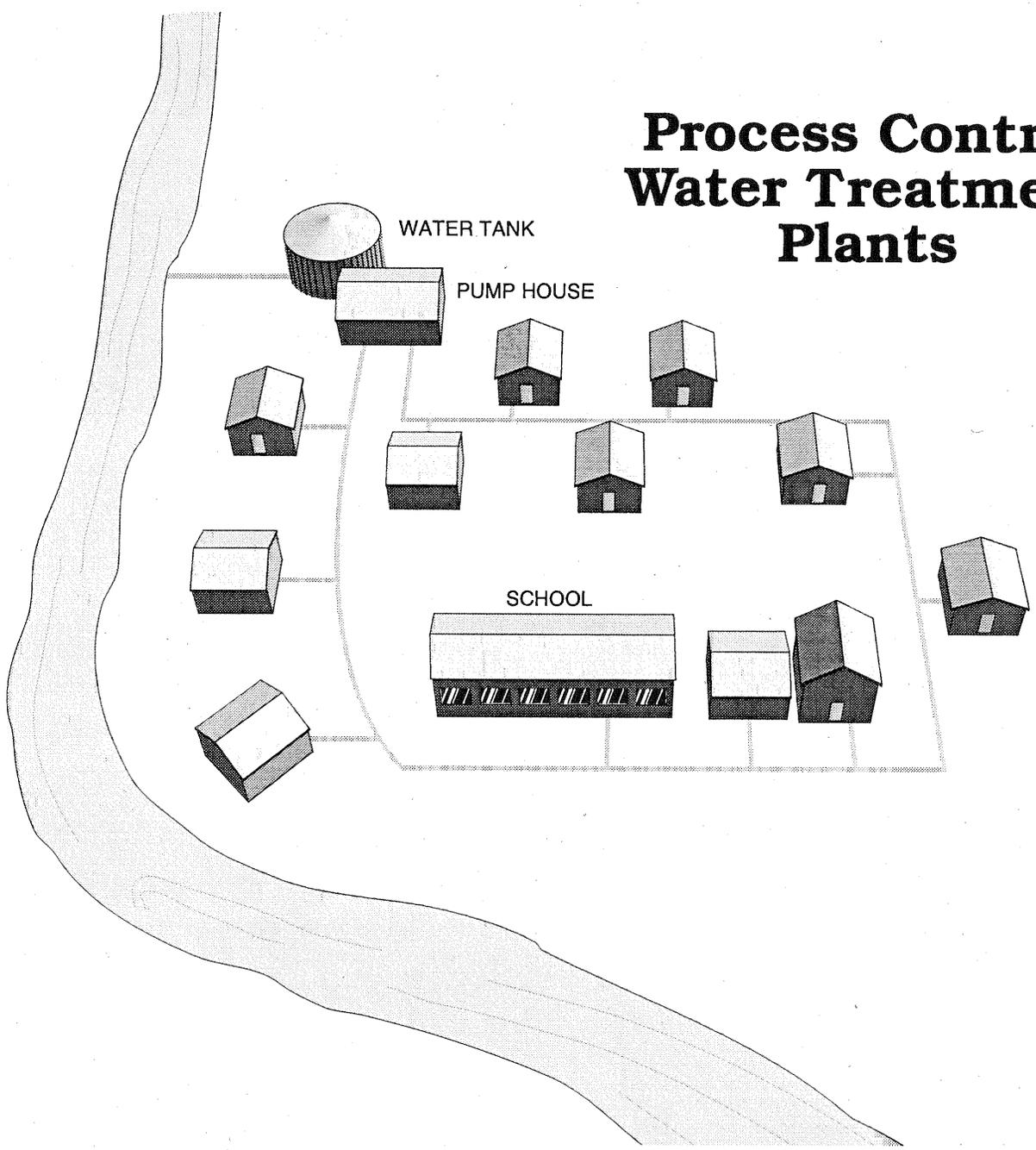


O & M of Small Water Systems

Process Control Water Treatment Plants



Alaska Department of Environmental Conservation
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O & M of Small Water Systems

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PROCESS CONTROL WATER TREATMENT PLANTS

WHAT IS IN THIS MODULE?

1. Typical process control goals.
2. The seven steps to process control.
3. Formulas and examples for calculating chemical concentrations.
4. How to perform the following test; Jar test, pH, Alkalinity and Turbidity.
5. How to use process control instruments.
6. How to use trend charts for process control.
7. How to calibrate a chemical feed pump.

KEY WORDS

- Aluminum Sulfate
- Soda Ash
- Process Control
- Dosage
- Concentration
- Jar test
- Turbidity
- pH
- Alkalinity

MATH CONCEPTS DISCUSSED

- Dilution
- Concentrations
- Feed rate
- Averages
- Trend charts

SCIENCE CONCEPTS DISCUSSED

- Dilutions
- Titration
- Coagulation
- Flocculation
- Mixing standard solutions

SAFETY CONSIDERATIONS

- Handling and mixing acids
- Handling concentrated alum
- High pressure

MECHANICAL EQUIPMENT DISCUSSED

- Chemical feed pumps
- Jar test

PROCESS CONTROL WATER TREATMENT PLANTS GOALS

The first step in the successful operation of a water treatment plant is to establish process control goals. Typical goals might include:

1. Maintain a turbidity removal of 95%.
2. Lower the finished water turbidity less than 0.05 ntu.
3. Lower the color to less than 5 units.
4. Remove Giardia cyst.
5. Reduce the bac-t and virus levels to the point that pathogenic organisms can be controlled by disinfection.
6. Disinfect the finished water so that the total coliform count remains less than 1/100 mil. In doing so the assumption is that the pathogenic organisms have been eliminated.
7. Maintain a fluoride level between 1.1 and 1.7 mg/L in order to reduce dental cavities in the customer's teeth.

CHEMICALS

Five Chemicals

There are six chemicals commonly used in rural Alaska:

1. Aluminum sulfate ($\text{Al}_2\text{SO}_4 \cdot 14\text{H}_2\text{O}$) as a powder containing 17% alum.
2. Soda ash (Sodium Carbonate Na_2CO_3) as a dense powder with a weight of 60 pounds per cubic foot.
3. One of many polymers.
4. Sodium hypochlorite (NaOCl) in a 12.5% solution and calcium hypochlorite ($\text{Ca}(\text{OCl}_2)$).
5. Sodium Fluoride (NaF) in a 4% solution.
6. Potassium Permanganate (KMnO_4).

PROCESS CONTROL

COAGULATION

Reference Text

For a complete discussion of the theory of coagulation you should see the Introduction to Treatment module.

Key Considerations

Proper coagulation is dependent on the alum concentration, the turbidity of the water, the amount of alkalinity in the water and the pH of the water.

What is proper coagulation

You will know when you have achieved proper coagulation when the turbidity maintains below 0.2 ntu and the aluminum carry through is less than 0.1 mg/L.

Key chemical

In order to obtain coagulation you must be in the correct pH range and feed the correct balance of alum and soda ash. Polymer is usually only used as an aid to coagulation. That is, it is used to fine tune and stabilize coagulation and thus produce the highest quality water.

