Section 4

Coagulation/Flocculation

COAGULATION AND FLOCCULATION

California State University: Sacramento
Volume I

Objectives

- Nature of Particulate Impurities in Water
- Coagulation
- Flocculation
- Mixing Mechanisms
- Process Performance Considerations
- Process and Support Equipment
- Enhanced Coagulation

Nature of Particulate Impurities in Water

- Surface water contains suspended and dissolved organic and inorganic material
- Settleable solids – Larger sized particles that can be removed from water by slowing down the flow to allow for gravity settling
- Nonsettleable solids – smaller sized particles that do not readily settle
  - Treatment is required to produce larger particles that are settleable
  - AKA Colloidal matter
    - Has a net negative charge

Nature of Particulate Impurities in Water

- Zeta potential
  - repelling force between any two particles of like charge
- Van der Waals force
  - attraction between particles pulling them together
- Particles will stay in suspension if zeta potential is greater than the van der Waals force

Coagulation and Flocculation

- Need for Coagulation and Flocculation
  - To remove particulate impurities, particularly nonsettleable solids and colors
  - Chemicals are added that will cause the particles to clump together in the coagulation process
  - The particles to gather together to form larger particles in the flocculation process

Coagulation and Flocculation

- Coagulation
  - reduces the zeta potential so that van der Waals force can pull particles together to form *microfloc*
- Flocculation
  - brings the microfloc particles together to form larger particles called *macrofloc*

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Coagulation

Process Description

- Coagulation describes the effect produced when certain chemicals are added to raw water
- Flash mixing
  - The mixing of the coagulant chemical and raw water
  - Equally distributes the chemical through the water
  - Chemical process (hydrolysis) occurs very quickly
    - approximately 2-5 seconds
  - Forms very small particles (microfloc)
- Detention time
  - The actual or theoretical time that it takes for water to pass through a basin
  - Less than 30 seconds (TN Design Criteria)

Basic Coagulant Chemistry

- Coagulation is a physical and chemical reaction
- Best pH range is 5 to 7 s.u.
- Alkalinity reacts with coagulants to form floc and serves as a buffer to prevent pH from changing
  - If alkalinity in source water is too low, complete precipitation of coagulant may not occur
    - Weak floc is easy shear/break or may dissolve back into solution
  - Alkalinity can be increased by addition of lime or soda ash

Coagulants

- Primary coagulants neutralize (destabilize) the electrical charge of particles, which causes them to begin to clump together
- Synthetic Organic Polymers
- Metallic Salts
  - Enough chemical must be added to exceed the solubility limit of the metal hydroxide, resulting in precipitation (aka floc formation)
  - Common additives:
    - Aluminum, Al^{+3}
      - Aluminum sulfate [$Al_2(SO_4)_3 \bullet 14H_2O$]
    - Iron, Fe^{+3}
      - Ferric sulfate [$Fe_2(SO_4)_3$]
      - Ferrous sulfate [$Fe_2(SO_4)_3 \bullet 7H_2O$]

Coagulants - Metallic Salts

- Metallic salts react with other ions in the water
  - Chemical quantities must be sufficient to exceed the solubility limit of the metal hydroxide
    - This will result in the formation of floc
    - The floc will adsorb onto the turbidity in the water

$$\underbrace{Al_2(SO_4)_3}_{\text{alum}} + \underbrace{3Ca(HCO_3)_2}_{\text{natural bicarbonate alkalinity}} \rightarrow \underbrace{2Al(OH)_3\downarrow}_{\text{aluminum hydroxide floc}} + \underbrace{3CaSO_4\downarrow}_{\text{calcium sulfate}} + \underbrace{6CO_2}_{\text{carbon dioxide}}$$

↓ Indicates precipitation occurring

Coagulants - Aluminum Sulfate

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- $Al_2(SO_4)_3 \bullet 14\ H_2O$
- Most widely used coagulant
- Available in liquid or dry form
- Neutralizes the negatively charged particles of color or turbidity almost instantaneously (1-2 seconds)
- Reacts with alkalinity present in water to form a jelly-like floc – aluminum hydroxide $Al(OH)_3$,
- Works best in pH range of 5.8 to 8.5
  - Liquid alum
    - Strong acid
  - Dry alum
    - Available in powder, lump form

