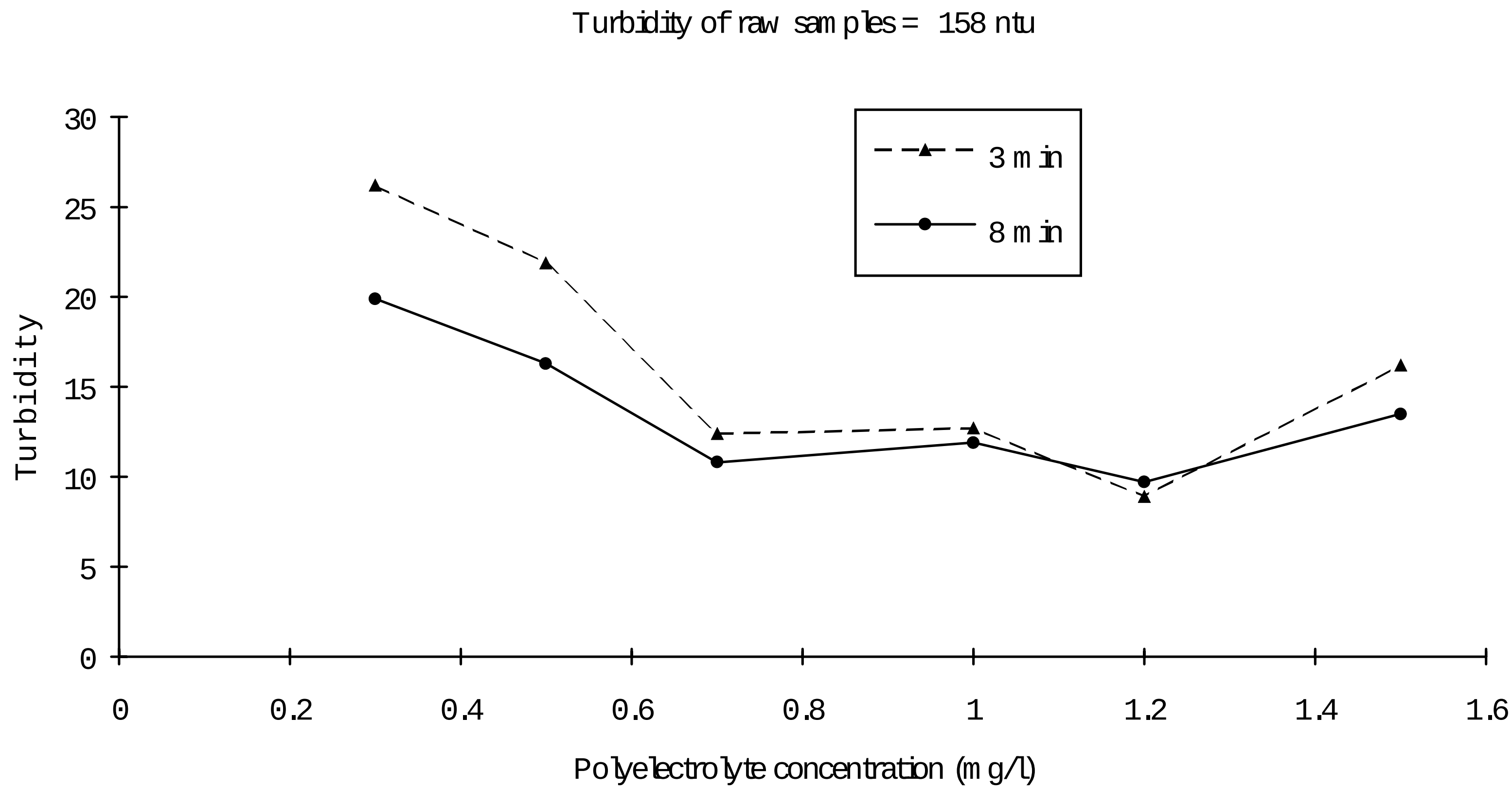
Settling Time: 3 and 8 minutes

Figure 4-20. Zeta Potential Distributions (Level-3; POL-EZ-2696)



MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L
E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L
Polyelectrolyte: PE-3: POL-EZ-2696; Polyelectrolyte Concentration = 0.3—1.5 mg/L
Settling Time: 3 and 8 minutes

Figure 4-21. Correlation of Zeta Potential and Turbidity (Level-3)



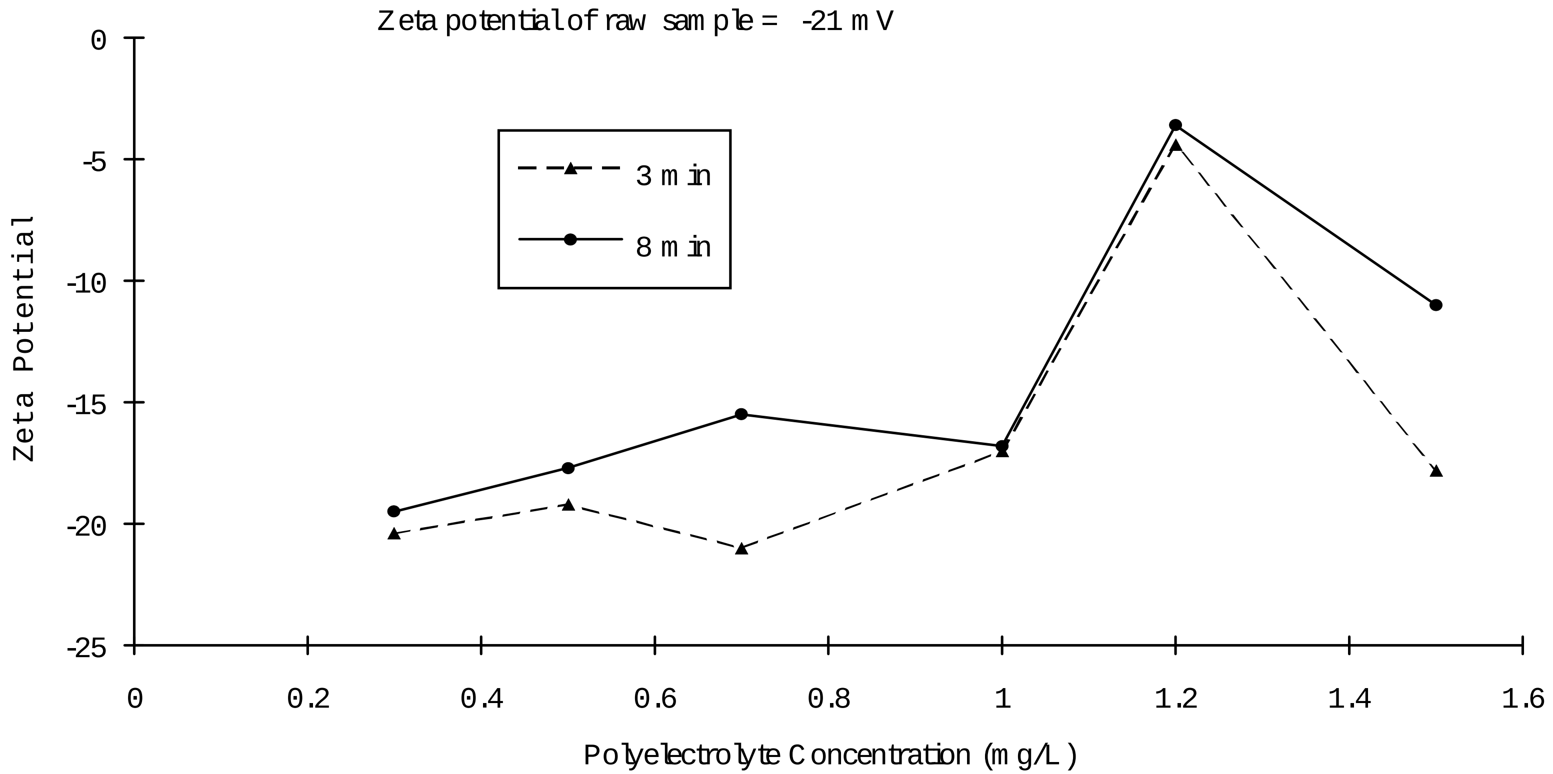
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-3: POL-EZ-2696; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 and 8 minutes