Importance of Turbidity and Color

Turbidity and color are not directly related to public health. However, we use turbidity and color as indicators of the efficiency of our treatment process. A high percentage of removal with a turbidity in the finished water below 0.2 ntu is considered good treatment. Most operators indicated that a turbidity of 0.1 ntu is considered good water and 0.2 is considered bad water.

ACTIVITIES REQUIRED FOR PROCESS CONTROL

Seven Steps

In order to control the plant process you must of course monitor the raw and finished waters. However, this does not control the process but merely reflects the results of control. Good process control usually requires 7 steps:

1. Performing a jar test to determine the correct dosage range.
2. Calibration of the chemical feeders. The development of curves or tables from the calibration that allows you to adjust the chemical feed to approximate the jar test results.
3. Determining the concentration of the batch alum, soda ash and polymer solutions.
4. Adjusting the chemical feeds to approximate the jar test.
5. Evaluating the results and fine tuning the chemical feeds.
6. Developing trend charts or tables that let you compare raw water turbidity to dosage, percent turbidity removal to dosage, water temperature to dosage, raw water pH to dosage and finished water aluminum level to dosage.

- 7. Analyzing data - fine tuning and adjusting as necessary.

BATCH CHEMICAL CONCENTRATION CALCULATIONS

Two Equations

There are several approaches to determining chemical concentrations. However, they all require the use of one of these basic equations.

- Dilution equation - $V_1 C_1 = V_2 C_2$
- Pounds, Lbs = $V_{MG} \times 8.34, \text{ lbs/gal} \times \text{Conc, mg/L}$

Concentration

Formula for determining the concentration of a chemical in a tank.

- $C_2 = V_1 \times C_1 / V_2$

$$C_2 = \frac{\text{-----, lbs of chemical added} \times 100\%}{\text{-----, gal in tank} \times 8.34 \text{ lbs/gal}}$$

Example:

The alum concentration at the City of Craig is made by adding 700 pounds of alum to the 500 gallon container.

- What is the concentration in the container?
- $V_1 \times C_1 = V_2 \times C_2$
- $700 \text{ lbs} \times 100\% = (500 \text{ gal} \times 8.34 \text{ lbs/gal}) \times C_2$

$$C_2 = \frac{700 \text{ lbs} \times 100\%}{500 \text{ gal} \times 8.34 \text{ lbs/gal}}$$

- $C_2 = 16.8\%$

To change to a concentration in mg/L • $16.8\% \times 10,000 \text{ mg/L} = 168,000 \text{ mg/L}$

Dosage

To determine the dosage of any chemical fed into the system we need to know the concentration of the chemical as determined above, the plant flow rate and the feed pump rate. The dosage should be determined from the jar test.

Example:

Determine the feed rate of the alum feed pump required to deliver a dosage of 50 mg/L at full flow of 525 gpm.

- $V_1 \times C_1 = V_2 \times C_2$

- $V_1 \times 168,000 \text{ mg/L} = 525 \text{ gpm} \times 50 \text{ mg/L}$

- $V_1 = \frac{525 \text{ gpm} \times 50 \text{ mg/L}}{168,000 \text{ mg/L}}$

- $V_1 = 0.1563 \text{ gpm}$

Converting to Gallons per Hour

Because the manufacturer's data on the chemical feed pumps is given in gallons per hour we need to convert this reading to gallons per hour. This will allow you to relate actual feed rates to manufacturer's specifications.

Feed rate in mL/min

- 0.1563 gpm X 60 min/hr = 9.4 gpm

In order to verify that the feed pump is set correctly we need to determine the feed rate in mL/min. This is because it is much easier to check the calibration of the feed pumps using a graduated cylinder.

- 1 gal = 3.78 or 3780 mL
- 0.1563 gpm X 3780 mL/gal = 591 mL/min
- This would be 197 mL/min per train (591/3 = 197)

Set the Equation

Based on the acquired data we can establish an equation that lets you determine the dosage based on the feed rate. That is, if you check the feed rate in mL/min using a graduated cylinder you can plug the number into this equation and determine the dosage in mg/L.

Equation - Alum Dosage

$$\text{Dosage, mg/L} = \frac{\frac{\text{Feed rate, mL/min}}{3780 \text{ mL/gal}} \times \text{Conc, mg/L}}{\text{Plant Flow, gpm}}$$

Formula for finding pump feed rate

$$\text{mL/min} = \frac{0.378 \times \text{mg/L (dosage)} \times \text{gpm (flow rate)}}{\text{\% in tank}}$$

Example:

Find the feed rate in milliliters per minute for a feed pump that must pump chlorine into a 2 inch line that flows at 50 gpm. The desired dosage is 3 mg/L.

$$\text{mL/min} = \frac{0.378 \times 3 \text{ mg/L} \times 50 \text{ gpm}}{2\%} = 28 \text{ mL/min}$$

Finding Concentration

Formula for finding the concentration needed to provide a set dosage at a specific chemical pumping rate.

$$\text{\% Conc} = \frac{0.378 \times \text{mg/L (dosage)} \times \text{gpm (flow rate)}}{\text{mL/min (feed pump rate)}}$$

Example:

Find the concentration needed to supply a dosage of 4 mg/L to a flow of 60 gpm when the chemical feed pump is producing 30 mL/min.

$$\% = \frac{0.378 \times 4 \text{ mg/L} \times 60 \text{ gpm}}{30 \text{ mL/min}} = 3\%$$

Formula for finding dosage in mg/L

$$\text{mg/L} = \frac{\text{gal of solution used} \times \text{\% of solution} \times 10,000}{\text{gal, flow for the day}}$$

Example:

Find the dosage in mg/L when 10 gallons was used from a 50 gallon tank to chlorinate a flow of 60,000 gallons. The concentration in the tank is 2%.

$$\text{----- mg/L} = \frac{10 \text{ gal} \times 2\% \times 10,000}{60,000 \text{ gal}} = 3.3 \text{ mg/L}$$

Feed Rate

Formula for finding the feed rate of a chemical feed pump with both speed and stroke adjustments.

Feed rate = Max pump output X % speed X % stroke

Example:

Find the feed rate of a pump with a maximum feed rate of 158 mL/min and the speed set at 65% and the stroke at 55%.

$$\text{Feed mL/min} = 158 \text{ mL/min} \times 0.65 \times 0.55 = 56.5 \text{ mL/min}$$

START-UP SEQUENCE

Sequence when you have to start from scratch:

1. Estimate or determine desired dosage.
2. Estimate the feed pump, pumping rate in mL/min when the settings are 50/50.
3. Determine the plant flow rate in gpm.
4. Determine the concentration needed in the tank.
5. Determine the amount of chemical needed.
6. Determine how long a tank of solution will last.

PROCESS CONTROL TESTING

JAR TEST

INTRODUCTION

Function

The jar test is used to determine the proper chemical dosage required for good coagulation and flocculation. The test is commonly used in potable water, secondary effluent prior to Advanced Wastewater Treatment, secondary clarifier influent and sludge conditioning practice.

Description

The jar test procedure requires the addition of various dosages and combinations of chemicals into beakers which are stirred in a manner which as closely as possible duplicates plant performance.