Coagulants - Ferric Chloride

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- $FeCl_3$
  - Highly corrosive
  - liquid is 35-45% strength
  - will crystallize at 30ºF
- Effective over wider pH range than alum, works better in cold water, forms heavier denser floc
- Requires 0.6 mg/L alkalinity for each mg/L ferric chloride
- Reacts with alkalinity in the water to form an insoluble hydroxide $Fe(OH)_3$

Coagulants - Ferric Sulfate

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- $Fe_2(SO_4)$ •3 H_2O or
- $Fe(SO_4)_3$ •2 H_2O
- Often used with lime softening
- Effective over wider pH range than alum, produces heavier denser flock
- Requires 0.75 mg/L alkalinity for each mg/L ferric sulfate
- Reacts with alkalinity in the water to form an insoluble hydroxide $Fe(OH)_3$

Coagulants - Polymers

- Polymers are commonly used as coagulation chemicals
  - Primary coagulants neutralize the electrical charges of the particles, which causes them to being to clump together
  - Coagulant aids add density to slow settling floc and toughness to minimize the floc breaking up
  - Synthetic organic polymers
    - Cationic polyelectrolytes – polymers that release ions with a positive (+) charge
    - Anionic polyelectrolytes – polymers that release ions with a negative (-) charge
    - Nonionic polyelectrolytes – polymers that release both positively and negatively charged ions

Coagulants

- Considerations when choosing a coagulant:
  - Polymer overdosing will adversely affect coagulation efficiency
  - Not all water supplies can be treated with equal success
  - Some polymers lose their effectiveness when used in the presence of a chlorine residual
  - Some polymers are dosage limited

Process Performance Considerations

- Coagulation Basins
  - Accomplished in a special rectangular tank with mixing devices
  - Can occur in the influent channel or pipeline
  - Shape of basin is part of system design

Coagulant Aids

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- May be added to:
  - Improve coagulation
  - Build stronger, more settleable floc
  - Overcome the effect of temperature drops that slow coagulation
  - Decrease amount of primary coagulant needed
  - Reduces amount of sludge produced

Coagulant Aids - Polymers

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Polymers
- Have extremely large molecules, that when dissolved in water, produce highly charged ions
- The basic types
  - Cationic (+)
  - Anionic (-)
  - Nonionic

Coagulant Aids - Polymers

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Cationic Polymer
- Produce **positively** charged ions when dissolved in water
- Advantages
  - Coagulant can be reduced
  - Floc settles better
  - Less sensitivity to pH
  - Flocculation of bacteria and algae are improved

Coagulant Aids - Polymers

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Anionic Polymer
- Produce **negatively** charged ions when dissolved in water
- Advantages
  - Increased floc size
  - Improved settling
  - Strong floc, generally

Coagulant Aids - Polymers

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Nonionic Polymer
- Have a balanced or **neutral** charge
  - They release both positively and negatively charged ions when dissolved
- Less expensive but have higher dosages
  - Cationic and anionic have dosages around 0.1-1.0 mg/L
  - Nonionic dose can range from 1-10 mg/L

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Flocculation

Flocculation

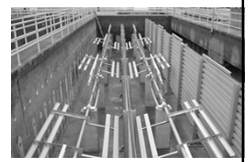
- Process Description
  - Slow stirring process that causes the gathering together of small, coagulated particles into larger, settleable particles
- Floc Formation
  - Controlled by rate at which collisions occur between particles
  - Purpose is to create a floc of good size, density, and toughness
  - Best floc size rages from 0.1 mm to 3 mm

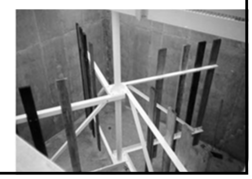
Flocculation

- Process Performance Consideration
  - Insufficient mixing will result in ineffective collisions and poor floc formation.
  - Excessive mixing may tear apart or shear the floc that has been formed
- Detention Time
  - Required for the necessary chemical reactions to take place
  - Minimum 30 minutes with 45 minutes recommended

