NAME:

CLASS PERIOD:

Sewer Science has been recognized with state and national awards from:

- Water Environment Federation
- National Association of Clean Water Agencies
- California Water Environment Association

SEWER SCIENCE

A wastewater treatment LAB for high school students

Student Workbook

presented by

SVCW

Silicon Valley Clean Water

One Drop at a Time

7027-6/18

SEWER SCIENCE

A Wastewater Treatment Lab for High School Students

Acknowledgments

Numerous organizations and individuals collaborated to develop this high school lab. The following agencies made significant contributions to the lab development:

Regional Water Quality Control Plant, Palo Alto, California

Department of Civil Engineering, San José State University, San José, California

Central Contra Costa Sanitary District, Martinez, California

Menlo-Atherton High School, Atherton, California

Los Altos High School, Los Altos, California

Gunn High School, Palo Alto, California

Las Lomas High School

Contra Costa Christian Junior High, Walnut Creek, California

Berean Christian High School, Walnut Creek, California

Monte Vista High School, Danville, California

Silicon Valley Clean Water, Redwood City, CA

Agreement by Student and Parent

This laboratory is being provided by a local wastewater treatment plant. To ensure the safety and full participation of all students, we ask that you read and sign this lab agreement.

EQUIPMENT

This laboratory equipment is on loan from the local wastewater treatment plant. If a student is involved in horseplay around the equipment, he or she may be liable for any costs to repair or replace the equipment.

HAZARDOUS CHEMICALS

There are hazardous chemicals in this lab, including sulfuric acid. Students must behave responsibly and maturely around the chemicals. Students will be required to wear gloves and goggles when performing the COD tests which use sulfuric acid.

POSSIBLE PRESENCE OF DISEASE-CAUSING ORGANISMS

At one step in the lab, we will be using a mixture of LIVE MICROORGANISMS to treat our simulated wastewater. There may be disease-causing organisms (pathogens) in that mixture. Students will be instructed on the safe handling of this mixture. Once the microorganisms have been added to the water, students will be required to wear gloves when handling the water and will use bleach-water to disinfect all surfaces. If there is misuse of the gloves or the water samples, students may be asked to sit out of this portion of the lab.

I have read and understood the above statements.

Signed by:

________________________ ________________________ ____________

Student Parent or Guardian Date

Acuerdo de Alumno y Padre

Este laboratorio está siendo provisto por una planta de tratamiento de aguas residuales. Para asegurar la seguridad y participación total de todos los alumnos, le pedimos que lea y firme este acuerdo sobre el laboratorio.

EQUIPO

Este equipo de laboratorio lo esta prestando la planta local de tratamiento de aguas residuales. Si un alumno se pone a jugar o hacer travesuras alrededor del equipo, él o ella puede ser considerado responsable de cualquier costo que se requiera para reparar o reemplazar el equipo.

QUÍMICOS PELIGROSOS

Hay químicos peligrosos en este laboratorio, incluyendo ácido sulfúrico. Los alumnos se deben comportar en forma responsable y madura alrededor de los químicos. A los alumnos se les requerirá utilizar guantes y anteojos de seguridad cuando realicen las pruebas de COD que utilizan ácido sulfúrico.

POSIBLE PRESENCIA DE ORGANISMOS QUE CAUSAN ENFERMEDADES

En algún momento, en el laboratorio, estaremos utilizando una mezcla de MICROORGANISMOS VIVOS para tratar nuestra agua residual simulada. En esa mezcla pueden existir organismos (patógenos) que causan enfermedades. A los alumnos se les instruirá en el manejo seguro de esta mezcla. Una vez que los microorganismos han sido agregados al agua, se requerirá que los alumnos utilicen guantes al manejar el agua y utilizarán cloro diluido en agua para desinfectar todas las superficies. Si existiera uso inapropiado de los guantes o las muestras de agua, se les podría pedir a los alumnos que no participen en esta porción del trabajo de laboratorio.

He leído y entiendo lo establecido arriba.

Firmado por:

____________________	____________________	________
Alumno	Padre o Tutor	Fecha

Lab Summary

		Objective	In Class	Suggested Homework
1	Wastewater Treatment	• Get the overall picture of wastewater treatment	• View introductory video • Review contents of workbook • Read pages 1-3 and do questions	• Finish questions in Section 1 and read Section 2
2	Water Quality Monitoring	• Learn quantitative methods of analyzing water	• Teacher demonstrations of the four methods of analyzing the wastewater: ammonia concentration, pH, turbidity, and chemical oxygen demand (COD)	• Finish questions in Section 2 and read Section 3
3	Wastewater	• Understand the different components of municipal wastewater	• Prepare simulated wastewater (using coffee grounds, cooking oil, etc.) • Discuss what each ingredient represents • Analyze wastewater parameters (pH, turbidity, ammonia, chemical oxygen demand (COD))	• Read Section 4
4	Primary Treatment	• Determine which types of waste are removed with primary treatment (sedimentation and flotation)	• Obtain samples from primary sedimentation • Analyze wastewater parameters • Move wastewater from sedimentation basin into aeration basin; add microorganisms (activated sludge) from treatment plant	• Finish questions in Section 4 and read Section 5
5	Secondary Treatment	• Get a sense of the many thousands of different organisms that “eat” organic and ammonia wastes	• Set up microscopes. Wear gloves & use bleach! • Use microscopes and handouts to identify microorganisms • Move wastewater from aeration basin back to sedimentation tank • Add aluminum sulfate to tank; observe	• Finish questions in Section 5 and read Sections 6 and 7
6	Treatment	• Learn about materials used to filter water	• Obtain samples from secondary sedimentation basin • Analyze wastewater parameters • Pour the water from sedimentation basin through a filter; gather a sample • Analyze the COD of the filtered water	• Begin graphs of turbidity, pH, COD and ammonia
7	Final Results & Conclusions	• Understand the strict standards for discharging treated wastewater into local waterways	• Analyze the turbidity, pH and ammonia concentration of the filtered water • Read the COD results • Compare your results with the discharge limits for a wastewater plant	• Interpret graphs of COD, pH, turbidity, and ammonia • Complete lab conclusions

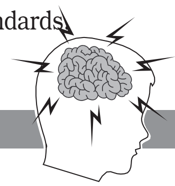
Table of Contents

Section 1

Wastewater Treatment

Introduction

Did you make wastewater today? You did if you brushed your teeth, flushed the toilet or took a shower. We all make wastewater, and this is a form of pollution. In the United States, the Clean Water Act of 1972 requires that local communities build and upgrade wastewater treatment plants. These plants treat wastewater from homes and businesses. They must meet very strict standards before their treated "effluent" (see glossary) can be discharged to our bays, creeks, and rivers. Wastewater treatment plants conduct laboratory analyses to prove that they are meeting the federal clean water standards.



Brainstorm Activity

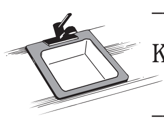
What is in domestic wastewater?

Toilet- ____

____

Bathtub/Bathroom sink- ____

____



Kitchen sink/Dishwasher- ____

____

Washing machine- ____

____

Wastewater treatment is essential to the health of humans and our environment. It usually includes the same steps that we use in this lab. Most wealthy nations treat their wastewater. However, in many parts of the world, countries do not have the money or technology to treat their wastewater. In these places, waste flows directly into lakes and rivers where people swim or fish, creating severe health problems.

How can waste be separated from water?

With a partner, create a list of different methods in which dissolved chemicals or solid materials can be separated from water. Refer back to your list of what is in domestic wastewater and think about how you would remove these materials from water. Share your ideas with the rest of the class.

____________________ ____________________

____________________ ____________________

____________________ ____________________

Design a treatment process to purify water. (Work individually or in teams—using butcher paper)

1. List separation methods you think are most important to remove waste from domestic wastewater.

   ____

   ____

   ____

2. Number those methods in order you think will work best.
3. Make a diagram of your treatment process, labeling each part.

4. Share your process with the class.

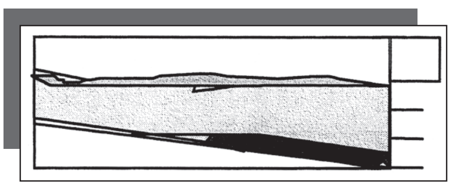
There are three main stages that local wastewater treatment plants may use to clean wastewater:

1. PRIMARY TREATMENT – Sedimentation and Flotation
2. SECONDARY TREATMENT – Biological Treatment and Secondary Sedimentation
3. ADVANCED TREATMENT – Filtration and Disinfection

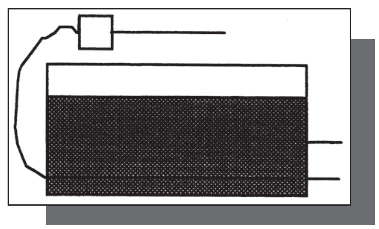
In this lab, you will do most of the processes that a municipal wastewater treatment plant does. You will treat simulated wastewater using the same treatment methods – chemical, physical, and biological – that are used at local wastewater treatment plants.

You will see what happens when the wastewater enters the first stage of wastewater treatment – primary sedimentation and flotation. Then you will use microscopes to view the microorganisms that are used in secondary (biological) treatment. Finally, you will conduct the final stage of treatment, including filtration and disinfection. Each day you will make qualitative and quantitative observations of your wastewater. At the end of the lab unit, you will compare your results with the effluent limits set by the U.S. Environmental Protection Agency.

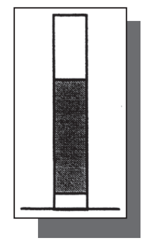
Below are drawings of the three types of tanks you will use to treat your wastewater.