Evaluating Results

After stirring, the mixtures are observed and the best condition selected. This condition then becomes the central point for other chemical combinations and dosages necessary. This could require several trials.

Items that Affect Results

Many items affect the chemical combinations and dosages required for proper coagulation and flocculation. These include:

1. pH of the water.
2. Turbidity.
3. Water temperature.
4. Amount and type of alkalinity.
5. Color of the water.
6. Type of chemicals.
7. The amount of mixing.
8. The order in which chemicals are added.
9. The type of mixing.

Most important Items

Of these items, the most critical are pH, temperature and turbidity. The alkalinity value becomes important when the total alkalinity of the water is below 80 mg/L. When this occurs, the addition of small amounts of primary coagulants may cause a depression in the pH.

JAR TEST HINTS

1. Make the jar test stock solution from the chemical that you are going to feed. Do not use a laboratory chemical.
2. Start your jar test by dosing with alum only.
3. Take the best results from the alum and make different dosages of soda ash to determine the approximate best pH range.

4. Once you have determined what appears to be the best pH level, vary the alum dosage around this pH. In other words, start over with clean jars, adjust the water in each jar to the most favorable pH and then add different dosages of the coagulant to the most favorable pH.
5. Select the best jar and filter the contents through a Whatman #1 filter to determine which concentrations have the best filtration capabilities.
6. For the alum-soda ash concentration that gives the best results add various concentrations of polymer to determine its ideal level.
7. Repeat the filtration process to determine the best combination based on filterability.
8. Test the final results for:
 - pH
 - Turbidity of filtered water
 - Alkalinity
9. Start these dosages into the plant.
10. Adjust the dosages to obtain the pH and alkalinity that was observed in the jar test.
11. Compare the final turbidity of the plant to a sample of water taken after sedimentation is allowed to settle for 1 hour.
12. Compare turbidity of the finished water to settled water passed through a Whatman #1 filter.

EQUIPMENT

- Variable speed (0-100 rpm) gang stirrer with four to six paddles
- Laboratory timer
- Four to six 1-liter beakers
- One 1-liter graduated cylinder
- 1, 5, 10 and 20 mL measuring pipets
- One sample container - 5 gallon minimum volume
- Pipet bulb

PREPARATION OF STOCK SOLUTIONS

The stock solutions are those that will be added to each beaker during the test. Stock solutions should be prepared at a concentration so that all of the 1 liter beakers can be dosed from a single pipet filling.

Chemicals used to prepare these stocks should come from those that are being fed at the plant.

Four types of chemicals are normally fed:

1. Dry chemicals - fed directly.
2. Concentrated solutions - fed directly.
3. Dry chemicals batch mixed prior to being fed.
4. Liquid chemicals batch mixed prior to being fed.

Desired stock solution concentrations can be selected from the table below.

Use Chemicals From Process

In order to have the jar test be reliable, it is important that the chemicals that are being used in the test be representative of the chemicals that are being fed. To do so requires making stock solutions directly from the feed chemicals. Each time a new batch of chemicals is received, a jar test should be performed with these chemicals. This will allow you to make adjustments for slight changes in chemical concentrations.

STOCK SOLUTION FROM DRY CHEMICALS

This is the most straightforward and requires making a stock based on anticipated dosage needs. The following table can be used to help determine the proper concentration.

Table #1

Approx Dosage Required, mg/L	Grams/Liter to Prepare	1 mL Added to 1 Liter Sample Equals	Stock Solution Conc., mg/L(%)
1 - 10 mg/L	1 g/L	1 mg/L	1,000 mg/L (0.1%)
10 - 50 mg/L	10 g/L	10 mg/L	10,000 mg/L (1.0%)
50 - 500 mg/L	100 g/L	100 mg/L	100,000 mg/L (10%)

Procedure

Use a volumetric flask to make the solution. Fill the flask one-half full of distilled water. Use a balance to measure the weight of the chemical to the nearest 0.1g. Add the chemical to the flask. Shake to mix. Finish filling to 1 liter. Mix and transfer the solution to a storage container. If a solution of less than 1 liter is desired, reduce the dry chemical by the appropriate amount.

STOCK SOLUTION FROM CONCENTRATED SOLUTIONS

Solutions of alum ferric acid, ferric sulfate and other concentrated solutions require the use of the specific gravity of the solution. If the specific gravity (sp. gr.) is not known, it can be found by weighing a known volume of the solution and comparing that weight to the weight of an equal volume of water; 10 mL of H₂O would weigh 10 grams. So if 10 mL of some other solution weighs 13.5 grams, then the sp. gr. of the solution is:

$$\frac{13.5 \text{ grams solution}}{10 \text{ grams water}} = 1.35$$

The amount of this concentrated solution needed can be found by the following formula:

$$\text{mL of Conc needed} = \frac{\text{--- \% stock X --- volume, mL of stock}}{\text{--- specific gravity X --- \% Conc.}}$$

STOCK SOLUTION FROM BATCH MIX DRY FEEDERS

Determine the concentration of the mixed batch solution. If this is not known, use the following formula:

$$\text{mg/L} = \frac{\text{--- lbs of chemical added X 1,000,000}}{\text{--- gal of water in tank X 8.34 lbs/gal}}$$

Select a required dosage from the table below:

Table #2

Approx. Dosage Required, mg/L	Stock Solution Conc. Needed, mg/L	1 mL Added to 1 liter Sample Equals
1 - 10 mg/L	1,000	1
10 - 50 mg/L	10,000	10
50 - 500 mg/L	1,000,000	100

Compute the volume of solution needed to make 1 liter of stock.

$$\text{Volume of Batch Mix, mL} = \frac{\text{--- Con of stock needed, mg/L X 1,000 mL}}{\text{--- Con of batch mix, mg/L}}$$

Place volume of batch in a 1 liter volumetric flask and dilute to 1 liter with distilled water.

STOCK FROM LIQUID BATCH

If the concentration of the liquid batch is known, go on to the second formula; if it is not, calculate as follows:

$$\text{Con, mg/L} = \frac{\text{gal of chemical added} \times 1,000,000}{\text{gal of container}}$$

Determine the desired dosage for each milliliter transferred from the stock to the jar. If you have no idea, pick a common value. Typical values are:

1 mL added will give 1 mg/L dosage, 10 mg/L dosage or 100 mg/L dosage.

After making this determination, select the required concentration of stock needed from table 2 or calculate as follows:

$$\text{Conc of stock needed, mg/L} = \frac{\text{Volume of jar (mL)} \times \text{dosage, mg/L}}{\text{Volume of stock to be transferred (mL)}}$$

The dosage refers to the desired dosage per mL of stock to be transferred to the jar. For instance 1 mL = 10 mg/L. In this case 10 mg/L would be placed in the formula.

The volume of stock to be transferred is the volume transferred from the stock solution to the jar. Typically this is 1 mL.

$$\text{batch, mL} = \frac{\text{Conc of stock, mg/L} \times 1000 \text{ mL}}{\text{Conc of batch, mg/L}}$$

PROCEDURE

- 1. Collect Sample** At least 5 gallons of sample should be collected and delivered to the lab within 15 minutes.

- 2. Check pH, Alkalinity, Temperature and Turbidity** This data should be recorded on the data sheet.