Types of Flocculators

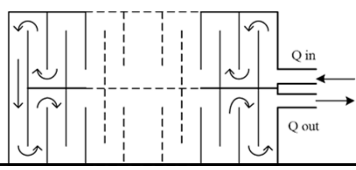
- Mechanical
  - Paddle wheel flocculators
    - Horizontal
      - Submerged mechanics
    - Vertical
      - Requires less maintenance
      - Propeller, paddle, or turbine types





Types of Flocculators

- Hydraulic
  - Turbulence resulting from the roughness in conduits or channels
    - Limited use due to very localized distribution of turbulence, inadequate detention time, and widely variable turbulence



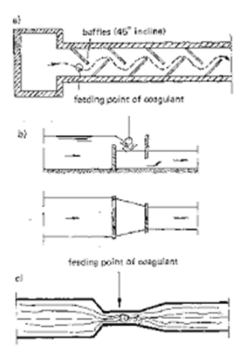
Flocculation Basin

- Rectangular for horizontal flocculators
- Nearly square for vertical flocculators
- Compartmentalized basins achieve best flocculation
  - Separated by baffles
  - Prevents short circuiting by having compartments/basins in series
- Solids-contact basins (upflow clarifiers)
  - Combines coagulation, flocculation and sedimentation process into a single basin

Mixing Mechanisms

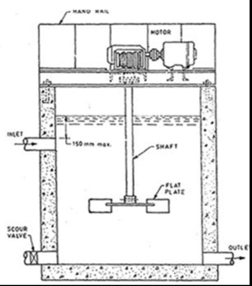
Methods of Mixing

- Hydraulic mixing using flow energy in the systems
  - With baffles or throttling valves if sufficient velocity to cause turbulence
  - Turbulence mixes chemicals with the water



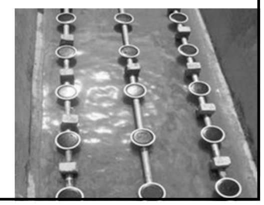
Methods of Mixing

- Mechanical mixing
  - Paddles, turbines, and propellers
  - Versatile and reliable
  - Use greatest amount of energy



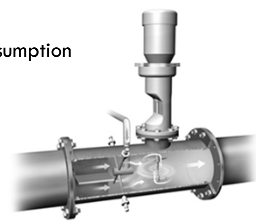
Methods of Mixing

- Diffusers and grid systems
  - Perforated tubes or nozzles
  - Equally distribute flow over entire basin
  - Sensitive to flow changes
  - Require frequent adjustments



Methods of Mixing

- Pumped blenders
  - Coagulant added directly to the water being treated through a diffuser in a pipe
  - Can provide rapid dispersion of chemical
  - No significant head loss
  - Considerably low energy consumption



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Process Performance Considerations

Interaction with Other Treatment Processes

- The effectiveness of the sedimentation and filtration processes depends upon successful coagulation-flocculation
- Disinfection can be affected by poor coagulation-flocculation performance
- Effective coagulation-flocculation promotes the removal of natural organic matter

Water Characteristics Affecting Chemical Selection

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turbidity alkalinity
pH
color temperature

- As water quality changes, coagulant effectiveness changes

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Water Characteristics Affecting Chemical Selection

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Turbidity

- Floc doesn't form well when turbidity is low
- May have to add weighting agent
- Coagulant dose must be raised when turbidity increases
- Don't lower coagulant dose too soon when turbidity starts to drop

Water Characteristics Affecting Chemical Selection

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pH

- There is an optimal range for each chemical
- Lime, soda ash, & caustic soda <u>raise</u> pH
- Sulfuric acid <u>lowers</u> pH

Alkalinity

- at least 10 mg/L left over

Water Temperature

- Reactions occur slower in colder water
- Requires more coagulant in cold water

Water Characteristics Affecting Chemical Selection

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Color

- Caused by organics, such as humic acid
- Highly colored water is often low in turbidity
- Usually has low alkalinity
- Color removal is an increasing concern because there seems to be a link between color-causing substances (organics) and THM formation when chlorine is added