Sedimentation Tank
primary treatment and secondary sedimentation



Aeration Basin
secondary (biological) treatment



Filter
advanced treatment (filtration)

Questions

After reviewing the contents of this workbook, watch an introductory video provided by your local wastewater treatment plant and answer the following questions:

1. List three processes for treating wastewater at a wastewater treatment plant:

2. List two chemicals or household products that should NOT go down your sink or toilet and explain why not?

3. Does storm drain (gutter) water go to the treatment plant OR does it flow directly to your local waterways?

4. List 3 human activities that pollute storm drains and suggest alternative behaviors.

Polluting Activity	Alternative Activity

Notes

Section 2

Water Quality Monitoring

Introduction

Wastewater treatment originated in the late 1800s when city populations were growing and scientists discovered that microorganisms can spread disease. Ensuring proper wastewater treatment and disposal is important for protecting public health and the environment. Untreated wastewater can spread disease and contaminate drinking water sources. Most Americans give little thought to what happens to their wastewater; the availability of safe, clean drinking water is often taken for granted. Many waterborne diseases such as cholera, typhoid and hepatitis are viewed as threats only for less-developed countries.

Chemists and engineers test the water at the wastewater treatment plant to make sure the water is being properly treated. These same tests can be used to monitor the quality of a creek, lake or bay water.

Brainstorm Activity

List ways that we can test the purity of water.

1. pH

WHAT IS pH?

pH is a measurement of how acidic or basic something is. The pH scale ranges from 1 to 14. A pH near 7 is considered neutral; that is, the solution is neither acidic nor basic. Very acidic solutions, such as lemon juice, have a low pH. Very basic solutions, such as ammonia, have a high pH.

The pH of Common Solutions

Lemon Juice	2.1
Orange Juice	2.8
Wine	3.5
Tomato Juice	4.1
Black Coffee	5.0
Urine	6.0

Rainwater	6.5
Milk	6.9
Blood	7.4
Baking Soda Solution	8.5
Borax Solution	9.2
Household Ammonia	11.9

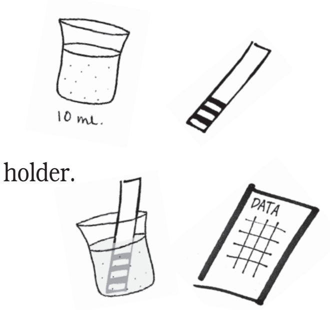
WHY IS pH IMPORTANT?

Bacteria at the wastewater treatment plant are most effective at eating the pollution if the pH is between 6.6 and 8.5. Therefore, you will need to test your wastewater to see if the pH is within that range. If it is too high or too low, you will need to add a chemical to it to change the pH.

Once the wastewater is treated, it is sent to the nearest water body, such as the San Francisco Bay. The fish, shellfish, birds, and plant life need the pH to be fairly neutral (6.5 to 8.5).

PROCEDURE FOR MEASURING pH (pH paper)

1. Obtain a 5 to 10 ml sample of the wastewater.
2. Take a strip of pH paper and stick the colored end into your sample.
3. Compare the color of the wetted pH paper to the color code on the side of the pH paper holder.
4. Record the pH value on your data table.



Sketch and describe the procedure for measuring pH in the 4 boxes below.

2. AMMONIA

WHY IS AMMONIA IMPORTANT?

The primary source of ammonia (NH_3) in wastewater is urine. Urine contains urea. One molecule of urea is made from 2 molecules of ammonia and 1 molecule of carbon dioxide. Urea (and ammonia) must be removed from wastewater.

There are two reasons that ammonia should not be dumped in a lake or bay. First, ammonia is highly toxic. Second, bacteria that naturally exist in a lake or bay will attack the ammonia in a reaction that requires oxygen. So when the bacteria react with the ammonia, they will be stealing dissolved oxygen from the water. That dissolved oxygen is needed in the water for survival of fish and other species.

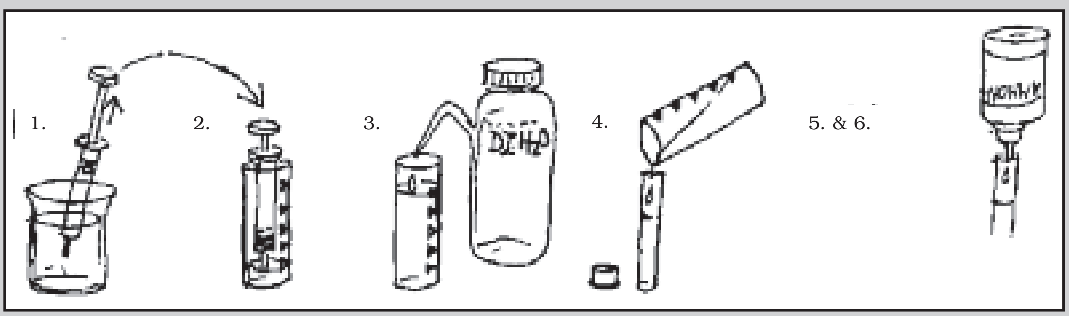
At the treatment plant, ammonia is removed by bacteria. Bacteria convert the ammonia and turn it into nitrate through a biological process called nitrification.

WHAT ARE THE UNITS OF MEASURE?

The units for ammonia concentration are milligrams/liter (mg/L).

PROCEDURE FOR AMMONIA MEASUREMENT

1. Using the syringe, pull in 2.5 milliliters (ml) of the wastewater sample beaker.
2. Empty the syringe into the 25 ml vial.
3. Dilute the sample by a factor of 10, by adding de-ionized water (D.I. water) from the squirt bottle up to the 25 ml line.
4. Using the syringe, stir the mixture in the 25 ml vial and pour 5 ml into the tiny test tube with the cap. (The 5 ml line is marked).
5. Add 8 drops from Ammonia Test Solution Bottle #1, holding the dropper bottle upside down in a completely vertical position to assure uniformity of drops. (Sodium salicylate)
6. Add 8 drops from Ammonia Test Solution Bottle #2, holding the dropper bottle upside down in a completely vertical position to assure uniformity of drops. (Sodium hydroxide, sodium hypochlorite).



7. Cap the test tube and shake vigorously for 5 seconds. Wait 5 minutes for the color to develop.
8. Read the test results by comparing the color of the solution to the appropriate Ammonia Color Card. The closest match indicates the mg/L of ammonia.
9. **Since you diluted by a factor of 10 in step 3, you must multiply by a factor of 10 to get your final result.**
10. Rinse vial, syringe and test tube with tap water after each use.

3. TURBIDITY

WHAT IS TURBIDITY?

Wastewater contains solid matter (or particles) of different sizes. Some of these particles are very small. These particles make the water look cloudy or turbid. Turbidity is a measurement of how many suspended particles are in water. It measures the clarity, not the color, of a water sample.

Fine particles, silt, and solids suspended in the water will cause the light passing through the water to scatter. It has been found that the amount of scattering is directly related to the amount of turbidity present.

WHY IS TURBIDITY IMPORTANT?

Turbidity is caused by suspended particles such as clay, silt, finely divided organic and inorganic matter, and microorganisms. Suspended particles are a problem for fish, since fine particles can interfere with oxygen absorption in their gills. Turbidity is an important measurement because it gives a good indication of the concentration of these particles. As wastewater moves through a treatment system, it becomes more and more clear, which means it becomes less and less turbid. Clean pure water has a turbidity of zero, although zero turbidity alone does not assure the sample is pure water.

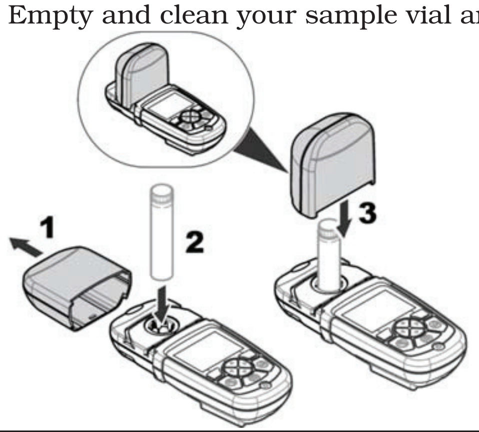
WHAT ARE THE UNITS OF MEASURE?

The units for turbidity depend on the type of meter you use to do the measurement. If you use a colorimeter, the units are Formazine Attenuation Units (FAUs). If you use a nephelometer or turbidity meter, the units are Nephelometric Turbidity Units (NTUs).

INSTRUCTIONS FOR USING THE HACH DR 900 COLORIMETER TO TEST TURBIDITY

1. Locate the provided vial with 10 milliliters of deionized water labeled "Blank"
2. Mix the sample beaker and fill the empty sample vial with 10 milliliters of sample.
3. Turn on the colorimeter with the blue button at the bottom of the instrument that looks like:

4. **Check to make sure the DR 900 reads "745 Turbidity" at the top of the screen***
5. Wipe the surface of both vials with a Kim Wipe.
6. Remove the cover and place the "Blank" vial in the hole, aligning the diamond shaped orientation mark towards you and covering the vial to not let in light
7. Press the center up arrow below the section that reads "Zero" to calibrate the instrument
8. Remove the "Blank" and place the sample vial in the hole, align the diamond shaped orientation mark towards you, cover the vial
9. Press the button below the section that reads "Read"
10. Record your result and the units, **"FAU"** in your lab book
11. Remove the sample vial and replace the cover. Turn off the colorimeter with the blue button at the bottom
12. Empty and clean your sample vial and put all materials back in the box for the next group



***If the instrument does not read program "745 Turbidity" press the button below the section that reads options. Select "favorites" and then select the proper program.**

4. CHEMICAL OXYGEN DEMAND

WHAT IS CHEMICAL OXYGEN DEMAND (COD)?