- 3. Select Stock Solutions** Past experience or manufacturer's recommendations may indicate the primary coagulant to start with. If the alkalinity is below 80 mg/L and expected dosages are greater than 20 mg/L for alum, then some source of alkalinity must be added (soda ash, lime or sodium bicarbonate).

- 4. Select a Dosage Range** This may be found by contacting other plants that are treating the same type of water or by just an educated guess. It doesn't make any difference where you start, keeping in mind that if you are close to optimum when you start you will save time. A typical range for potable water might be 10 to 60 mg/L in 10 mg/L steps.

- 5. Mix Rapidly** Try to duplicate the rapid mix of the plant. Usually a mix of 100 rpm.

- 6. Add Chemicals** While the rapid mix continues, add chemicals to each beaker in order and dosages previously determined. The chemicals should be added as rapidly as possible so that the start time for each beaker is about the same.

- 7. Continue Rapid Mix** Duplicate plant rapid mix detention time (20 seconds to 5 minutes).

- 8. Mix Slowly** Slowly decrease stirrer speed to duplicate plant floc basin. Usually approximately 5 rpm. Continue for 15 to 30 minutes. Again try to duplicate plant floc basin. Observe and record floc size, appearance and general action. As the floc begins to form, record when floc first appears and in which container. Continue observing the floc as the stirring period proceeds.

- 9. Shut Off Mixer and Raise the Stirrers**

- 10. Allow Floc to Settle**

- 11. Make Observations** The floc will start to settle, duplicating the sedimentation basin in the plant. During this period, observe and record the size of the floc, the settling rate and the general appearance of the floc. Observe the supernatant (clear liquid above the floc) as the floc settles. Is it clear or turbid? Are small pieces of floc left suspended in the supernatant? Carefully remove some of the supernatant and run pH, turbidity and alkalinity tests. It is also a good idea to filter some supernatant through coarse filter paper and run these three tests. These observations and tests, run on all beakers, will help you determine which dosage gives the best results.

12. Make Readings

Test supernatant for pH and turbidity. If test is being conducted for sludge conditioning, siphon off supernatant and test sludge filter leaf, capillary suction time and specific resistance.

13. Repeat as Necessary

When the slow stirring is completed, one of these four conditions will usually prevail:

1. No floc in any of the beakers.
2. Good floc in all beakers.
3. One jar with weak floc.
4. A range from no floc to floc.

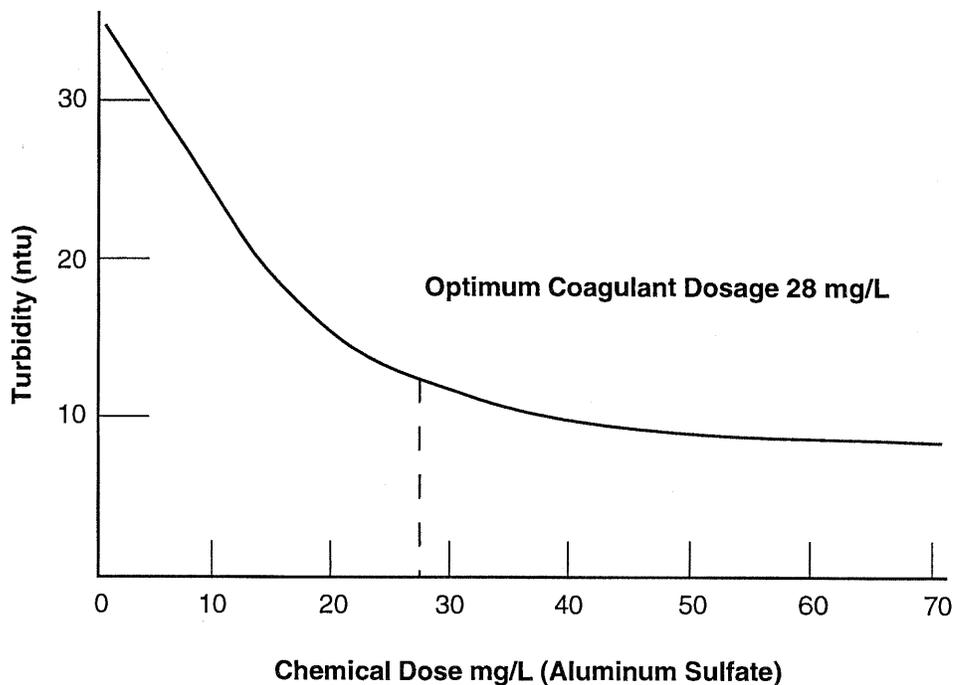
Each of these conditions requires a slightly different approach and are discussed in the student workbook. However, generally the process is to hold all parameters except one steady and vary that one until it's at its best point. Then vary a second parameter and so forth until the best quality floc is produced.

JAR TEST DATA										
DATE					SAMPLE LOCATION					
TIME					SAMPLER					
ANALYST					TIME OF TEST					
INITIAL DATA										
TURBIDITY				ntu's	COLOR				UNITS	
pH				mg/L	TEMPERATURE				° F	° C
ALKALINITY				mg/L					mg/L	
				mg/L					mg/L	
DOSAGE DATA										
CHEMICALS					pH		FLOC			
Jar #	mg/L	mg/L	mg/L	mg/L	INITIAL	FLOC	Time to Appear	Size	Settling Rate in/min	
1										
2										
3										
4										
5										
6										
Jar #	Super-natant Turbidity ntu's	FILTERED SUPERNATANT ANALYSIS							STIRRING	
		Turbidity ntu's	pH	Color	Alk mg/L	mg/L	mg/L	mg/L	Time min.	RPM
1										
2										
3										
4										
5										
6										
Notes										

FINE TUNING YOUR JAR TEST

The following information was compiled from the April 1987 issue of the Opflow:

- Focus on obtaining the optimum pH.
- Change only one variable at a time.
- Use plastic beakers - they maintain the water temperature better.



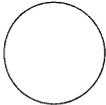
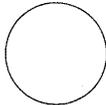
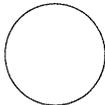
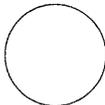
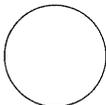
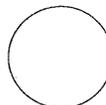
- Compare jar test supernatant turbidity to turbidity at end of sedimentation basin.
- Test effluent for presence of coagulant.
- Compare test results of changes in alkalinity, pH and chlorine demand at the final effluent.
- Select the most cost effective dosage rate by comparing jar test dosage to supernatant turbidity. Select the point at which an increase in dosage would have a minimum effect on supernatant turbidity.

VERIFYING RESULTS

It is very difficult to duplicate jar test results in the plant. Therefore after the feed rate has been set it is desirable to compare plant results with the jar test to determine if you are over or under feeding the coagulant. The following is a simple method of verifying the feed rate.

Set up a jar test as follows:

- Collect a sample from the effluent of the flash mix.
- Place 800 mL of sample in the first jar, 900 in the second and 1000 mL in each of the other jars.
- Dose the jars as shown below.