Water Characteristics Affecting Chemical Selection

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Total Organic Carbons (TOC)

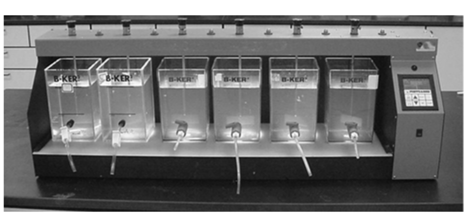
- Measured in raw and finished water
- Disinfection By-Product (DBP) precursor

Specific Ultraviolet Absorbance (SUVA)

- Measures UV light at 254 nm and divides that value by the Dissolved Organic Carbon (DOC)
- The SUVA is an indicator of humic content (a DBP precursor)

Process Control

- Most important consideration is selection of the proper type and amount of coagulant chemical
- Determined by jar testing



Process Actions

- Monitor process performance
- Evaluate water quality conditions (raw and treated)
  - Visual observations and routine laboratory tests
    - Turbidity, alkalinity, pH, color, temperature, chlorine demand
- Check and adjust process controls and equipment
- Visually inspect facilities
  - Observation of turbulence of water in flash mix
  - Observation of size & distribution of floc in floc basins
    - Uneven distribution could mean short-circuiting

Preparation of Chemical Solutions

- Concentration depends on type of polymer and the polymer's molecular weight
  - The higher molecular weight, the more difficult it is to mix the polymer into solution
    - Solution becomes very viscous (thick)
  - Anionic and nonionic dry polymers often prepared as very weak solutions (0.25%-1%)
  - Cationic dry polymers have small molecular weights so they can be prepared at high solutions (5%-10%)

Recordkeeping

- Source of water quality
  - pH, turbidity, temperature, alkalinity, chlorine demand, and color
- Process water quality
  - pH, turbidity, and alkalinity
- Process production inventories
  - Chemicals used, chemical feed rates, amount of water processed, and amount of chemicals in storage
- Process equipment performance
  - Types of equipment in operation, maintenance procedures performed, equipment calibration and adjustments
- Entries should include date, time, and operator initials

Abnormal Conditions

- Changes in source water turbidity
  - Verify the effectiveness of coagulant and dosage
  - Best accomplished by running a jar test
- Visual observations of flash-mixing intensity as well as the condition of the floc in the floc basins
  - Adjust mixer speed or coagulant dose

Abnormal Conditions

- Alkalinity, pH, and temperature changes impact floc formation
  - Temperature change may require adjustment of mixing intensity
- Sudden increases in filtered water turbidity
  - Due to poor coagulation-flocculation performance
  - Add filter-aid, such as nonionic polymer
  - Run jar tests to see how to best adjust the process

Troubleshooting - Coagulation Process

Coagulation Process Effluent Quality Changes	Operator Actions	Possible Process Changes
• Turbidity • Temperature • Alkalinity • pH • Color	• Perform necessary analyses to determine extent of change • Evaluate overall process performance • Perform jar tests if indicated • Make appropriate process changes • Increase frequency of process monitoring • Verify response to process changes at appropriate time	• Change coagulant(s) • Adjust coagulant dosage • Adjust flash-mixer/flocculator mixing intensity • Adjust coagulant aid or filter aid • Adjust alkalinity or pH

Troubleshooting - Flocculation

Flocculation Basin Floc Quality Changes	Operator Actions	Possible Process Changes

• Turbidity
• Alkalinity
• pH
	• Evaluate source water quality
	• Perform jar tests if indicated
	• Verify process performance:
	  • Coagulant feed rate
	  • Flash-mixer operation
	• Make appropriate process changes
	• Verify response to process changes at appropriate time
		• Change coagulant(s)
		• Adjust coagulant dosage
		• Adjust flash-mixer intensity
		• Adjust alkalinity or pH