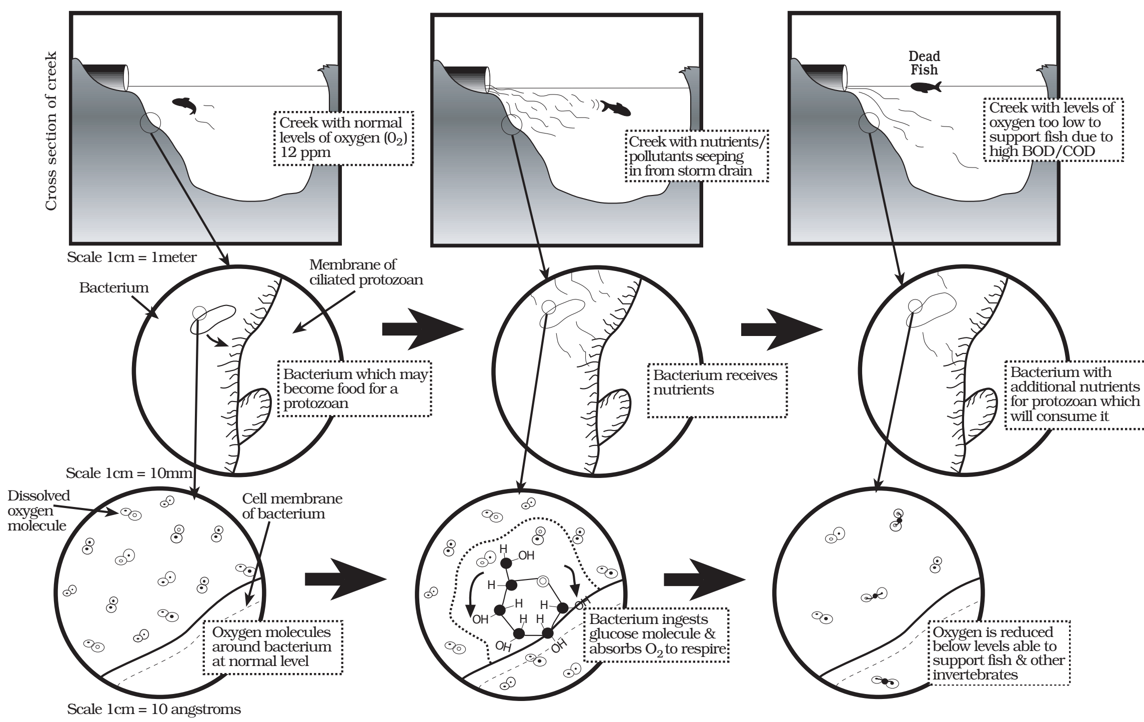
Chemical oxygen demand measures the amount of dissolved oxygen that would be removed from the water to react with (oxidize) pollution in the water and break it down into simple compounds like carbon dioxide and water.

Dissolved oxygen is the small amount of oxygen that is naturally dissolved in water. How can a gas, like oxygen, be in a liquid? Think of it like the carbon dioxide gas that is dissolved in soda to make it fizz. Dissolved oxygen is very important to water life. Fish breathe oxygen through their gills. A river, lake or ocean must have enough oxygen dissolved in the water in order to support life. Just like you probably don't like flat soda, fish don't like "flat" water. When your soda can is open and sits around for a day, it loses its fizz because carbon dioxide gas dissolved in the soda is released to the atmosphere. If the COD of a body of water is high, then the oxygen dissolved in the water will react with the pollution, reducing the amount of oxygen available to the fish. When lake or river water loses its oxygen, fish suffocate and die.

WHY IS COD IMPORTANT?

Chemical Oxygen Demand (COD) is a measure of the amount of oxygen that would be needed to destroy all the pollution in the water. If polluted wastewater is dumped into a lake, river, or ocean, the pollution is slowly altered or destroyed by bacteria and chemicals in the water. This is an oxidation reaction that requires oxygen. Oxygen that is dissolved in the water gets "stolen" from the water as these reactions take place. That dissolved oxygen was being used by the fish and other water creatures who need the oxygen to breathe and survive.

Oxygen levels are reduced after nutrients/ pollutants drain into a creek or bay. The effect is measured by analyzing the BOD (Biochemical Oxygen Demand) or COD (Chemical Oxygen Demand).



WHAT ARE THE UNITS OF MEASURE?

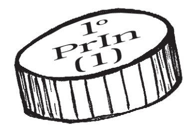
The units for COD are milligrams/liter (mg/L). A value of 200 mg/L means that in one liter of water, 200 mg of dissolved oxygen will be removed to oxidize that pollution. At the treatment plant, raw wastewater enters the facility with a COD of 500 to 1,000 mg/liter. By the time the water is treated and is ready to be discharged to a sensitive body of water, the COD should be less than 40 mg/liter. For comparison, distilled water has no pollution in it to react with oxygen so it has a COD of zero.

PROCEDURE

CAUTION!! The liquid in the COD tubes contains sulfuric acid. WEAR GLOVES AND PROTECTIVE EYEWEAR THROUGHOUT THIS PROCEDURE.

A. Preparation

1. Label a COD lid with (your class period) and the treatment: eg. (Primary Influent = PrIn(1), Primary Effluent = PrEf(2), Secondary Effluent = SecEf(3), Advanced Effluent = AEf(4)



2. Obtain 0.5 ml of wastewater with a calibrated pipette.
3. Wearing gloves and protective eye wear, carefully pipette the water into the COD vial.
4. Screw the lid on tightly and invert the vial several times to mix.
5. The sample must be heated in an incubator at 150 ^{o}C for one hour. The color of the liquid will change color as it incubates.
6. If this is the first day of the lab, make a "blank" or "zero" sample by using a clean pipette tip to obtain 0.5 mL of distilled water. Add this to a new COD vial that you have labeled "zero". Mix and let the blank sample heat in incubator for 60 minutes.

B. Collect Results Using a Hach Portable Colorimeter

1. ON THE NEXT CLASS DAY, turn on the colorimeter. Make sure it says "program 18" on the read-out. If it does not, then press PRGM. Next press 18 and then ENTER.
2. Insert the prepared "zero" COD vial and cover the vial with the colorimeter cap. Press the button marked "zero."
3. Remove the "zero" vial. Insert your sample vial and cover it with the colorimeter cap. Press the button marked "read."
4. Record the result.

All COD samples must be collected by the teacher for proper disposal. DO NOT pour the liquid from the vials down the sink.

Questions

In this lab we used four different tests to determine the quality of the water as it is treated. Each of these four tests is described in the proceding pages. Read the procedure for each method and answer the following questions:

1. pH is a measure of ____

2. A pH of 8.5 is (circle one) acidic / basic / neutral.

3. What is the primary source of ammonia at a wastewater treatment plant? ______________________

4. Name one reason that ammonia should not be dumped into the bay. ___________________________

   ____

5. If the measured turbidity is zero, does that prove our water is pure? ________

6. Does coffee have a higher or lower turbidity than drinking water? ____________________________

7. COD stands for ____

8. If pollution removed all the oxygen in a body of water, what happens to the animal life in the water? ____

   ____

9. Untreated wastewater can:

   a. spread disease

   b. contaminate drinking water

   c. harm aquatic life

   d. all of the above

10. What law enforces water regulation in the United States? ___________________________________

Section 3

Urban Wastewater

Introduction

Today you will make wastewater that has similar properties to real wastewater that flows to treatment plants every day. Then, you will qualitatively observe and quantitatively analyze that wastewater. The table below lists the sources of solids in typical domestic wastewater. But how much of the wastewater is composed of these pollutants? It might surprise you to find out that most of wastewater is just WATER. In fact, domestic wastewater contains only 2 percent solids. The remaining 98 percent is water!

Materials List

- Primary Sedimentation Tank, with sampling ports positioned over a lab sink
- Balances or scales (6)
- 1-liter beakers (8)
- 50-ml beakers (8)
- 25-ml graduated cylinders (2)
- Dry wastes — Baking soda, dry pet food, cereal, toilet paper, plastic waste and USED coffee grounds
- Liquid wastes — ammonia and vegetable oil
- Test stations to monitor water quality (pH, ammonia, turbidity and chemical oxygen demand)

Procedure

A. Make the Wastewater

1. Each team will be assigned one of the wastes listed in the table below.
2. For your waste, select an amount within the range given in the table.
3. Measure the waste and write down the exact weight or volume in the column marked “Amount Used.”
4. Fill 1000 ml beaker with water, add your waste and mix.
5. Add wastes to tank. Mix thoroughly.
6. Discuss what each of the eight wastes represents in typical wastewater.
7. Write your answers in the last column in the table below.

Team #___ **Waste substance**	**Recommended amount** (range)	**Amount used** (remember to write units!)	**What types of waste might this represent in REAL sewage water?**
1. Dried used coffee grounds	5 to 8 grams		
2. Ground-up breakfast cereal	2 to 4 grams		
3. Ground-up pet food	2 to 4 grams		
4. Cut-up plastic	1 to 4 grams		
5. Baking Soda	3 to 4 grams		
6. Torn-up toilet paper pieces	2 to 6 grams		
7. Ammonia	5 to 10 ml		
8. Vegetable oil	10 to 20 ml		

B. Collect Sample

The purpose of sampling is to get information about a large volume of material using a small amount of material.

1. Before the wastes start separating in the sedimentation tank, open a sampling port and obtain 50 ml of sample in a beaker.
2. Set aside for analysis.

C. Hypothesis: Predict what will happen as the wastewater settles after 20 minutes.

1. After 20 minutes ____ will float to the top of the water.
2. ____ will settle out to the bottom of the tank.
3. ____ will stay mixed in the water.