						
Sample	800 mL	900 mL	1000 mL	1000 mL	1000 mL	1000 mL
Raw water	200 mL	100 mL	0 mL	0 mL	0 mL	0 mL
Dosage	0 mg/L	0 mg/L	0 mg/L	0.5 mg/L	1.0 mg/L	1.5 mg/L

- Flash mix at 80 rpm for 1 min.
- Slow mix at 20 rpm for 20 min.
- Allow to settle for 30 min. - While settling, obtain a grab sample from the effluent of the sedimentation basin.
- Compare the results and make chemical feed rate adjustments.
- Compare settling rates.
- Compare turbidity of supernatant.

EVALUATION OF JAR TEST RESULT

Test and compare the following:

- rate of floc formation
- type of floc
- clarity of water between particles
- size of floc
- amount of floc formed
- settling rate
- clarity of supernatant

USING LAB FILTERS IN THE EVALUATION

- Use Whatman No. 40 filter paper - filter the supernatant and compare the turbidity with the plant turbidity.
- Compare the length of time to filter 100 mL.
- The shorter the time the better the coagulation, flocculation and sedimentation.

CALIBRATION OF CHEMICAL FEEDERS

When to Calibrate

Chemical feed pumps should be calibrated at start-up and then quarterly.

Why Calibrate

The calibration of the chemical feed pump is the only reliable method of determining the actual feed rate of the pump. It is from this data that we are most able to properly set the pump. The second reason for calibrating the pump is to obtain data that allows us to develop a calibration curve. It is from the calibration curve that we can determine the proper setting to obtain the desired dosage.

Equipment

The following equipment is necessary in order to complete the calibration.

1. Five gallon bucket
2. 1000 mL graduated cylinder
3. Stop watch
4. Writing pad
5. Pen or pencil
6. Latex gloves
7. Safety goggles

Considerations

When calibrating an auto paced feed pump, shut off the auto pacing. That is, change the local/remote switch to local.

With pumps that have both speed and stroke length settings a series of calibrations will need to be made for each major stroke length setting, i.e. 20%, 40%, 60%, 80% and 100%.

Assumption

In proceeding with the calibration process described below it is assumed that feed pumps with stroke length and stroke frequency are being calibrated.

General Procedure

The calibration of a chemical feed pump is accomplished in four general steps.

1. Calibrate the pump by observing amount pumped from suction side of the pump. Calibrating from the suction side is much more accurate than calibrating from the discharge side of the pump. The discharge rate will vary with an increase in discharge pressure. Therefore, the amount that is measured during calibration may be more than what is actually pumped when the pump is pumping against a high head.
2. The greatest accuracy is obtained by manually setting the stroke length and making a series of readings at various stroke frequencies.
3. The data is recorded in a table.

PROCEDURE - SPECIFIC

4. The data from the table is then transferred to a graph.
1. Adjust the speed to 10% and the stroke length to 20%.
2. Shut off the pump.
3. Fill the graduated cylinder to 800 mL with solution from the tank.
4. Set the cylinder on the floor beside the tank.
5. Remove the suction line from the tank and place it in the cylinder.
6. Fill the cylinder to 1000 mL.
7. Start the pump.
8. After running 1 min, observe level in cylinder and start the stop watch.
9. Run the pump for at least 1 min - 3 min is better.
10. At end of time, observe reading.
11. Record the data.
12. Adjust the stroke frequency to the next step (commonly this is either 10 or 20 percent increments).
13. Refill the cylinder to 1000 mL .
14. Repeat steps 9 through 13 for each setting.
15. Adjust the stroke length to the next increment (10 or 20% increments) and repeat steps 9 through 14.
16. Upon completion - return the suction line to the tank, clean the cylinder.
17. Transfer the data to a graph.

Example

Frequency/Stroke

The following data was collected during a calibration of a chlorine feed pump.

Under normal operations the frequency setting of the pump is controlled by a signal from the plant flow meter. In our example there were four pumps that supplied water to the plant. With one pump running the signal from the meter would set the feed pump at 20%, with two pumps running the signal would be set at 40% and so on. Therefore, the decision was made to calibrate the pumps at these various frequency settings. This will allow the operator to make chemical feed adjustments by changing only the stroke length.

O & M of Small Water Systems

20% Frequency - based on 1 minute samples

Stroke	Start level	Stop level	mL	mL/min
20%	1000	993	16	16
40%	985	947	38	38
60%	920	860	60	60
80%	800	724	76	76

40% Frequency - based on 1 minute samples

Stroke	Start level	Stop level	mL	mL/min
20%	1000	978	22	22
40%	950	885	65	65
60%	850	742	108	108
80%	700	555	145	145.8

60% - based on 2 minute samples

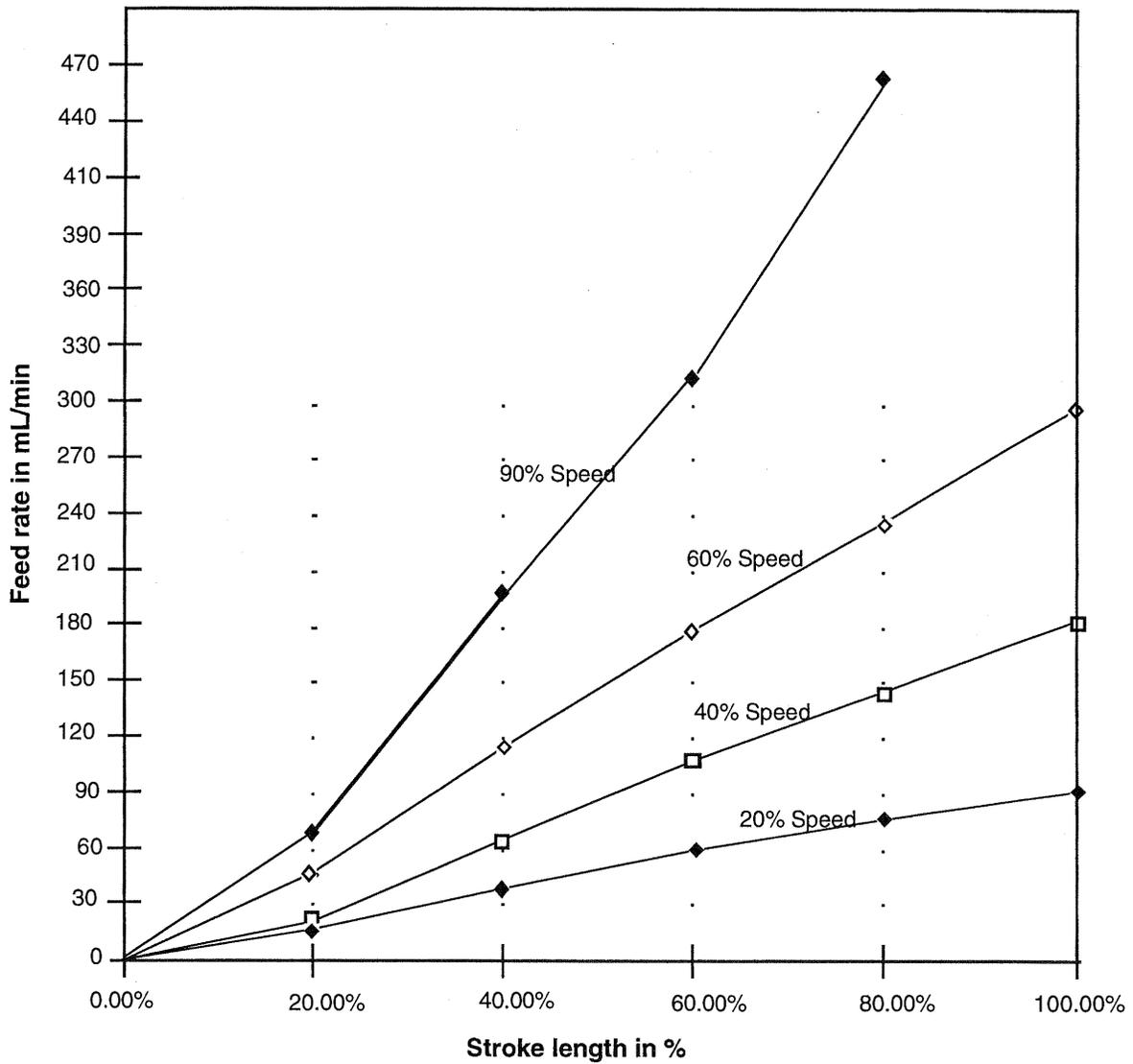
Stroke	Start level	Stop level	mL	mL/min
20%	1000	905	95	47.5
40%	875	645	230	115
60%	600	244	356	178
80%	1000	525	475	237.5