Figure 4-22. Turbidity Distributions (Level-3; POL-EZ-2466)



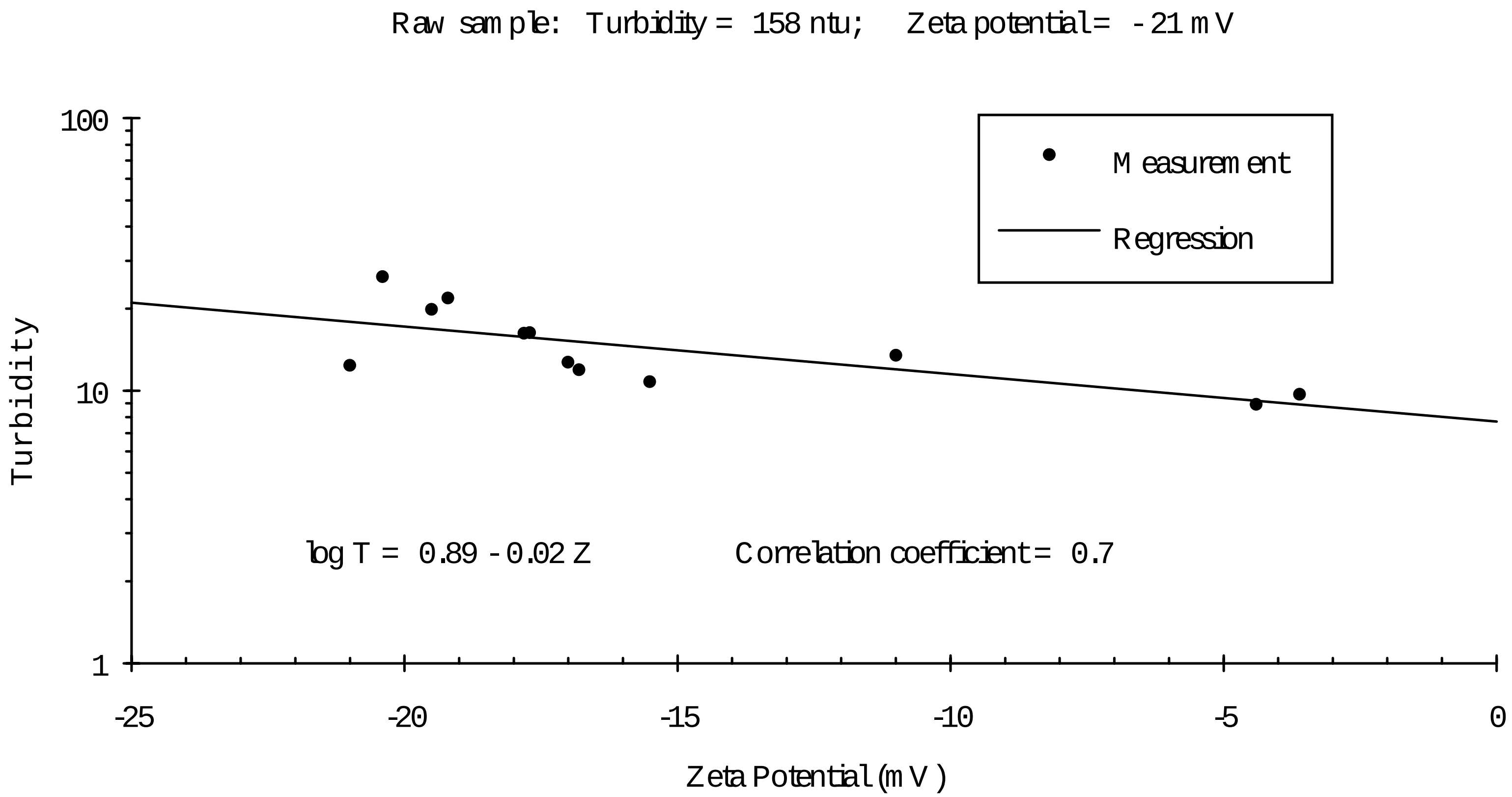
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-1: POL-EZ-2466; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 and 8 minutes

Figure 4-23. Zeta Potential Distributions (Level-3; POL-EZ-2466)