D. Analyze the wastewater

1. Break the class into teams and do assigned water quality tests
2. Follow instructions for assigned test (see Section 2)
3. Write the data on your team data table below.
4. In 10 to 20 minutes observe the sedimentation tank
5. Draw and label what you see in the tank in the box below.

Team Data Table For Primary Influent or Original Wastewater

Sample #1

Section 3

	Date and Time	pH	Ammonia Concentration* (mg/Liter)	Turbidity	Chemical Oxygen Demand (mg/Liter)
Original Wastewater					

*To find the ammonia concentration, remember to multiply the lab result by 10.

Transfer your data to table on page 31.

Notes

Section 4 Primary Treatment

Introduction

The first stage in wastewater treatment is to remove large solids and oil scum, decreasing the turbidity and chemical oxygen demand. Two treatment processes are used together – sedimentation and flotation. Particles that are denser than water, such as sand and gravel, settle to the bottom. Floatable material, such as vegetable oil, is skimmed off the top and pumped to a thickener.

Materials List

- 50-ml beakers
- Test stations (or labeled testing trays) to monitor the water quality
- Aeration basin with lid
- Aquarium pump
- Bleach-water in squirt bottles (BE CAREFUL NOT TO SQUIRT ONTO YOURSELF OR OTHERS - CLOTHING COULD BECOME DAMAGED OR DISCOLORED!)
- Activated sludge (Obtain from local wastewater treatment plant. It should be less than 24 hours old.)

Procedure

A. Hypothesis of Settled Wastewater

Parameter	**I hypothesize that after primary treatment (sedimentation & flotation) the value of this parameter will:**			**Because:**
	increase	decrease	stay the same	
pH				
Ammonia concentration				
Turbidity				
Chemical oxygen demand (COD)				

Procedure

B. Observe Sedimentation Tank

1. Observe the liquid in the tank. Which wastes appear to have settled?
2. Which wastes are probably dissolved?
3. Which wastes appear to have floated to the top?
4. Compare these results to your hypothesis:
5. Draw actual appearance of tank *labeling* what each substance is.

C. Analyze the Wastewater

1. Each team should obtain a 50-ml sample from one of the sampling ports.
2. Within each team, every 2-3 students will do one test.
3. Record the raw data and the average on your team data table below.
4. Wash glassware. Wash hands and wipe desk.

Team Data Table For Primary Effluent

Sample #2

Section 4 After primary sedimentation and flotation	Date and Time	pH	Ammonia Concentration* (mg/Liter)	Turbidity	Chemical Oxygen Demand (mg/Liter)

*To find the ammonia concentration, remember to multiply the lab result by 10.

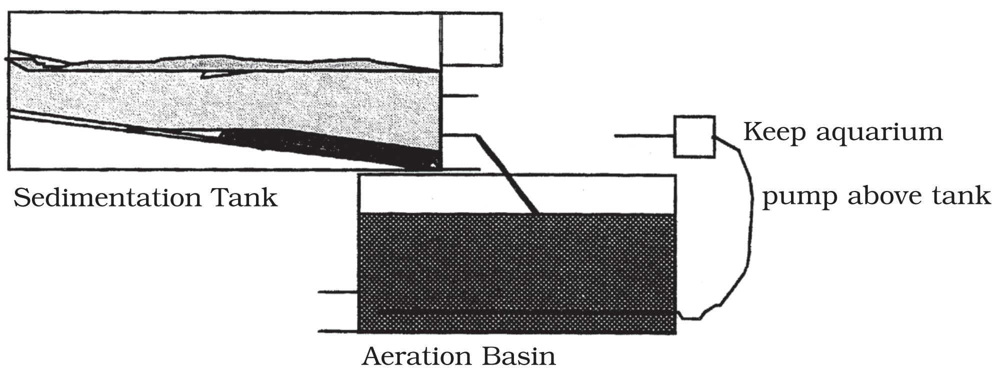
Transfer your data to table on page 31.

D. Transfer Wastewater to Aeration Basin

You are now ready to simulate the second step of wastewater treatment – biological treatment. It is time to transfer the wastewater from the sedimentation tank to the aeration basin and add microorganisms and oxygen.

WARNING: KEEP AQUARIUM PUMP ABOVE THE AERATION TANK AT ALL TIMES SO WATER CANNOT FLOW IN AND DAMAGE IT.

1. Place sedimentation tank higher than aeration tank. For instance, set aeration basin into sink. Place sedimentation tank next to the sink, high enough so water will drain into top of aeration basin.
2. Open middle sedimentation tank sampling port and let water drain into the top of the aeration basin. Take care not to drain out the floating scum or the settled sediment.
3. USING GLOVES, add about 500 ml of *activated sludge** to the aeration basin. Be careful not to spill the sludge. Wash hands thoroughly after handling the sludge container.
4. Plug in the aquarium air pump.



** Activated sludge comes from secondary treatment at a wastewater treatment plant and should be capable of processing ammonia in waste. The sludge should be attached to a pump with pipette to keep sample aerated.*

Questions

The first step of wastewater treatment is a physical process. Wastes that have different densities than water are physically removed. Wastes that have a higher density than water (greater than 1 g/cm3) settle to the bottom while wastes with lower densities than water (less than 1 g/cm3) float on the top.

1. Has the turbidity increased, decreased or stayed the same? __________ Why or why not? _______________

____

2. Why is the bottom of the sedimentation tank slanted? ____

____

3. What wastes dissolved in the water? ____

4. How are we going to remove the dissolved wastes? ____

____

Notes

Section 5

Secondary (Biological) Treatment

Introduction

Something Eats This Stuff?!

Sugars, complex carbohydrates, oils, proteins, and ammonia (NH_3) are sources of food for microorganisms. These nutrients are composed of the elements carbon, oxygen, hydrogen and nitrogen. In step two of wastewater treatment, microorganisms consume (eat) the biodegradable materials. At the treatment plant, wastewater and microorganisms are mixed together. Air is added to the process so that the aerobic (oxygen-using) organisms can absorb the oxygen (O_2) and eat the pollutants. As they consume (eat) the pollutants, the microorganisms convert those compounds into solids (more microorganisms) which are later separated from the wastewater. Activated sludge is the group of microorganisms used in an aeration basin to remove wastes from water.

Microorganisms include bacteria, protozoans, fungi, algae, and viruses. When we get sick, we tend to think of microorganisms as "bad guys." But we need them! This lab shows how microorganisms are beneficial for all of us. We also use bacteria in other aspects of our lives, such as making foods and beverages (yogurt, cheese, & wine for example). In fact, we all have bacteria, (E. coli) in our intestines to help us digest our food!

Many bacteria need oxygen in order to survive and consume waste. These are called aerobic bacteria. We add air to the biological treatment unit to keep these bacteria alive. Other bacteria do not need oxygen. They are called anaerobic bacteria.

Equations 1a and 1b show the two ways that aerobic bacteria use organic waste to produce either more bacteria or energy.

Equation 1a - Bacteria using organic wastes to make more bacteria

COHNS* (organic matter) + O_2 + bacteria + energy $C_5H_7O_2N$ (new bacterial cells)

Equation 1b - Bacteria oxidizing organic wastes in the wastewater, producing energy

COHNS (organic matter) + O_2 + bacteria CO_2 + NH_3 + energy + other end products

** Carbon, oxygen, hydrogen, nitrogen, sulfur*

Nitrification

Ammonia is a significant component in wastewater, originating from urine. Humans and other mammals excrete a compound called urea in urine. Urea, made in the liver, consists of 2 ammonia molecules and 1 carbon dioxide molecule. The urea molecules can dissociate in the wastewater, creating ammonia and carbon dioxide (CO_2). Ammonia must be removed from the water before the water is released back to the environment because it is toxic to many aquatic organisms at low concentrations.

Because ammonia does not float or settle, but instead dissolves, it cannot be removed with the primary treatment. Fortunately, it can be removed by biological treatment. Several types of bacteria are able to convert ammonia into nitrate in a process called nitrification. The bacteria also use some of the ammonia to make more bacteria cells. These special bacteria are in the genus Nitrosomonas and the genus Nitrobacter.

Below are two chemical equations that show how ammonia is changed into nitrates or into bacteria. Ammonia (NH_3) ionizes to ammonium ion (NH_4^+) when pH is less than 9.3, which wastewater usually is. In Equation 2, the ammonium ion (NH_4^+) is oxidized to nitrate (NO_3^-) by nitrifying bacteria, which gain energy from the reaction for their growth and maintenance (just like we gain energy from food to grow or maintain our bodies). Equation 3 shows that bacteria also use some ammonia to form new bacterial cells ($C_5H_7O_2N$).

Equation 2 - ammonium ion & oxygen react to form nitrate, hydrogen ions, and water (nitrification)

$$NH_4^+ + 2O_2 \quad NO_3^- + 2H^+ + H_2O$$

Equation 3 - carbon dioxide, bicarbonates, ammonium ion and water react to form bacteria and oxygen

$$4CO_2 + HCO_3^- + NH_4^+ + H_2O \quad C_5H_7O_2N \text{ (bacteria) } + 5O_2$$

Secondary Sedimentation

Once the microorganisms have done their work (removing the pollution) you need to remove them. You will transfer the water from the aeration basin back to the sedimentation tank. Sedimentation – the same process used to remove some of the initial wastes – is used to remove the microorganisms from the water. Because this is the second time in the treatment process that we use sedimentation, we refer to it as secondary sedimentation.

Chemical Flocculation

Aluminum Sulfate ("alum") is added to help the bacteria and other small solid particles settle out during the secondary sedimentation process.