90% Frequency - based on 1/2 minute sample

Stroke	Start level	Stop level	mL	mL/min
20%	1000	967	33	66
40%	900	803	97	194
60%	775	617	158	316
80%	600	442	232	464

Curve

The following family of curves were plotted from the data in the 20%, 40% and 60% frequency settings above. The three curves correspond to the 20%, 40% and 60% frequency readings. The stroke length was plotted along the bottom and the milliliters per minute plotted along the side. To use the curve, determine the frequency and stroke settings. Select the proper curve to correspond with frequency. Find the stroke setting along the bottom. Follow this reading up until you reach the proper frequency curve. Now extend a line to the left and read the flow in mL/min.



OTHER LAB TEST

pH

INTRODUCTION

pH is a measure of hydrogen ion (H^+) concentration and is generally used to describe a system as being acidic or basic. It is not to be confused with alkalinity or acidity, which are entirely different tests. pH measurements are taken at various points throughout a treatment plant, and any abnormal readings can be an indication of a change in water quality.

EQUIPMENT

Electronic pH meter

REAGENTS

Standard pH buffer

PROCEDURE (METER)

- 1. Warm up instrument** The instrument should be left in the standby position. If the instrument is not on and in the standby position, turn it on and allow it to warm up for 30 minutes.
- 2. Adjust the temperature** The temperature is usually set at room temperature. If solutions of lower or higher temperatures are being checked, the standard and the sample must be at the temperature set on the meter.
- 3. Adjust the needle to 7** while in the standby position.
- 4. Rinse the probe** with distilled water.
- 5. Immerse the probe in the buffer** Use about 20 mL desired standard buffer in a clean beaker.
- 6. Switch to "pH" position**
- 7. Adjust pH to standard** The needle should read the pH of the standard buffer used.
- 8. Switch to standby**
- 9. Remove the probe and rinse** Rinse with distilled water. Discard the standard buffer. Do not put back into the bottle.
- 10. Immerse the probe in the sample** Use about 20 mL samples in a clean beaker.
- 11. Switch to "pH" position**
- 12. Read pH directly off scale**
- 13. Switch to stand-by**
- 14. Remove the probe and rinse**

**15. Leave the probe immersed
in the buffer**

The probe should be continuously soaked in the buffer which has the pH value closest to the suspected pH of the sample to be measured.

NOTE:

Although the pH buffer or sample should be well mixed, excessive agitation can trap extra CO₂ and lower the pH of the solution being tested. Samples containing large amounts of dissolved CO₂ must be measured quickly since the CO₂ can escape into the atmosphere.

ALKALINITY

INTRODUCTION

Description

The alkalinity of a water is the capacity of that water to accept protons. Alkalinity is caused by bicarbonates, carbonates and hydroxides in the water. The amount of alkalinity is expressed in terms of an equivalent amount of calcium carbonate (CaCO_3) in mg/L.

Types of Alkalinity

Two types of alkalinity are measured: that due primarily to the hydroxide (called phenolphthalein alkalinity) and that due to all three components (called total alkalinity). Measurement of alkalinity is performed by titration with acid to a point where the alkalinity is neutralized. Phenolphthalein alkalinity can be detected by using the color indicator phenolphthalein, which changes color at a pH end point of 8.3. Total alkalinity can be measured in much the same way. A color indicator, bromcresol green-methyl red is used. This indicator gives a color change about pH 3.7. A pH meter can be used, measuring the pH end point of 3.7.

About Color Indicators

Using color indicator solutions is often difficult due to turbid samples and variation in end point color determinations. Use of a standard pH meter is recommended.

EQUIPMENT

Buret
500 mL Erlenmeyer flask
100 mL graduated cylinder
pH meter

REAGENTS

Sodium hydroxide	NaOH
Sulfuric acid	H_2SO_4
Sodium carbonate	Na_2CO_3
Sodium thiosulfate pentahydrate	$(\text{Na}_2\text{S}_2)_3 \cdot 5\text{H}_2\text{O}$
Phenolphthalein	
Bromcresol green sodium salt	
Methyl red sodium salt	
Alcohol (propanol)	

REAGENT PREPARATION

1. Sulfuric Acid, 0.02 N (H_2SO_4)

To a 1000 mL volumetric flask containing approximately 500 mL of boiled distilled water, add 2.80 mL of concentrated sulfuric acid (H_2SO_4) and dilute to one liter with additional boiled distilled water. This will give you a 0.1 N stock solution of sulfuric acid. To prepare 1 liter of 0.02 N stock, dilute 1:5 by adding 200 mL 0.1 N stock H_2SO_4 to 800 mL boiled distilled water.

2. Sodium Carbonate, 0.02 N (Na_2CO_3)

In a 1000 mL volumetric flask, dissolve 1.060 g anhydrous sodium carbonate (Na_2CO_3) in boiled distilled water and dilute to one liter with additional boiled distilled water. Sodium carbonate (Na_2CO_3) should be dried at 140 C. overnight before using.

3. Phenolphthalein Indicator

In a 1000 mL volumetric flask, dissolve 0.5 g phenolphthalein in one liter of 50% isopropyl alcohol. Add 0.02 N sodium hydroxide (NaOH) by drop until a faint pink color appears.

4. Bromocresol Green Methyl Red Indicator

In a 100 mL volumetric flask, dissolve 0.02 g methyl red solution salt and 0.10 g bromocresol green sodium salt and dilute to 100 mL total with distilled water.

5. Sodium Thiosulfate, 0.1 N ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$)

In a 100 mL volumetric flask, dissolve 2.48 g sodium thiosulfate pentahydrate ($\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$) in boiled distilled water and dilute to 100 mL with boiled distilled water.