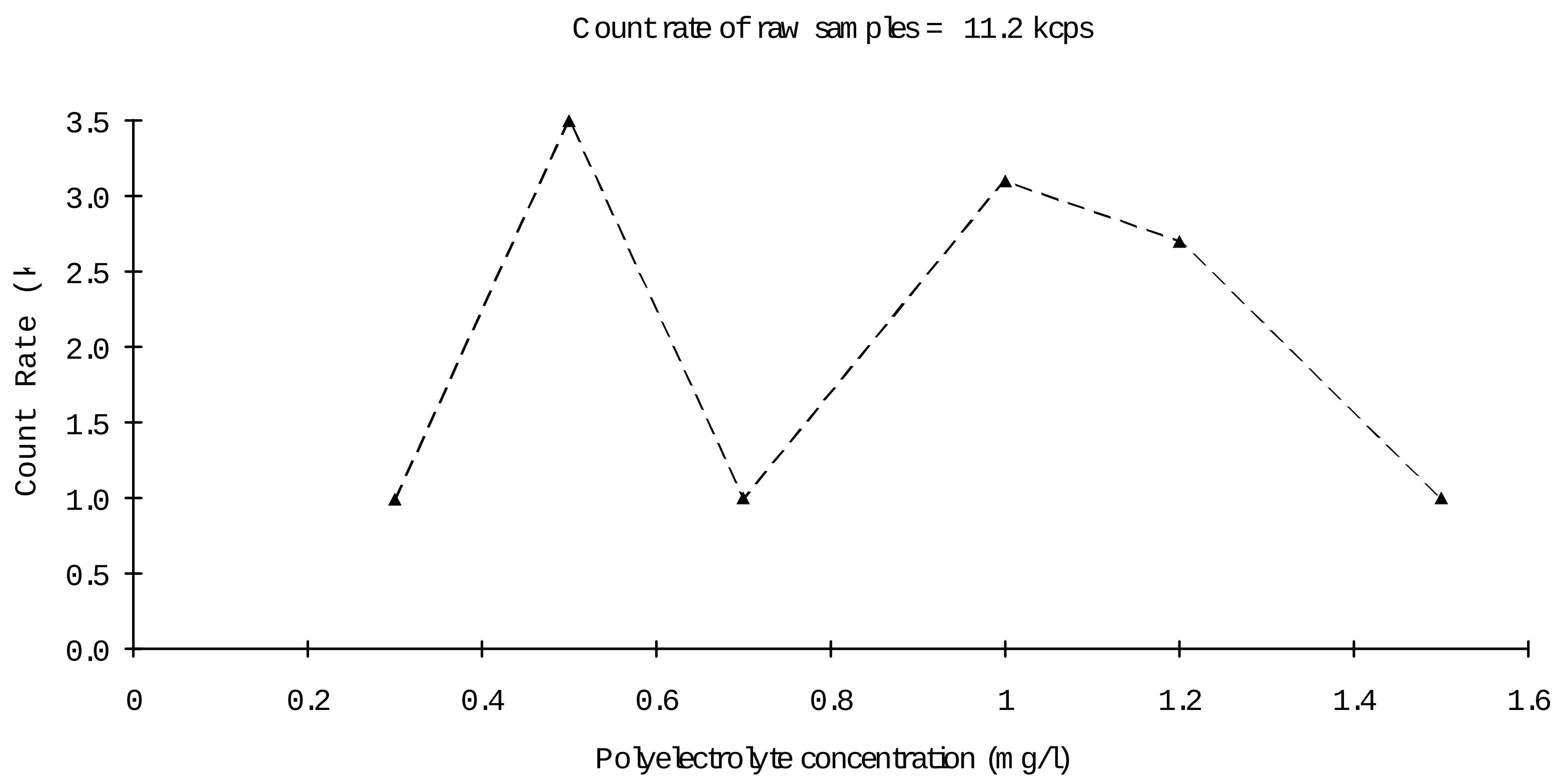


MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-1: POL-EZ-2466; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Figure 4-24. Correlation of Zeta Potential and Turbidity (Level-3)



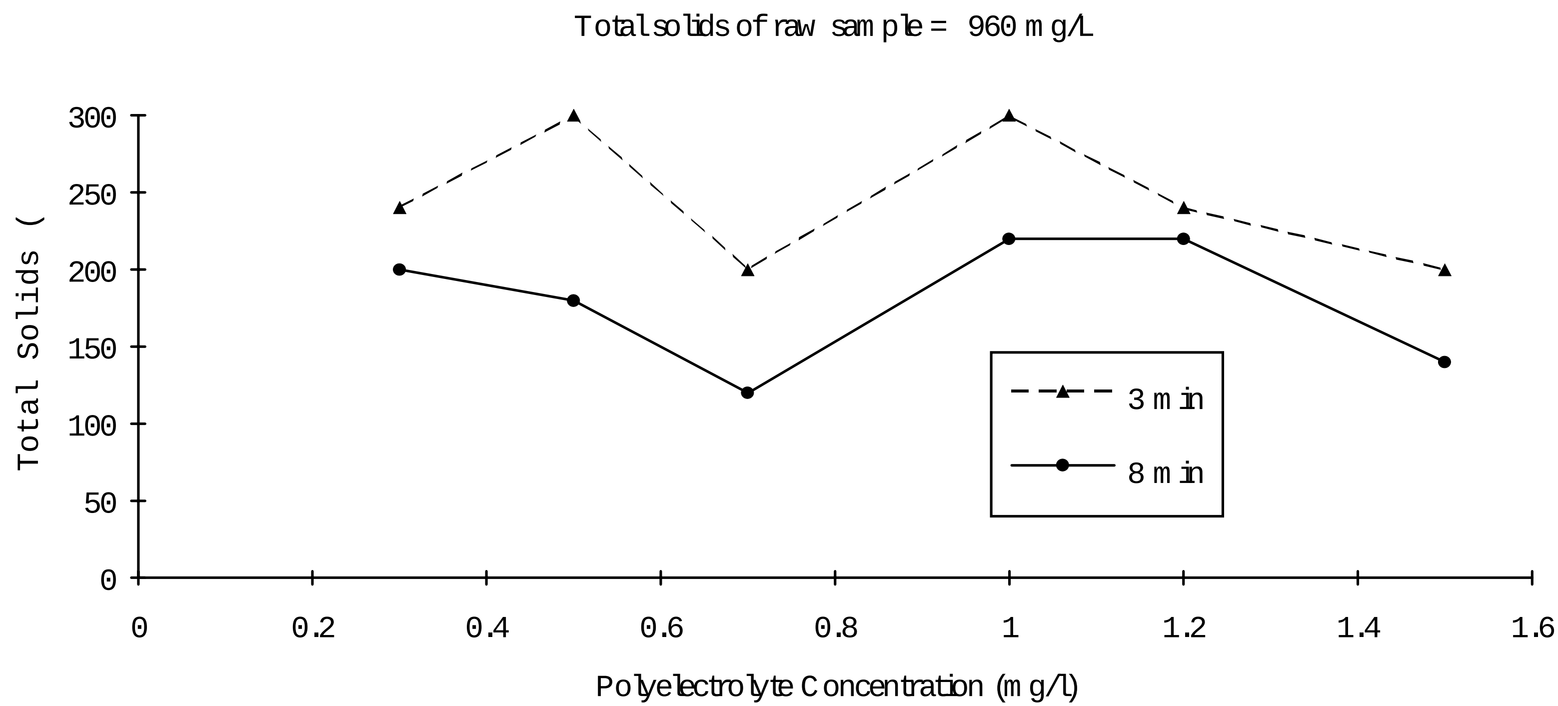
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-1: POL-EZ-2466; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 minutes