Equation 4 shows how the aluminum sulfate reaction works. The sulfate ions in the alum react with calcium ions, naturally present in most water. The aluminum ions then react with hydroxide ions to form an insoluble "floc" or precipitate. This precipitate forms a "white cloud" of solids in the water. As the cloud slowly settles through the water, small bacteria bodies are captured in it and forced to settle to the bottom of the tank. The addition of alum may decrease the pH of the water.

Equation 4 - hydrated aluminum sulfate (alum) reacts with calcium carbonate to form calcium sulfate, aluminum hydroxide (a solid), carbon dioxide and water.

$$A1_2(SO_4)_3 \bullet 18H_2O + 3Ca(HCO_3)_2 \quad 3CaSO_4 + 2A1(OH)_3\text{(white,solid)} + 6CO_2 + 18H_2O$$

Materials List

- Microscopes
- Gloves
- Long glass pipette with a rubber bulb
- Eye droppers
- Slides and cover slips
- Poster and/or handouts that present drawings of microorganisms
- .25 % Bleach-water in plastic squirt bottles 5ml bleach + 95ml H_2O (BE CAREFUL NOT TO SQUIRT ONTO CLOTHING - BLEACH WILL DAMAGE OR DISCOLOR FABRIC)
- Sedimentation tank
- Aluminum sulfate (alum) dissolved in water at a concentration of 10 grams/liter (0.0l g/ml)
- Stir rods

Procedure

CAUTION!! The microorganisms used in this exercise are from a local wastewater treatment plant. Pathogens (disease-causing organisms) may be present in the activated sludge samples. Use gloves at all times when working with the activated sludge water. Wash hands after all work and disinfect work areas by wiping areas with a bleach-water solution.

A. Activated Sludge

Health of sludge based on organisms present

At a wastewater treatment plant, employees look at the microorganisms in the sludge as an indicator of the sludge's health. Examining the health ensures that the treatment plant is running correctly and helps to detect changes in the composition of the wastewater entering the plant.

You too can determine the health of your sludge based on the information below.

Healthy sludge contains a large variety of crawling and stalked ciliates, water bears, and rotifers.

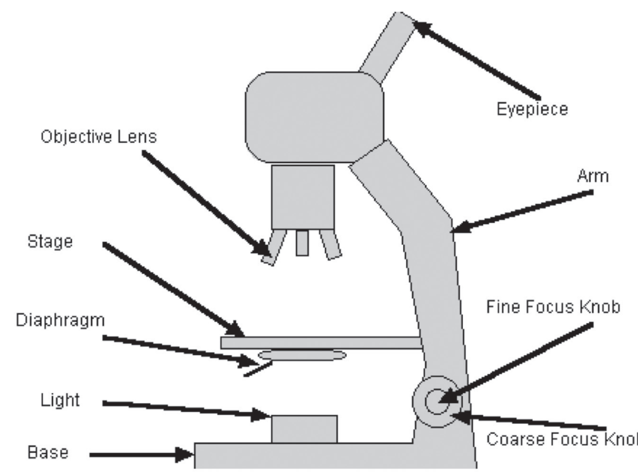
Intermediate sludge contains mainly crawling, stalked and free-swimming ciliates. It does not have many of the higher organisms.

Poor sludge contains mostly free-swimming ciliates and flagellates. The sludge usually has high turbidity and lower oxygen levels.

B. Microscope Lab

1. Wearing gloves, and using a long glass pipette, obtain a sample from the bottom of the aeration basin (try to get a sample with brown clumps in it).
2. Place one drop of the sample onto a slide and cover with a cover slip.
3. Starting on LOW power, focus the microscope (you should see brown clumps of bacteria) then SLOWLY move the slide, looking for motionless and mobile organisms.
4. Draw one or more of the organisms you see under the microscope.
5. Using poster and descriptions on Pages 22-23, try to identify the organism(s) you see.
6. Clean the eye droppers, slides and cover slips with a dilute bleach solution. Wipe up any spills and disinfect with the bleach solution. Remove gloves and wash hands.

The Parts of a Typical Microscope



Microscope Power: ________x

Estimated Size in Microns: ________________

Possible names or types of these Organisms:

____

Microscope Power: ________x

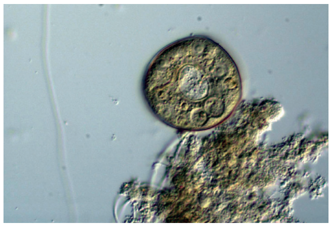
Estimated Size in Microns: ________________

Possible names or types of these Organisms:

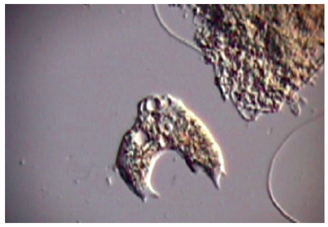
____

Important Facts About Microorganisms

Amoeba



Arcella- Shelled amoeba



Proteus- Naked amoeba

Features: Two types of amoeba are found in activated sludge: shelled and naked amoeba. Naked amoeba lack specific shape while the shelled amoeba take the shape of their shell. The shell is made up of sand particles. The yellow color is caused by iron deposits.

Size: The shelled amoeba are 50 to 60 microns in diameter while the naked amoeba are about the same size but change shape.

Habitat: Amoeba like abundant oxygen, large amounts of bacteria and reduced amounts of sludge particles.

Food: Amoeba eat both, particulate food, which is mostly bacteria, and dissolved food, which is absorbed through plasma membrane.

Free-swimming Ciliates

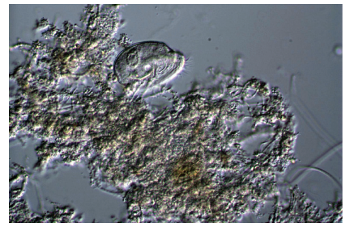
Features: The body is covered with uniform length cilia and is either foot-shaped or cigar shaped and somewhat flexible. The cell has either one or two large water cavities. It also has a large feeding groove used to trap bacteria.

Size: The free-swimming ciliates are medium to large (100-300 microns).

Habitat: They like activated sludge with large amounts of bacteria and reduced and well-dispersed sludge particles.

Food: Feeds on bacteria

Crawling Ciliates



Features: Also known as creeping ciliates. The body is shaped somewhat like a flea. They are called crawlers because cilia have been modified to form what resemble legs on the bottom-side of its body.

Size: The crawling ciliates are smaller than the free-swimming ciliates (15-30 microns)

Habitat: They like activated sludge with large amounts of bacteria and well-developed sludge particles.

Food: Feeds on bacteria

Stalked Ciliates

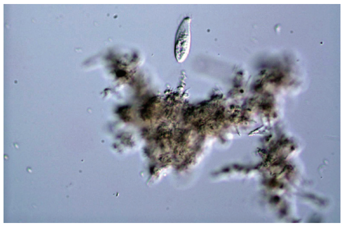
Features: There are at least a dozen species found in activated sludge. They are oval to round shaped and there is one organism found on each stalk except during cell division. Some species form colonies of organisms. Stalked ciliates consume food via vorticellids, oral cilia that wind completely around the top of the cell. The stalk contains a contractile filament that can rapidly coil up like a spring to cause rapid contraction, which may be a way to avoid predators.

Size: Depending on the species they can be from 30-150 micron in size.

Habitat: They live in the mature sludge particles where they can attach to each other.

Food: Mostly bacteria and other protozoans

Flagellates



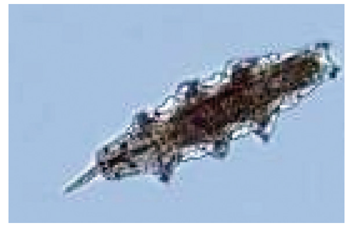
Features: Oval shaped body moves in a corkscrew motion by whipping action of one or more flagellum. There are plant types, which are pigmented with chlorophyll and animal-like types, which are nonpigmented. The flagella enables movement as well as the ability to catch food.

Size: 10 to 20 microns

Habitat: Flagellates like abundant oxygen, small bacterial population and a thinner sludge.

Food: Small particles and dissolved nutrients.

Tardigrade (Water Bear)



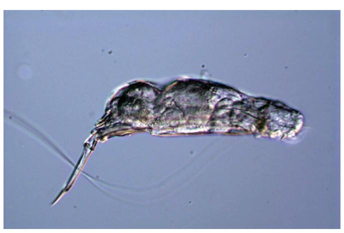
Features: Looks like a caterpillar and has claws. They are aggressive feeders, move around a lot and eat continuously.

Size: 0.2 - 0.5 mm in length (size of a dot made with a pencil)

Habitat: Found in aeration tanks with lots of sludge

Food: Body fluids of other microorganisms such as nematodes, rotifers and protozoan.

Rotifers



Features: They can be sack-shaped, spherical or worm shaped. They have a head, which possesses cilia for movement and food gathering, a body that has a thick cuticle (skin) and foot that has a gland that produces an adhesive for attachment. There are male and female rotifers. The male is much smaller and structurally simpler. Rotifers have reproductive organs and lay eggs. They move by swimming and/or crawling.

Size: 0.2 to 0.8 mm

Habitat: Needs abundant oxygen

Food: They feed upon algae, bacteria, protozoa and dead organisms.

Nematode (Round Worm)

Features: Most species of nematodes are very similar in appearance. The body is cylindrical, nonsegmented and tapering at both ends. The sexes are separate. Young hatch from eggs. They prefer to crawl over and through the sludge particles. Very few free-living nematodes swim, but when forced to swim they move by whip-like or rapid lashing action.

Size: 0.5 - 3 mm in length and 0.02 - 0.05 mm in diameter.

Habitat: Commonly observed in activated sludge.