6. Sodium Hydroxide, 0.02 N (NaOH)

To make 100 mL 0.02 N NaOH , dissolve 0.08 g NaOH in distilled water and dilute to a total of 100 mL. Alternatively, make 1 N stock NaOH by dissolving 4 g NaOH in distilled water and diluting to a total of 100 mL. Then prepare 0.02 N by diluting 2 mL of 1 N with distilled water to a total of 100 mL.

PROCEDURE

1. Standardization of 0.02 N Sulfuric Acid (H₂SO₄)

Using a 10 mL volumetric pipet, transfer 10 mL of 0.02 N sodium carbonate (Na₂CO₃) to a 250 mL Erlenmeyer flask and add 90 mL of boiled distilled water. Run this standardization sample through Steps 6 and 7 to follow. Calculate the normality.

$$N \text{ of H}_2\text{SO}_4 = \frac{0.02}{\text{mL, H}_2\text{SO}_4 \text{ used to reach total alkalinity end point}}$$

2. Prepare Samples

If the sample contains considerable suspended material, it may be necessary to remove the suspended material. This can be done by centrifugation or filtration.

If residual chlorine is present, remove it by adding 1 drop of 0.1 N sodium thiosulfate (Na₂S₂O₃ • 5H₂O).

3. Place 100 mL of the Sample in a 500 mL Erlenmeyer Flask

It is advisable to run duplicate samples.

4. Add 2 drops of Phenolphthalein Indicator

5. Titrate with Sulfuric Acid, 0.02 N (H₂SO₄)

The phenolphthalein end point is reached when the pink color just disappears. Record this volume as mL of phenolphthalein alkalinity. If there is no pink color after the addition of phenolphthalein, record the phenolphthalein alkalinity as 0.0 mL.

6. Add 3 drops of Bromcresol Green Methyl Red Indicator

7. Continue Titrating with Sulfuric Acid, 0.02 N (H₂SO₄)

The total alkalinity end point is reached at the appearance of the light grey or clear color.

Record the total volume of sulfuric acid used as mg/L of total alkalinity. The total volume includes acid used in Steps 5 through 7.

CALCULATIONS

1. Phenolphthalein Alkalinity

$$\text{mg/L, P. Alk as CaCO}_3 = \frac{\text{mL phenolphthalein end point} \times N \times 50,000}{\text{mL of original sample}}$$

2. Total Alkalinity

$$\text{mg/L, Alk as CaCO}_3 = \frac{\text{mL total alkalinity end point} \times N \times 50,000}{\text{mL of original sample}}$$

N = exact normality of the sulfuric acid (H₂SO₄) used for the titrations as calculated in PROCEDURE Step 1.

Original Sample = the mL of undiluted sample used. If 100 mL were used

undiluted, the original sample would be 100 mL. If 10 were diluted to 100 mL to be tested, the original sample would be 10 mL.

3. Example

Where: N = 0.0202
mL P. Alk. end point = 4.5 mL
mL original sample = 100 mL
mL T. Alk. end point = 11.0 mL

$$\text{P. Alk. mg/L as CaCO}_3 = \frac{4.5 \text{ mL} \times 0.0202 \times 50,000}{100 \text{ mL}} = 45.5 \text{ mg/L}$$

$$\text{T. Alk. mg/L as CaCO}_3 = \frac{11.0 \text{ mL} \times 0.0202 \times 50,000}{100 \text{ mL}} = 111.1 \text{ mg/L}$$

ALTERNATE PROCEDURE (USING pH METER)

1. Steps 1 through 3 as in Preceding Procedure

4. Start Reading pH with Meter

Place an Erlenmeyer flask on a magnetic stirrer and immerse the pH meter electrodes, using the correct technique for reading the pH with a pH meter.

5. Titrate with Sulfuric Acid, 0.02 N (H_2SO_4)

While stirring the sample with the pH meter in the "pH" position, titrate rapidly to a pH of .5, then slowly to a pH of 8.3.

Record the mL of acid used as phenolphthaline alkalinity.

6. Continue Titration

Titrate rapidly to a pH of 4.2, then slowly to a pH of 3.7.

Record the total mL of acid used as total alkalinity.

CALCULATIONS

The calculations are the same as used in the preceding procedure.

NOTE:

For a more accurate determination of alkalinity, the equivalency point of the titration can be graphically determined by plotting pH vs. mL H_2SO_4 titrant used. Refer to Standard Methods and Chemistry of Sanitary Engineers for details.

TURBIDITY - (NEPHELOMETRIC METHOD)

INTRODUCTION

Description

Turbidity is an expression of the optical properties of a water which cause light to be scattered and absorbed rather than be transmitted in a straight path. The measurement of light scattered at a 90 degree angle is performed with a nephelometer. As the turbidity increases, the amount of light scattered will increase.

Sources of Turbidity

This turbidity is usually caused by finely divided suspended matter such as clay, silt, plankton and other organic and inorganic material.

Relationship to TSS

Attempts to correlate turbidity to suspended solids is impractical due to the fact that turbidity is related to particle size, shape and refractive index, as well as quantity.

Application

The procedure outlined below is general and can be applied to several brands of nephelometers. Be sure to read carefully the manufacturer's operation manual for your particular instrument.

Test Frequency

Turbidity tests may be performed at any time. However, Alaska regulations require that the frequency of testing be matched with the system type. A listing of system types and the frequency of testing is found on pages 293 & 294.

EQUIPMENT

Several nephelometers and turbidimeters have been approved by the Environmental Protection Agency. Manufacturers include Hach, HF Instruments and Turner Designs.

REAGENTS

Due to the precision necessary for this instrument, it is recommended that standards be purchased rather than prepared. One standard must be on hand for each range used. These purchased standards are called Primary Standards.

Standards purchased after 1992 are very stable and will need to be replaced only when the glass shows any visual sign of scratching. Under normal use these standards should be replaced once a year.

Preparation of standards is described in the 18th Edition of Standard Methods.

PROCEDURE

1. Collect sample

Samples may be stored up to 24 hours in the dark.

2. Calibrate the instrument

Be sure to check the manufacturer's instruction for warm-up time and calibration. A separate standard must be used to calibrate each scale used.

3. Mix the sample

The sample should be thoroughly mixed by shaking 15 times through a one-foot arc. The air bubbles should be allowed to dissipate before testing

Cold Water Problems

When the water is cold the heat from the turbidimeter may cause condensation to develop on the outside of the glass or gas bubbles to form on the inside of the glass. Either condition will give a false, high turbidity reading. It may be necessary to either read the results quickly or allow the sample to warm slightly before proceeding.

4. Clean sample cell

The sample cell must be free of fingerprints, water spots and accumulated dust, all of which will give false readings. Use lint free Chem-Wipes.

5. Pour sample into cell

Check the manufacturer's information for the amount of sample.

6. Wipe spilled sample from outside of cell

7. Place cell in instrument

8. Place cover over cell

9. Adjust scale

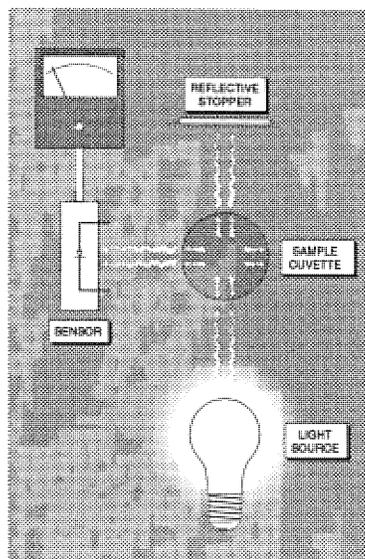
Once the proper range has been found, it may be desirable to check calibration with the standard for that range.