Figure 4-25. Particle Count Rate Distribution (Level-3; POL-EZ-2466)



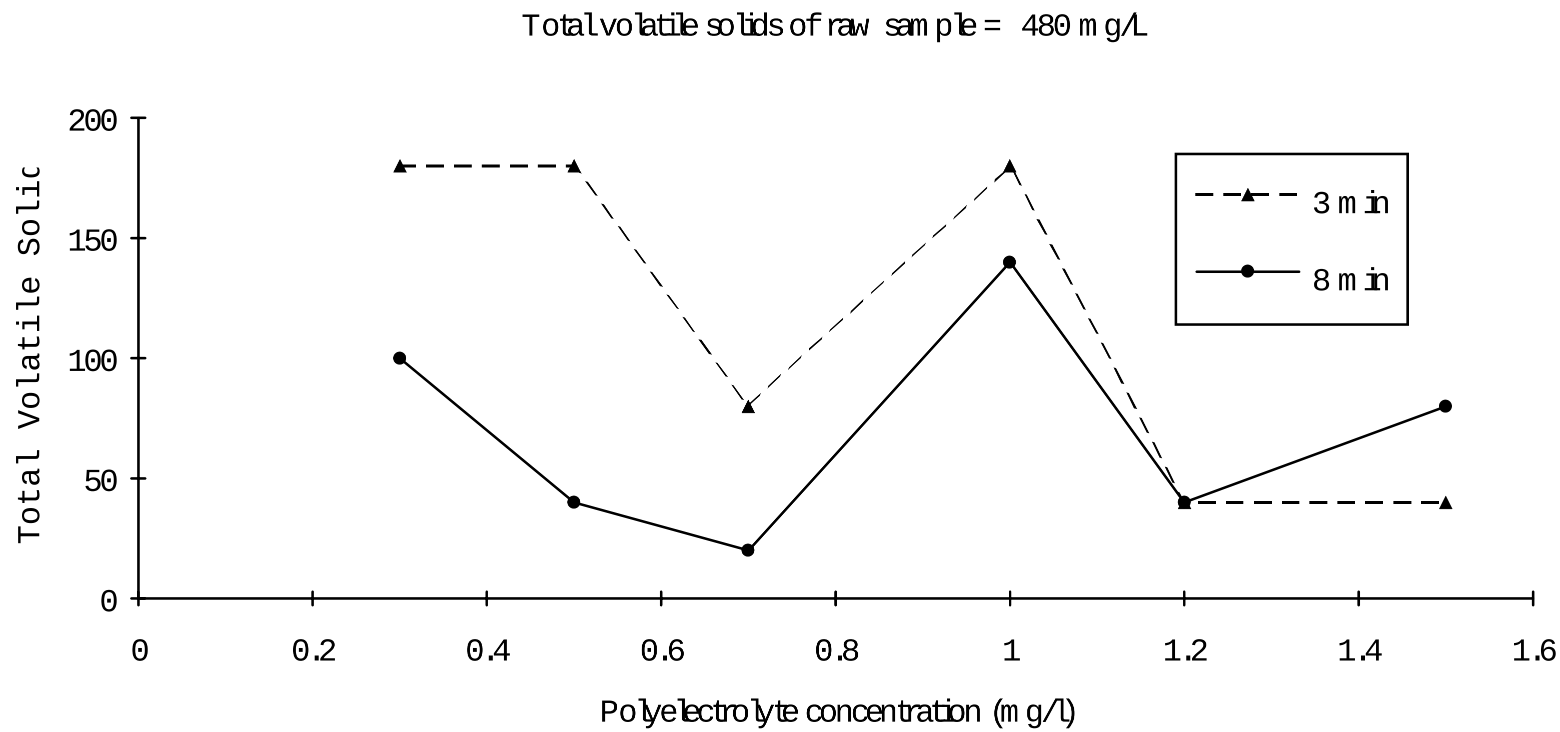
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-1: POL-EZ-2466; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 and 8 minutes

Figure 4-26. Total Solids Distributions (Level-3; POL-EZ-2466)



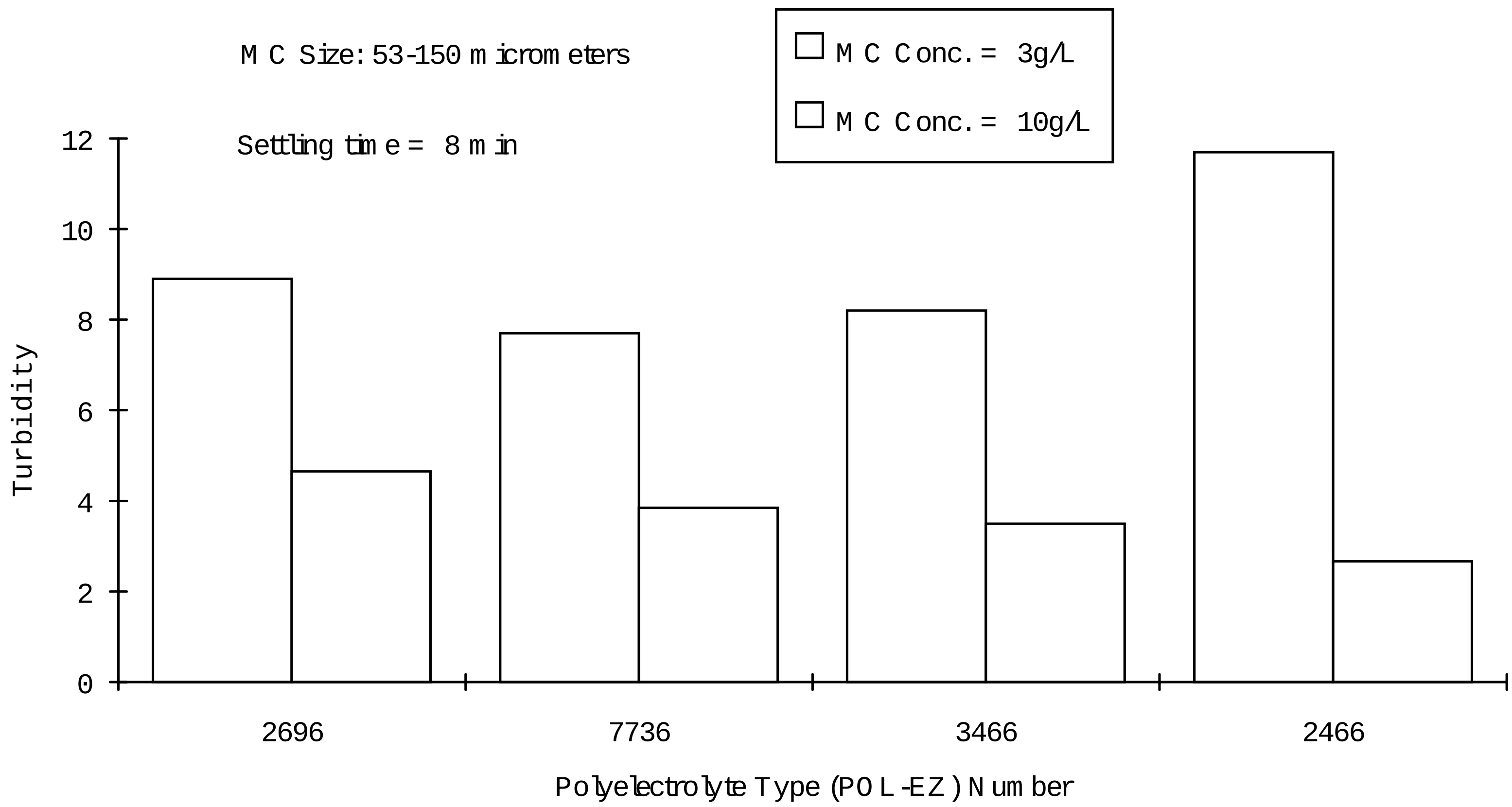
MC-1: MC Size Range = 53—150 μm; MC Concentration = 3 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Polyelectrolyte: PE-1: POL-EZ-2466; Polyelectrolyte Concentration = 0.3—1.5 mg/L