Food: They feed upon algae, bacteria, protozoa, rotifers and dead organisms.

C. Secondary Sedimentation

After all teams have obtained their samples for the microscope lab, you need to transfer the wastewater from the aeration basin back into the sedimentation basin:

1. Wearing gloves, place the sedimentation basin into a lab sink. Make sure all sampling ports are tightly closed!
2. Move the aeration basin so that it is sitting on the counter next to the sink. The sampling ports from the aeration basin should be above the sedimentation tank.
3. Select a sampling port to use to drain the wastewater from the aeration basin.
4. Carefully open the aeration basin sampling port of the aeration basin and drain sludge and liquid into the sedimentation tank.
5. Place the sedimentation tank back on the counter.
6. Add 75 ml of aluminum sulfate (alum) solution to the tank. Mix thoroughly with a stir rod. Replace lid.
7. Wash the aeration basin and the stir rod with bleach and soapy water.
8. Remove gloves and thoroughly wash your hands. Wipe the surrounding counters with a bleach-water solution using a squirt bottle.
9. Periodically check the tank. Within 10 to 15 minutes, you should see a white cloud develop in the water and slowly drop to the bottom of the tank.

Questions

Biological Treatment

1. Why are microorganisms used at a wastewater treatment plant? ______________________________________

   ____

2. What types of pollution do microorganisms remove from real wastewater? ______________________________

   ____

3. Which wastes in your simulated wastewater do you think the microorganisms might be removing? ________

   ____

4. Why is it important to pump air through the aeration basin? ____

   ____

5. Based on the microorganisms present in your wastewater sample, what is the health of your sludge? Why?____

   ____

6. (Optional) List organisms that are the same as, or appear similar to, microorganisms you have observed in other labs: ____

Chemical Flocculation

7. Why did we add aluminum sulfate to the water? ____

   ____

Section 6 Advanced Treatment

Introduction

Filtration and disinfection comprise the final stage of wastewater treatment. After the microorganisms have settled to the bottom of the sedimentation tank, you will use a filter to further clean the water.

Filtration

You will transfer the water from the secondary sedimentation basin to a filtration unit. The filter is used to remove very fine particles that are not dense enough to settle and are not eaten by bacteria and other microbes. Wastewater treatment filters often consist of two materials: sand and charcoal. The coal layer sits on top of the sand layer. The water travels down the filter, reaching the charcoal first. The charcoal takes out the large solids that were suspended in the water. Then the water moves into the sand portion of the filter. The sand particles are so small that they are packed tightly together in the filter. The very small particles in the water get trapped in the packed sand. The water is able to travel between the sand and reach the bottom of the filter.

Disinfection

In secondary treatment, we purposely added bacteria and other organisms. While these bacteria were added to “eat” the pollutants in the water, some of those same bacteria may be dangerous to our health. Therefore, we must destroy any remaining microorganisms in the water before we discharge the water back into the environment. There are two different ways that treatment plants may disinfect the water: ultraviolet radiation or chlorination. In this lab we will use chlorination.

Chlorination is a common way to destroy organisms that may endanger human health, such as pathogenic (disease-carrying) organisms. Several different chemicals may be used to chlorinate water for disinfection. Wastewater treatment plants may use chlorine gas (Cl_2), chlorine dioxide (ClO_2), or sodium hypochlorite (NaOCl, bleach). In class, we will use bleach to disinfect the filtered wastewater.

Equation 5 shows the addition of bleach (sodium hypochlorite) to water. Once the bleach is added to water, the sodium (Na^+) and hypochlorite ion (OCl^-) dissociate and react with water to make hypochlorous acid and sodium hydroxide. The hypochlorous acid (HOCl) is the active disinfectant, oxidizing remaining bacteria. The hypochlorous acid will also react with any remaining ammonia.

Because the reaction is not immediate, it is important that the bleach has sufficient time in the water to destroy the bacteria. This is called “contact time.” At the treatment plant, the chlorine reacts with the filtered wastewater for 1.5 hours.

Equation 5 - When bleach (sodium hypochlorite, NaOCl) is added to water, it reacts to form hypochlorous acid (HOCl) and sodium hydroxide

$$NaOCl + H_2O \rightarrow HOCl + NaOH$$

Dechlorination

Now, we have removed the harmful bacteria from the wastewater, but what if there is still hypochlorous acid left in the water? Do we want that strong disinfectant to enter a river or lake? No, because it is toxic to aquatic organisms. So the final step at the plant, called dechlorination, removes excess chlorine from the water.

Although dechlorination is not included in the lab unit, it is used by treatment plants to remove excess chlorine that could be harmful to aquatic organisms. The plant adds sulfur dioxide gas (SO_2) to water. The reaction is shown in Equation 6. Unlike the chlorination reaction, this one is almost instantaneous, so a long contact time is not needed.

Equation 6 - Sulfur dioxide gas reacts with the hypochlorous acid and water, to create chlorine ions, sulfate ions, and hydrogen ions.

$$SO_2 + HOCl + H_2O \rightarrow Cl^- + SO_4^{-2} + 3H^+$$

Materials List

- A filter with two layers: sand on the bottom and charcoal on top
- Two 1- or 2-liter beakers
- Bleach
- Stir rods

Procedure

A. Analyze Results from Biological Treatment after Flocculation & Sedimentation

1. Each team should obtain a 50-ml sample from one of the sampling ports.
2. Within each team, every 2-3 students will do one test.
3. Record the raw data and the average on your team data table below.
4. Wash hands.

Team data table for Secondary Effluent or after biological treatment flocculation and sedimentation

Sample #3

	Date and Time	pH	Ammonia Concentration* (mg/Liter)	Turbidity	Chemical Oxygen Demand (mg/Liter)
Section 6 After biological treatment and secondary sedimentation					

*To find the ammonia concentration, remember to multiply the lab result by 10.

Transfer your data to table on page 31.

B. Filtration and Disinfection

1. Set the filter next to a lab sink, with the clamped tube at the bottom draining into the sink.
2. Unclasp the bottom tube.
3. Slowly transfer at least 2 liters of your wastewater from the sedimentation basin through the filter. Let the first 1 liter flow into the sink and down the drain.
4. Capture the next 1 liter in a beaker or flask. Make sure the water enters the beaker and does not spill into the sink or onto the floor. Do not let the water overflow the top of the filter.
5. Add 2 drops of bleach per each 1 liter of filtered water. Stir the container and let it sit for 10 minutes.

Notes

Section 7
Final Results and Conclusions

Introduction

All wastewater treatment plants have water quality regulations that they must follow to meet requirements set by the U.S. Environmental Protection Agency (EPA). Under the Clean Water Act the EPA works in partnership with states, local governments and tribes to regulate discharges into surface waters. Pollution limits are set by the EPA and are based on the body of water in which the effluent is being discharged.

Procedure

TEST THE QUALITY OF THE FILTERED WATER

1. Each team should obtain a 50 ml sample from beaker of newly filtered water.
2. Within each team, every 2-3 students will do one test.
3. Record the raw data and the average on your team data table below.
4. Wash hands.

Team Data Table For Advanced Effluent (after filtration)

Sample #4

	Date and Time	pH	Ammonia Concentration* (mg/Liter)	Turbidity	Chemical Oxygen Demand (mg/Liter)
Section 7 After Filtration					

*To find the ammonia concentration, remember to multiply the lab result by 10.

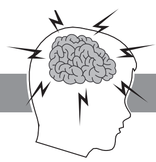
Transfer your data to table on page 31.

Discussion

Review of the Treatment Process

The table below shows the amount of time each step takes at the wastewater treatment plant. Compare the plant's treatment time with the amount of time we needed for treatment in this lab.

	PRIMARY	SECONDARY		ADVANCED		
	Primary Sedimentation	Biological Treatment	Floculation Sedimentation	Filtration	Disinfection	TOTAL TIME
Plant time (hours)	2 hours	4 to 6 hours	2 hours	0.5 hours	1.5 hours	10 to 12 hours
Your lab (hours)						



Conclusions- Did we clean the water?

1. Write down all the class data and averages for the week on Page 31.
2. Plot the chemical results for your wastewater. Use a separate graph for each parameter you measured. Time should be on the X axis and the values (**and units**) for your measurements should be on the Y axis.
3. Use your graphs to answer the questions below.

Parameter	Did this parameter increase or decrease during treatment?	Which treatment process created the largest change?
pH		
Ammonia Concentration		
Turbidity		
Chemical Oxygen Demand		

Compare Your Treated Water to EPA Requirements

The U.S. Environmental Protection Agency (EPA) sets limits for treated wastewater. Two sets of limits are listed below — the lower limits are for protected or sensitive fresh waters, while the higher limits are for discharging the treated water into a marine (salt water) environment or into deep waters. In the table, compare your treated wastewater to the two sets of discharge limits.

Parameter	Limit to Discharge the Treated Wastewater into Marine Water or Deep Water	Limit to Discharge Treated Wastewater into a Sensitive Bay or River	Value for Your Treated Water
pH	between 6.0 and 9.0	between 6.5 and 8.5	
Ammonia	no limit	< 3 mg/L	
Turbidity	no limit	< 10 NTU (nephelometer) < 20 FAU (colorimeter)	
Chemical Oxygen Demand (COD)	< 50 mg/L	< 40 mg/L	

Data Table for Class Results

	Date and Time	pH	Ammonia oncentration* (mg/Liter)	Turbidity	Chemical Oxygen Demand (mg/Liter)
Sample #1 Section 3 Original Wastewater Page 13					
Sample #2 Section 4 After primary sedimentation and flotation Page 16					
Sample #3 Section6 After biological treatment and secondary sedimentation Page 27					
Sample #4 Section 7 After Filtration Page 29					

*To find the ammonia concentration, remember to multiply the lab result by 10.