Troubleshooting - Source Water Quality

Source Water Quality Changes	Operator Actions	Possible Process Changes
• Floc formation	• Observe floc condition in basin: • Dispersion • Size • Floc strength (breakup) • Evaluate overall process performance • Perform jar tests if indicated: • Evaluate floc size, settling rate, and strength • Evaluate quality of supernatant: clarity (turbidity), pH, and color • Make appropriate process changes • Verify response to process changes at appropriate time	• Change coagulant(s) • Adjust coagulant dosage • Adjust flash-mixer/flocculator mixing intensity • Adjust coagulant aid • Adjust alkalinity or pH

Laboratory Tests

- Process Control Water Quality Indicators
  - Turbidity, alkalinity, chlorine demand, color, pH, temperature, odor, and appearance
- Sampling Procedures
  - Either grab samples or continuous sampling
  - Process samples must be representative
    - Water that is nearly as identical in content and consistency as possible to that in the larger body of water being sampled

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Process and Support Equipment

Types of Equipment

- Liquid (solution) feeders
  - A diluted solution of known concentration is fed directly into water being treated
  - Fed through metering pumps and rotameters
- Dry feeders
  - Deliver a measured quantity of dry chemical during a specified time
  - Volumetric feeders – deliver a specific volume of chemical during a given time
  - Gravimetric feeders – delivers a predetermined weight of chemical in a specific unit of time
    - More accurate

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Chemical Feed Equipment

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Flash Mixers

- Provide agitation to evenly mix coagulant through water
- Add chemicals to center of mixing chamber
- Coagulation occurs in less than 1-2 seconds
- This stage determines the success of coagulation
- Detention time should not exceed 30 seconds (Design Criteria)

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Chemical Feed Equipment

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Types of Flash Mixers

- Mechanical mixers
- Static mixers
- Pumps and conduits
- Baffled chambers

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Chemical Feed Equipment

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Mechanical Mixers

- Placed in a chamber or tank
- Mounted in a pipeline (*in-line mixers*)
- Most reliable and versatile
- Use most energy

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Chemical Feed Equipment

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Static Mixers

- Produce turbulence and mixing through use of fixed sloping vanes
- Effective and economical to install and operate
- High head loss
- Mixing energy directly related to flow with no way to adjust

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Chemical Feed Equipment

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Pumps and Conduits

- Chemicals added to suction side of low-lift pump
- Mixing energy caused by turbulence in pipeline
- Energy determined by speed of pump

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Chemical Feed Equipment

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Baffled Chambers

- Mixing occurs as water travels over and under baffles
- Turbulence related to flow, cannot be controlled

Operation and Maintenance

- Equipment Operation
  - Before starting equipment, be sure unit is properly lubricated and its operational status is known
  - After start up, always check for excessive noise and vibration, overheating, and leakage

Operation and Maintenance

- Preventive Maintenance Procedure
  - Keep motors free of dirt and moisture
  - Ensuring good ventilation in equipment work areas
  - Checking pumps for leaks, unusual noise, vibrations, or overheating
  - Maintaining proper lubrication and oil levels
  - Inspecting for alignment of shafts and couplings
  - Checking bearings for wear, overheating, and proper lubrication
  - Exercising infrequently used valves on a regular schedule and checking all valves for proper operation
  - Calibrating flowmeters and chemical feeders

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Enhanced Coagulation

Enhanced Coagulation

- Process designed to remove NOM from water by adjusting both the coagulant dose and the pH
  - Adjust pH by adding acid or alkali
  - Differs from "sweep" method where pH range is achieved by overdosing the coagulant
- Natural organic matter comprised of organic acids called humic substances
  - Composed of humic and fulvic acids

Chemical Reactions

- Fulvic and humic substances in water are negatively charged
- Negative charge is neutralized and destabilized by positively charged coagulants
- Destabilized particles come together and form larger floc particles that can be settled out
- Chemistry that deals with this particular coagulation process is known as charge chemistry

Chemical Reactions

- pH range for color removal with aluminum sulfate is 5.5 – 7.0
  - Optimum pH is 5.8
- pH range for color removal with ferric sulfate is 4.0 – 6.2
  - Optimum pH is 4.5
- At the lower (optimum) pH, four effects take place that enhance coagulation
  - Humic and fulvic molecules dissociate
  - Coagulant demand decreases
  - Flocculation is improved at lower pH
  - Sulfuric acid addition preconditions the organic compounds