Settling Time: 3 and 8 minutes

Figure 4-27. Total Volatile Solids Distributions (Level-3; POL-EZ-2466)



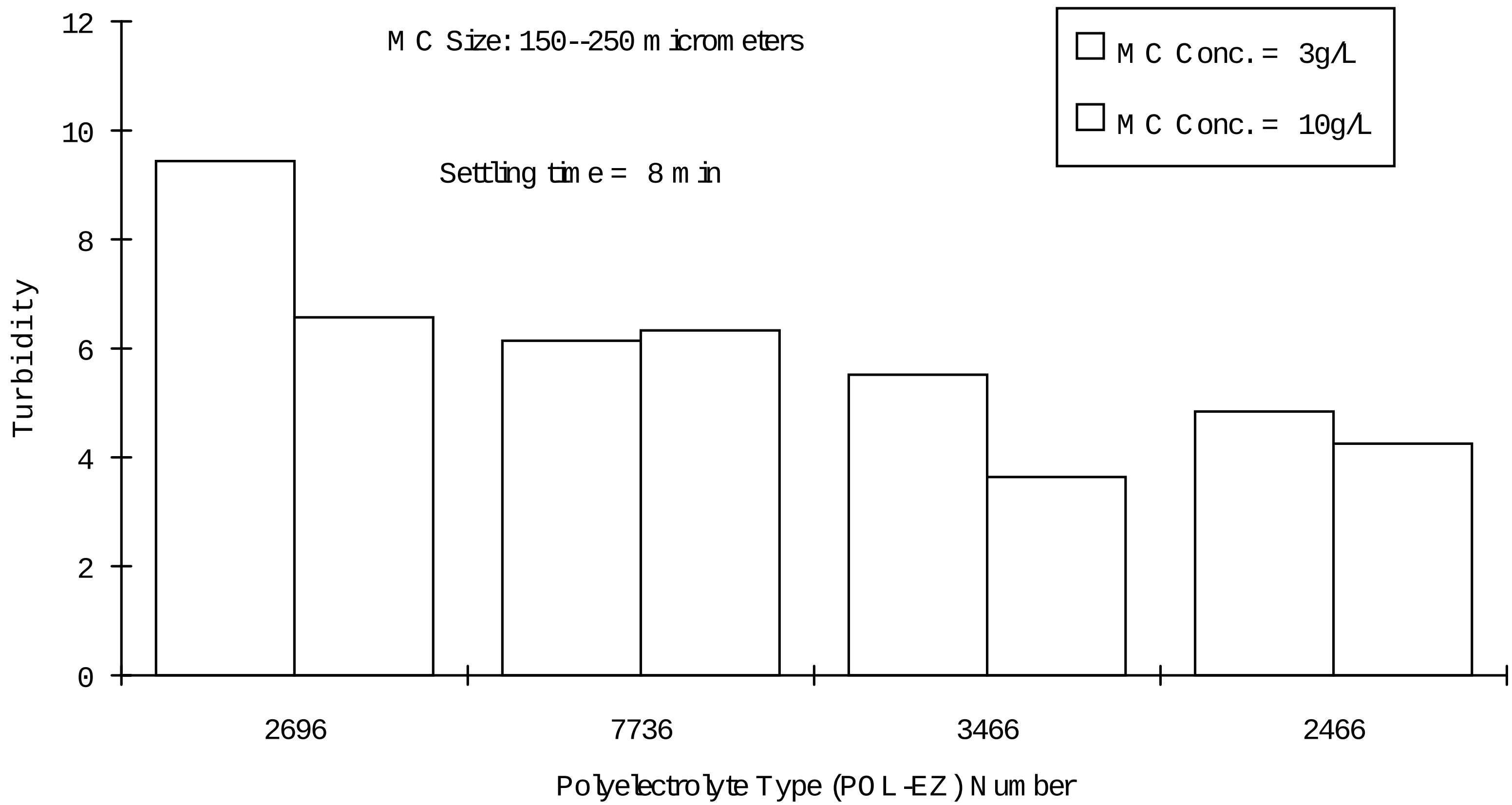
MC-1: MC Size Range = 53—150 µm; MC Concentration = 3 and 10 g/L

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Coagulant Aid (Polyelectrolyte) Identification in Table 3-4