Basic Graphing Rules

Remember there are many kinds of graphs. The type chosen depends on the characteristics of the data to be displayed.

a) **Pie charts** – Best for showing parts of the whole (percents.)
b) **Bar graphs** – Best for comparison of many items.
c) **Line graphs** – Best for continuous change, usually over time. Use it when measuring progress towards a goal, to show the relative improvement.

In this Exercise, please use a Line Graph.

Creating the Line Graph

1. The horizontal axis (x-axis) is used for the quantity that can be controlled. This is called the ***independent variable*** representing different time periods or names of things being compared. Example: Treatments (raw, primary, secondary, advanced).

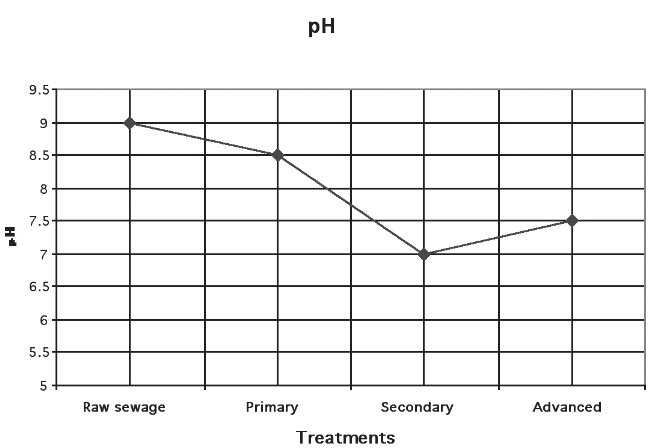
2. The vertical axis (y-axis) typically has numbers for the amount of stuff being measured. The y-axis usually starts counting at 0, but does not have to start at 0 and can be divided into as many equal parts as you want. This is called the ***dependent variable***.

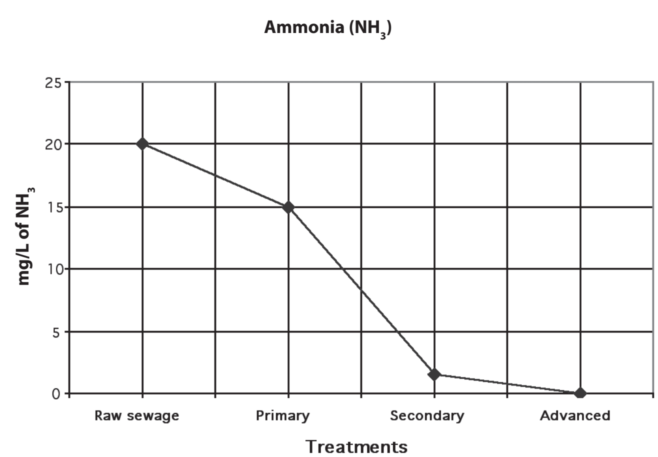
3. Choose the scale so the graph becomes large enough to fill most of the available space on the paper.

4. Each regularly spaced division on the graph paper should equal some convenient, constant value. In general, each interval should have a value that can be easily divided visually such as 1, 2, 5, or 10, not 3, 6, 7, or 9.

5. **An axis does not need to start at zero**, particularly if the plotted values cluster in a narrow range not near zero.

6. Label each axis with the quantity and unit being graphed. For example Y-axis might be labeled **mg/L** and the X-axis might be labeled **Treatments. See example below.**





Notes

GRAPH 1: pH

GRAPH 2: Ammonia

GRAPH 3: Turbidity

GRAPH 4: COD

Lab Write-Up

Your Conclusions

Summarize the lab and present your conclusions in the space provided below or attach additional pages to this workbook. Be sure to discuss the following:

- The purpose of the lab
- Summarize the overall procedures
- Compare the classroom treatment processes to the steps used at a real treatment plant.
- Discuss the results of your wastewater treatment. Do you think it would be safe to discharge your treated water directly into a local lake, river or ocean? Why or why not?
- List any household chemicals or industrial pollutants that we did not test for that might be important to the wastewater treatment plant.
- Suggest improvements or changes to this lab.
- How does wastewater treatment affect your life? For example, what would happen if we didn't have wastewater treatment? Discuss public health, environmental, and other issues.

Lab Write-up

Lab Write-up

Appendix

A. JOBS IN WATER QUALITY

B. EXTRA CREDIT OR ADVANCED ASSIGNMENTS

C. GLOSSARY

D. SCHEMATIC OF A TYPICAL WASTEWATER TREATMENT PLANT OR WATER RECYCLING FACILITY

A. Jobs in Water Pollution Control

Generally, the type of job and level of pay in the wastewater field is determined by education, experience, and level of responsibility. The minimum educational requirement for working in the field is a high school diploma. The table below gives you an idea of what is available in the San Francisco Bay Area today.

Entry Position	$/Hour	Monthly Salary	Annual Salary	Education
Utility Worker	$30	$5,241	$62,892	High School
Plant Mechanic	$32	$5,663	$67,956	High School
Plant Operator	$35	$6,104	$73,248	High School
Environmental Inspector	$39	$6,832	$81,984	Bachelor's degree
Staff Engineer	$55	$9,626	$115,512	Bachelor's degree

Positions listed below require educational levels plus experience. Some also require specific certifications.

Supervisory Position	$/Hour	Monthly Salary	Annual Salary	Education and Experience
Senior Plant Mechanic	$43	$7,508	$90,096	High School with experience
Senior Operator	$45	$7,795	$93,516	High School with
Maintenance Supervisor	$65	$11,285	$135,420	High School with
Lab Director	$80	$13,937	$167,244	Higher degree preferred
Assistant Manager	$105	$18,292	$219,504	Bachelor's degree

Note: Data from 2018 SVCW salary chart.

For more detailed job descriptions and salaries, visit **www.centralsan.org** or **www.svcw.org**

B. Extra Credit or Advanced Assignments

POLLUTION ALTERING THE GENDER OF MARINE SPECIES

Medication, such as prescription drugs, over-the-counter pain relievers, and other remedies, can get into the environment through the sewer system. These medications cause problems for aquatic organisms, interfering with their growth and reproduction, and causing increased bacterial resistance. This is an emerging problem in the water quality field and a solution must be found. Find articles, books, or websites that summarize this environmental problem. What are the sources of the medications? Where has this problem been reported? What are potential solutions to this problem? Two excellent websites about this issue are www.nodrugsdownthedrain.org and www.dontrushtoflush.org.

FIELD TRIP TO LOCAL WASTEWATER TREATMENT PLANT

Take a field trip to your local wastewater treatment plant. Then either a) write a letter requesting a job interview, b) prepare a sketch of the operations, or c) create a poem. In each case, you must describe how the local plant is different from the lab, on the basis of size, types of treatment operations, types of filter material, method of disinfection, and amount of time it takes to treat the water.

CHEMICAL REACTIONS FOR DISINFECTION

Contact your local wastewater treatment plant and ask what chemical or process they use to disinfect the water. This may include ultraviolet light or a different type of chlorine-based chemical. Write out the chemical reaction for their specific process.

LEARN ABOUT WATER QUALITY CAREERS

Interview or job shadow a wastewater professional to find out more about water quality careers. Prepare a report or give a presentation to your class summarizing what you learned.

C. Glossary

Activated sludge	This is a term for the group of microorganisms used in an aeration basin to remove wastes from the water.
Advanced treatment	This is the last step of wastewater treatment. There are two parts, filtration and disinfection. The water is filtered with sand and charcoal. This water is then disinfected with chlorine or with ultraviolet light. If chlorination is used, then the water is dechlorinated before being released.
Aluminum sulfate (Alum)	Aluminum sulfate, ($Al_2(SO_4)_3$), is used in treatment of drinking water and occasionally in the treatment of wastewater. It reacts with carbonates in the water to form a cloudy white precipitate in the water. This fine cloud slowly settles to the bottom of the tank. As it does, small suspended solids, such as bacteria, are pulled down to the bottom and separated from the water.
Ammonia (NH_3)	Ammonia is a substance made of nitrogen and hydrogen. It is toxic to water life. When bacteria break down urine, as happens in a diaper pail, the urine turns to ammonia, which has a pungent odor. Ammonia is a strong base with a high pH.
Biological treatment	Use of microorganisms to remove wastes from the water.
Chemical Oxygen Demand (COD)	A measure of the amount of oxygen needed to destroy pollution, turning it into elements and simple molecules such as water and carbon dioxide. This is a vital test for determining the quality of the water leaving the treatment plant. The water entering the treatment plant may have a COD of 1,000 mg/L. Each stage in wastewater treatment reduces both the BOD and COD of the water.
Chlorination	Chlorination is one way to disinfect water. It is used in swimming pools and hot tubs to destroy bacteria and other microorganisms. It is used in wastewater treatment plants to destroy the microorganisms that were used in the biological treatment process.
Dechlorination	After chlorination has been used to destroy microorganisms, any remaining chlorine would be toxic to aquatic organisms. Removing chlorine before the treated water can be released is called dechlorination.
Density	Density is the weight of a substance divided by its volume. For instance, 1 gram of water takes up 1 cubic centimeter of volume, so its density is 1 g/cc. In a mixture, the most dense material will settle to the bottom and the least dense material will float to the top. Vegetable oil is less dense than water. That's why if you have a salad dressing of oil and water, the less dense oil floats on top of the more dense water.
Disinfection	Disinfection is the treatment of water to kill microorganisms that may cause diseases or otherwise harm human health.