10. Read and record data

The reading is recorded as units of ntu's (Nephelometric Turbidity Units).

11. Discard sample and clean sample cell

NEPHELOMETRIC TURBIDIMETER



OTHER PROCESS CONTROL INSTRUMENTS

SCM

Streaming Current Monitor

This instrument measures net residual charge value of the water after coagulation.

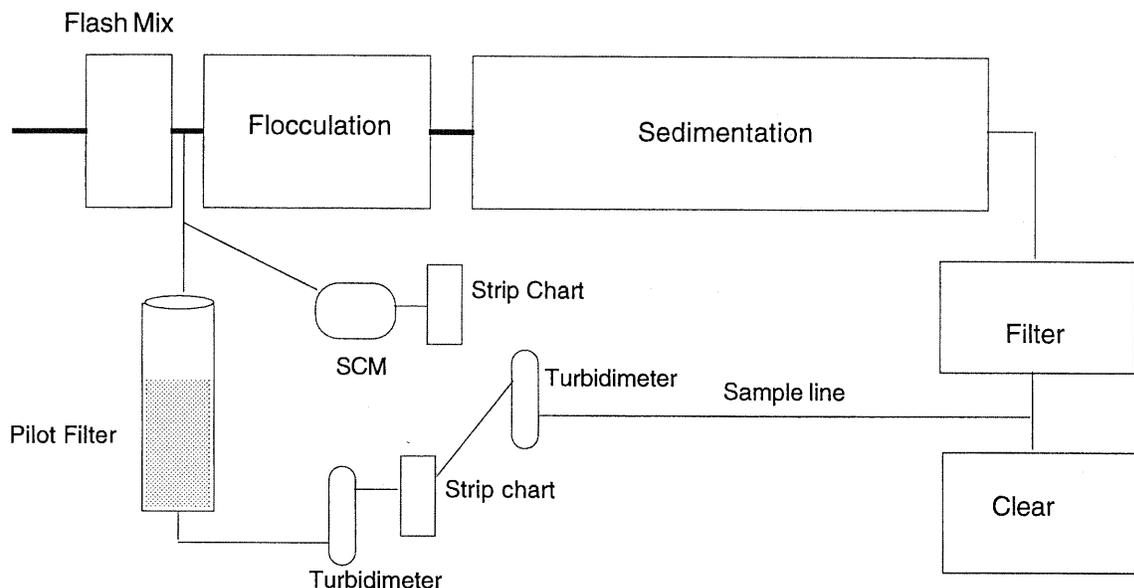
The instrument obtains a sample after the flash mix. For best results a strip chart of the results should be maintained. There is no specific number that indicates the best results. As an operator you must determine for your water what number gives the best results.

The number then becomes a target for controlling coagulation.

The advantage of the instrument is its quick response to changes in turbidity, color or coagulant dosage.

ZETA POTENTIAL

An observation of the time required for a number of particles to travel a given distance under an applied electrical field. This is a laboratory instrument rather than an on-line instrument. While the theory is that the closer the zeta potential can be brought to zero the better the coagulation, practice does not seem to prove this to be true. The instrument works well on some waters in the Midwest and south. Operators treating waters on the west and East coasts where the alkalinity is very low (below 80 mg/L) find the instrument difficult if not impossible to use to control coagulation.



PILOT FILTERS

These are small filters obtaining a sample of water from the flash mix. The filters are normally constructed with filter media identical to that installed in the plant filters. The pilot filter turbidity is intended to parallel the plants final turbidity. Since the pilot filter does not have the advantage of flocculation or sedimentation the final effluent will normally be much higher than the actual plant turbidity.

In order to compensate for the lack of flocculation and sedimentation a polymer is commonly fed at the pilot filter.

The turbidity of the pilot filter is monitored and chemical feed adjustments are made accordingly. Because the pilot filter is reacting directly to the flash mix, the changes in plant conditions can be observed long before the effluent is effected.

Analysis

One of the difficulties that operators often encounter is how to analyze the data collected from performing a plant evaluation and/or how to evaluate the flood of data that is collected on a daily basis at most plants.

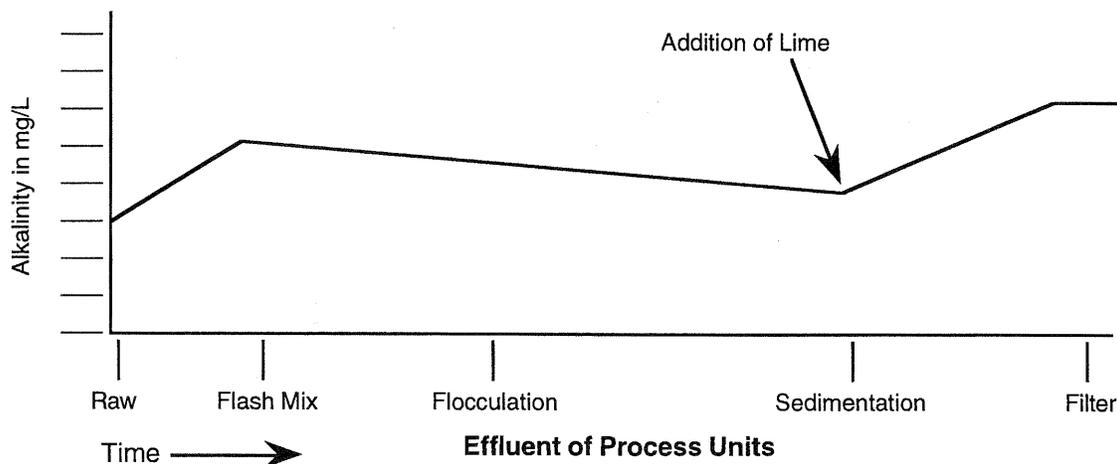
The following are brief overviews of various plant data analysis tools

PLANT DIAGRAM

A block diagram of the plant should be drawn and the chemical data such as alkalinity, pH and turbidity shown at the influent and effluent of each process unit.

CHEMICAL PROFILES

A second method of showing a chemical profile is to develop a graph as shown below and plot the various constituents on the graph.



TREND CHARTS

Common trend charts plot significant plant data against time. This allows the operator to determine how a change in various constituents impacts the plant's performance. The chart is used to show trends rather than absolute values. For instance, as the raw water temperature drops does the plant performance also begin to drop? And what is the time delay between changes in water temperature and changes in final turbidity?

OTHER GRAPHS

Common graphs are used by operators to get a feel for plant performance and to allow them to make chemical feed adjustments. Types of graphs used are:

- Filtration rate vs turbidity.
- Turbidity vs chemical dosage.
- Raw water turbidity vs final effluent turbidity.
- Head loss vs time for each filter.
- Turbidity vs time for each filter (when you use continuous strip chart recorders this is done for you).
- % water used for backwash vs total production.