Process Control

- Color results from presence of minerals, inorganic chemicals, metals, decomposition of organic matter from soils, aquatic organisms, and vegetation
- True color – color of the water from which turbidity has been removed (filtered)
- Apparent color – color of the water that includes the color and the suspended matter
- Measured in color units
- Color is reported in whole numbers from 1 to 500
- Sample pH is always reported with color units
  - Color determinations will increase as the pH of the water increases

Process Control

- pH optimization necessary for coagulation
  - Automated pH is a must
  - pH backfeed process control loop required
  - Must have pH monitoring meter located after flash mix and feed valve controllers for acid and alkalinity chemical addition

Troubleshooting

Treatment Condition Flocculator Effluent	Corrective Action
High coagulation pH with optimum color removal	1. Increase acid feed 2. Decrease alkalinity adjustment in raw water source
High coagulation pH without optimum color removal	1. Increase coagulant 2. Decrease acid feed to maintain optimum pH
Low coagulation pH with optimum color removal	1. Decrease acid feed 2. Increase alkalinity adjustment in raw water source
Low coagulation without optimum pH color removal	1. Decrease acid if below optimal pH zone 2. Increase coagulant and alkalinity
Loss of acid feed	1. Increase coagulant to achieve optimal pH

Troubleshooting

Treatment Condition Flocculator Effluent	Corrective Action
Optimal pH without optimized color removal	1. Increase coagulant, decrease acid, or increase alkalinity
Optimal pH and color removal with floc carryover	1. Decrease coagulant 2. Increase polymer 3. Increase removal of settled floc 4. Decrease flow-through velocities
High turbidities and coagulant residuals in settled water	1. Check for floc carryover 2. Adjust polymer feed to enhance settling 3. Jar test to determine optimum acid and coagulant dosage

Coagulation and Flocculation
Vocabulary

A. Alkalinity
B. Anionic Polymer
C. Apparent Color
D. Cationic Polymer
E. Coagulants
F. Coagulation
G. Colloids
H. Composite Sample
I. Disinfection By-product
J. Floc
K. Flocculation
L. Grab Sample
M. Jar Test
N. Natural Organic Matter (NOM)
O. Nonionic Polymer
P. Particulate
Q. Polymer
R. Precipitate
S. Representative Sample
T. Total Organic Carbon
U. Trihalomethanes
V. True Color
W. Turbidimeter
X. Turbidity

_____ 1. An insoluble, finely divided substance which is a product of a chemical reaction within a liquid.

_____ 2. A single sample of water collected at a particular time and place which represents the composition of the water only at the time and place.

_____ 3. An instrument for measuring and comparing the turbidity of liquids passing light through them and determining how much light is reflected by the particles in the liquid.

_____ 4. A polymer having positively charged groups of ions. Often used as a coagulant aid.

_____ 5. A polymer having negatively charged groups of ions.

_____ 6. A sample portion of material or water that is a nearly identical in content and consistence as possible to that in the larger body of material or water being sampled.

_____ 7. Very small, finely divided solids (particles that do not dissolve) that remain dispersed in a liquid for a long time due to their small size and electrical charge.

_____ 8. A laboratory procedure that simulates a water treatment plant's coagulation/flocculation units with differing chemical doses and also energy of rapid mix, energy of slow mix, and settling time.

_____ 9. Color of the water that includes not only the color due to substances in the water but suspended matter as well.

_____ 10. Derivatives of methane often formed during chlorination by reactions with natural organic materials in the water.

_____ 11. The clumping together of very fine particles into larger particles (floc) caused by the use of chemicals (coagulants).

_____ 12. A contaminant formed by the reaction of disinfection chemicals with other substances in the water being disinfected.