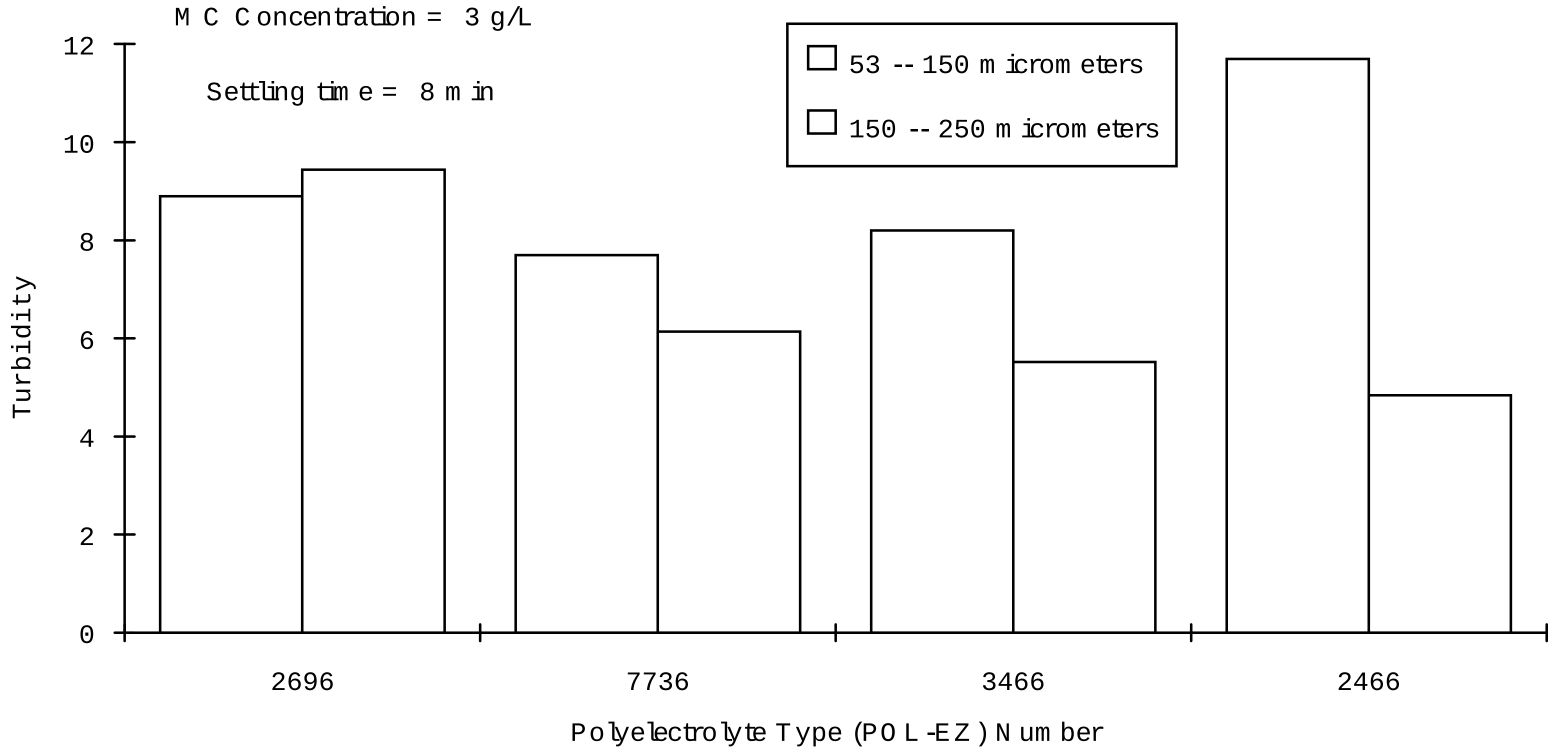
Polyelectrolyte Concentration = 1 mg/L; Settling Time = 8 minutes

Figure 4-28. Turbidity for Different MC Concentrations (Small MC)



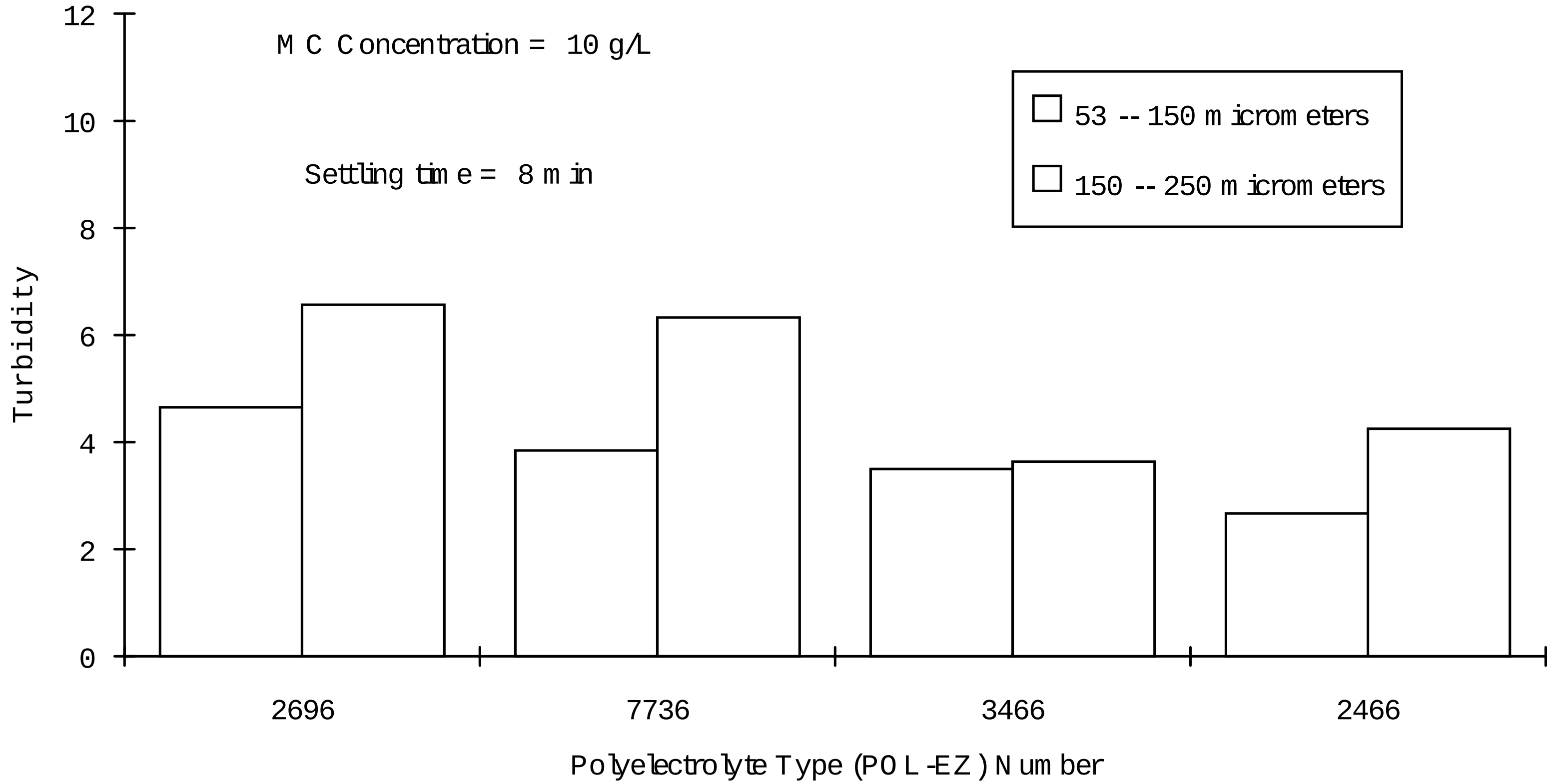
MC-1: MC Size Range = 150—250 µm; MC Concentration = 3 and 10 g/L
E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L
Coagulant Aid (Polyelectrolyte) Identification in Table 3-4
Polyelectrolyte Concentration = 1 mg/L; Settling Time = 8 minutes

Figure 4-29. Turbidity for Different MC Concentrations (Large MC)



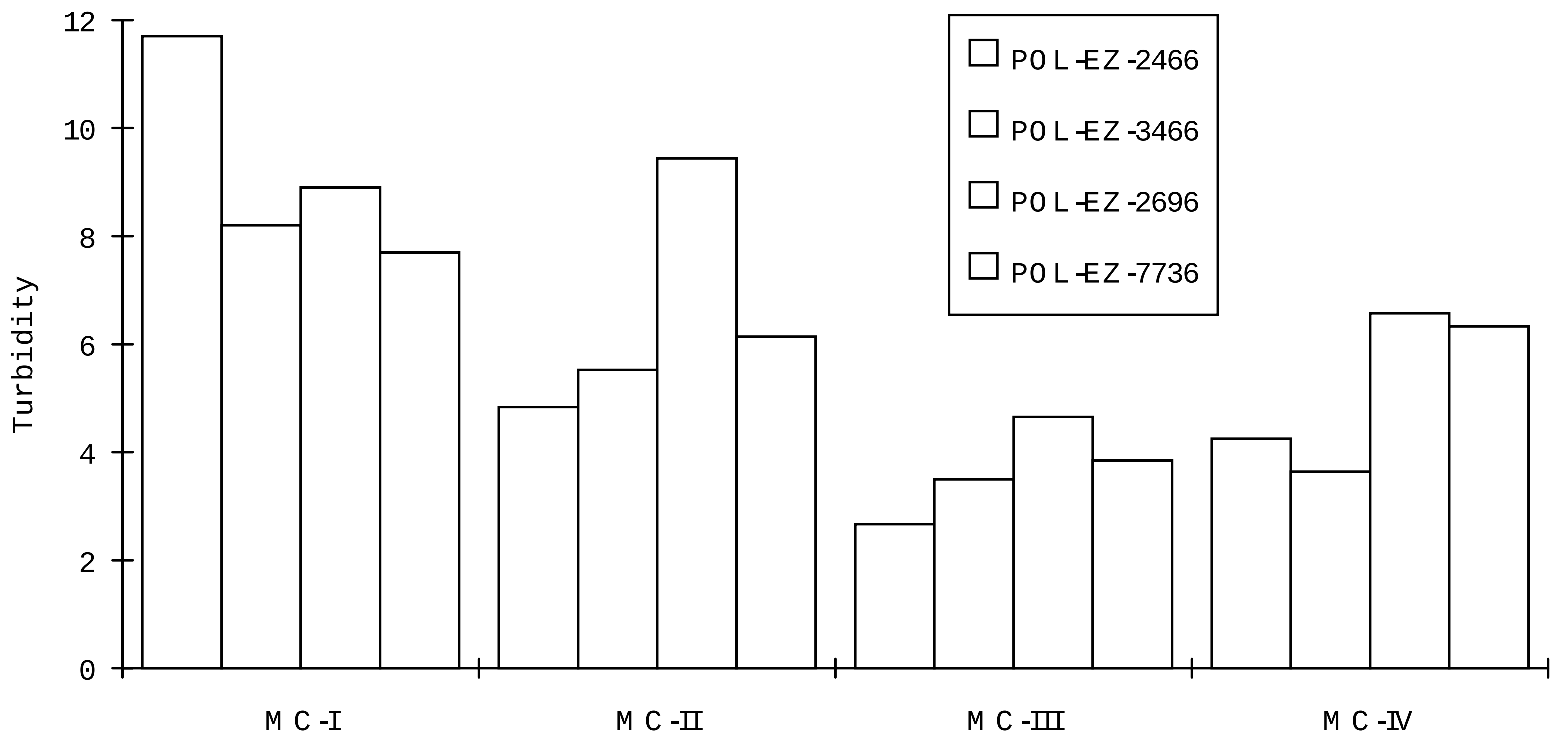
MC-1: MC Size Range = 53—150 µm and 150—250 µm; MC Concentration = 3 g/L
E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L
Coagulant Aid (Polyelectrolyte) Identification in Table 3-4
Polyelectrolyte Concentration = 1 mg/L; Settling Time = 8 minutes

Figure 4-30. Turbidity for Different MC Sizes (Low MC Dosage)



MC-1: MC Size Range = 53—150 µm and 150—250 µm; MC Concentration = 10 g/L
E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L
Coagulant Aid (Polyelectrolyte) Identification in Table 3-4
Polyelectrolyte Concentration = 1 mg/L; Settling Time = 8 minutes

Figure 4-31. Turbidity for Different MC Sizes (High MC Dosage)