_____ 13. A polymer that has no net electrical charge.

_____ 14. Clumps of bacteria and particulate impurities that have come together and formed a cluster.

_____ 15. The cloudy appearance of water caused by the presence of suspended and colloidal matter.

_____ 16. A very small solid suspended in water which can vary widely in size, shape, density, and electrical charge.

_____ 17. Chemicals that cause very fine particles to clump (floc) together into larger particles.

_____ 18. Humic substances composed of humic and fulvic acids that come from decayed vegetation.

_____ 19. The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing

_____ 20. Color of the water from which turbidity has been removed.

_____ 21. A collection of individual samples obtained at regular intervals.

_____ 22. The capacity of water to neutralize acids or resist a change in pH.

_____ 23. A measure of the amount of organic carbon in water.

_____ 24. A long-chain molecule formed by the union of many monomers; used with coagulants to aid in binding small suspended particles to large chemical flocs.

Answers

1. R	4. D	7. G	10. U	13. O	16. P	19. K	22. A
2. L	5. B	8. M	11. F	14. J	17. E	20. V	23. T
3. W	6. S	9. C	12. I	15. X	18. N	21. H	24. Q

Coagulation and Flocculation
Review Questions

1. What is the purpose of coagulation and flocculation?

2. What happens in the coagulation and flocculation processes?

3. What is the primary purpose of flash mixing?

4. Why are both primary coagulants and coagulant aids used in the coagulation process?

5. List four methods of mixing coagulant chemicals into the plant flow.

6. What is a hydraulic mixing device?

7. What is flocculation?

8. How long is the typical mixing time in the coagulation process?

9. What is the recommended minimum detention time for flocculation?

10. What is an advantage of vertical flocculators over horizontal flocculators?

11. Why is coagulation-flocculation important to other treatment processes?

12. How is the effectiveness of the solids removal processes commonly monitored?

13. List the typical functions performed by an operator in the normal operation of the coagulation-flocculation process.

14. Which laboratory tests would you use to monitor the coagulation-flocculation process?

15. What would you look for when visually observing the performance of a coagulation-flocculation process?

16. What information should be recorded for all entries in a record book?

17. What kinds of sudden changes in either raw or filtered water quality are signals that you should immediately review the performance of the coagulation-flocculation process?

18. What is the relationship between pH and color in a water sample?

19. List the process control water quality indicators of importance in the operation of the coagulation-flocculation process.

20. How do chemical liquid feeders work in the coagulation process?

21. Selection of a chemical feeder for a given application depends on what factors?

Answers

1. To remove particulate impurities and color from the water being treated
2. Chemicals are added that will cause the particles to begin to clump together
3. To rapidly mix and uniformly distribute the coagulant chemical throughout the water
4. Primary coagulants are used to neutralize the electrical charge of the particles and cause the particles and cause the particles
5. Hydraulic mixing, mechanical mixing, diffusers and grid systems, pumped blenders

6. Hydraulic mixing devices rely on the turbulence created by flowing water to mix chemicals with the water
7. A slow stirring process that causes the gathering together of small, coagulated particles into larger, settleable floc particles
8. 2-5 seconds with 30 seconds as maximum detention time
9. 30 minutes minimum with 45 minutes recommended
10. Vertical flocculators usually require les maintenance since they eliminate submerged bearings and packings
11. It influences the effectiveness of the sedimentation, filtration, and disinfection processes. It causes bacteria and other disease-causing organisms to be bound up in suspended solids and floc.
12. By measuring the turbidity of filtered water
13. Monitor process performance, evaluate water quality conditions, check and adjust process controls and equipment, visually inspect facilities
14. Turbidity, alkalinity, temperature, color, pH, and chlorine demand
15. Observe the degree of agitation of the water in the flash mix and observe the size and distribution of floc in the flocculation basin
16. Date, time of an event, and initials of the operator making the entry
17. pH, alkalinity, temperature, or chlorine demand
18. Color determinations are always extremely pH dependent and will always increase as the pH of the water increases
19. Turbidity, temperature, alkalinity, chlorine demand, color, pH, odor and appearance
20. They feed a solution of known concentration directly into the water being treated
21. Type of chemical compound, availability of chemical, chemical form (dry or liquid), and the amount to be fed daily