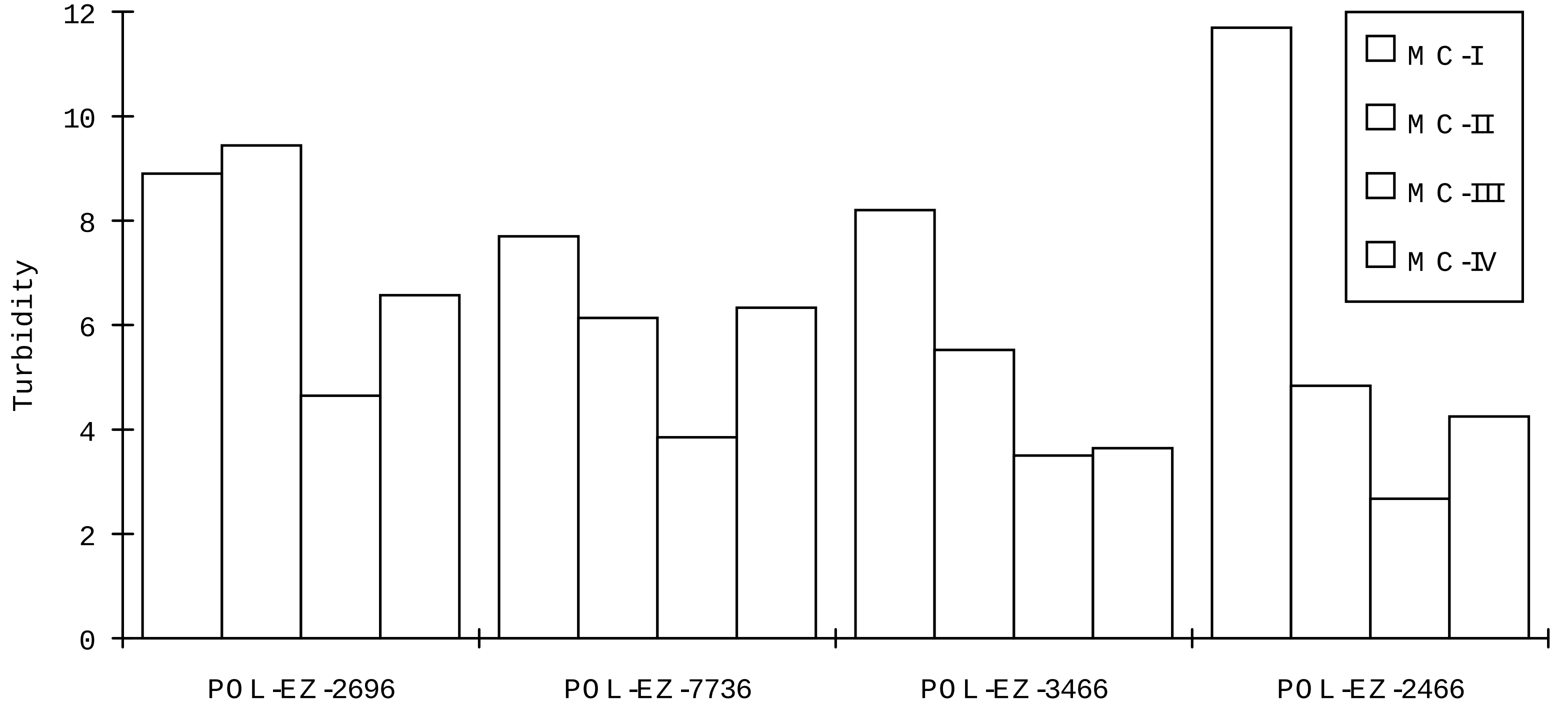
MC Group Identification, Size Range and Concentration in Table 3-8

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Coagulant Aid (Polyelectrolyte) Identification in Table 3-4

Polyelectrolyte Concentration = 1 mg/L; Settling Time = 8 minutes

Figure 4-32. Turbidity Summary for Confirmative Tests (by MC Group)



MC Group Identification, Size Range and Concentration in Table 3-8

E-1 (Electrolyte): Aluminum Sulfate Concentrations = 40 mg/L

Coagulant Aid (Polyelectrolyte) Identification in Table 3-4

Polyelectrolyte Concentration = 1 mg/L; Settling Time = 8 minutes

Figure 4-33. Turbidity Summary for Confirmative Tests (by Coagulant Aid Group)

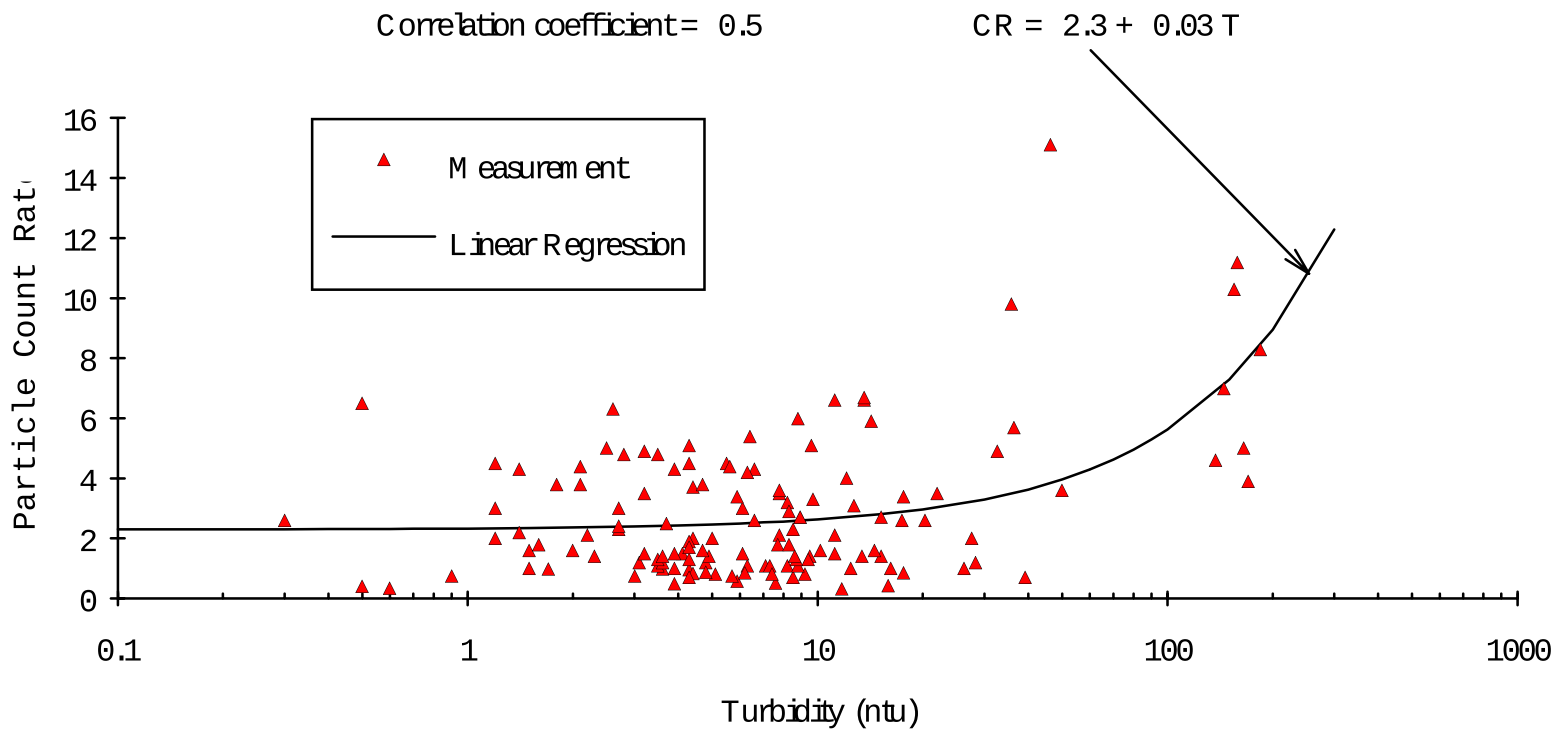


Figure 4-34. Correlation of Particle Count Rate and Turbidity