Dissolved oxygen	A small amount of oxygen is naturally dissolved in water. How can a gas, like oxygen, be in a liquid? Think of it like the carbon dioxide gas that is dissolved in soda to make it fizz. When a can of soda is opened and sits around for a day, it loses its fizz because the amount of carbon dioxide gas dissolved in the soda is reduced. Dissolved oxygen doesn't make a fizz like carbon dioxide does. Fish breathe dissolved oxygen through their gills. It is important that the dissolved oxygen concentration in a river, lake or ocean is high enough so that the fish don't suffocate and die.
Effluent	This is the term for the treated water as it exits the treatment plant and goes into a local creek, river, or ocean.
Feces	Solid human waste.
Flotation	A physical process that is used in wastewater treatment to remove oils, grease, and solids floating on the surface of the water. Screens and skimming devices are used at the wastewater treatment plant to remove larger objects, grit, floating scum, oil, and grease.
FAU	Formazine Attenuation Units
Influent	Liquid flowing into plant or next treatment process
Microorganisms	These are small organisms, visible under a microscope, that may be as small as just a single cell. Wastewater treatment is one example of how we use microorganisms in daily life. We use other microorganisms to make foods, such as cheese. We also all have microorganisms in our intestines to help us digest.
Nitrates (NO_3)	Bacteria use ammonia, which is toxic to water life, and turn it into nitrates, which are not toxic to water life.
Oxidation	In wastewater treatment, oxidation is the name for a chemical reaction that requires oxygen to break down pollution into smaller compounds such as carbon dioxide (CO_2) and water (H_2O).
pH	A measure of how acidic or basic a substance is. The pH scale ranges from 1 to 14.
ppm	Parts Per Million
Primary treatment	This is the first step of wastewater treatment. Water is pumped into a large sedimentation tank. Material that is less dense than water floats to the top and is skimmed away. Solids that are denser than water sink to the bottom of the tank and are pumped away.

Protocol	In a laboratory, the description of how to do a test or experimental procedure is referred to as a protocol.
Secondary treatment	This is the second step of wastewater treatment. In large tanks, billions of microorganisms break down the materials that did not sink or float in primary treatment. These “suspended” or “dissolved” solids are removed from the water by the microorganisms.
Sedimentation	A physical process used in wastewater treatment to remove particles that are more dense than water.
Sludge	Solids in raw sewage that are separated from the wastewater throughout the stages of treatment. They undergo additional treatment, called digestion, and become biosolids. Biosolids, as they are rich in nutrients and organic materials, are mostly used as a soil amendment or fertilizer.
Suspended solids	Suspended solids are the solids that are in wastewater that neither sink nor float. These solids are not removed in primary treatment.
Turbidity	Turbidity is a measure of the level of cloudiness of the water. The small particles in very cloudy water scatter light.
Wastewater treatment	Wastewater treatment is the process of removing pollution from water so the water can be safely returned to local rivers, lakes, or oceans. Wastewater treatment is essential to the health of humans and our environment. In the United States, wastewater treatment is required by Clean Water Act which is enforced by the U.S. Environmental Protection Agency. It usually includes the same steps that we use in this lab. Other wealthy nations also treat their wastewater. However, in many parts of the world, countries do not have the money or technology to treat their wastewater. In these places, waste flows directly into lakes and rivers where people swim or fish, creating health problems.

Notes

HOW THE SVCW WASTEWATER TREATMENT PLANT WORKS

Wastewater treatment is one of the “hidden” necessities of life on the Peninsula. SVCW serves more than 200,000 people and businesses in our service area. By effectively treating wastewater at an advanced, two-stage biological treatment facility, SVCW helps keep San Francisco Bay environmentally clean and safe. The treatment plant uses microorganisms to remove organic material and toxins from the wastewater it treats. Sewage arrives at the plant through a series of pipelines and pump stations. The sewage then passes through physical and biological processes which result in high quality effluent being discharged to the deep water channel of the San Francisco Bay. The SVCW facility is designed to remove more than 97 percent of all solids, organic material and pathogens from the wastewater.

1 Primary sedimentation

The wastewater slowly flows through the primary sedimentation tanks where settling and skimming removes solids, floating grease and scum.

2 Fixed film reactors

The fixed film reactors are the first stage of the biological treatment. Wastewater is pumped to the top of the fixed film reactors where bacteria on the reactors consume most of the organic matter in the wastewater.

3 Activated sludge

The second stage of the biological treatment process is activated sludge. The microorganisms and the biodegradable matter they consume are collectively called “activated sludge.” Air is continuously mixed into the wastewater and activated sludge which provides oxygen for the microorganisms to grow and consume the remaining biodegradable matter. This occurs in the aeration basin.

4 Secondary clarifiers

The activated sludge flows to the secondary clarifiers for final settling to separate the activated sludge from the wastewater. The activated sludge is sent back and reused at the aeration basins. At this point in the treatment process about 90% to 95% of the solids and biodegradable matter has been removed from the wastewater.

5 Final filtration

The dual media filters have two layers, sand and anthracite coal, through which the secondary effluent flows to remove most of the remaining suspended particles.

6 Disinfection

Chlorine bleach (sodium hypochlorite) is applied to the secondary clarifier effluent. The chlorine kills nearly all remaining bacteria.

7 Recycled water

During the dry season SVCW further treats some of the plant flow with coagulation and higher disinfection for use as recycled water for landscape irrigation in the SVCW service area.

8 Solids conditioning

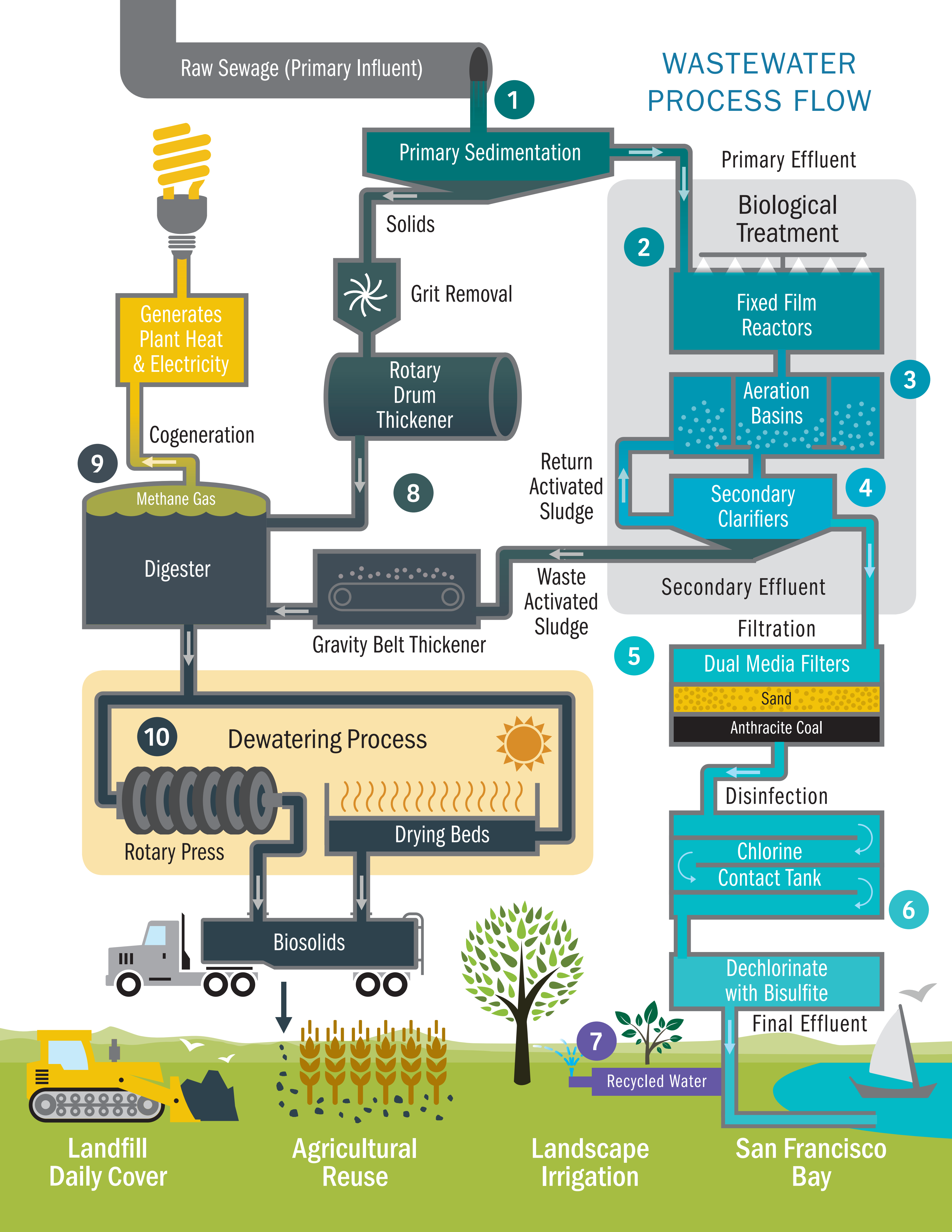
Solids captured in the primary sedimentation tanks are pumped to the grit removal process and sent to the rotary drum thickener to thicken the solids and remove water. Waste activated sludge is thickened using a gravity belt thickener. Thickened solids are pumped to the anaerobic digesters for organic solids breakdown and stabilization.

9 Anaerobic digestion

Anaerobic (absence of oxygen) digestion is a two stage biological process first converting large organic compounds to organic acids, and then converting these to carbon dioxide and methane. The process reduces solids volume, stabilizes the solids reducing the chance of odor and reduces pathogens. The finished product is called biosolids. The methane gas is used to produce some of the electricity needed to run the plant’s equipment, and for process and building heating.

10 Dewatering process

Much of the water in the biosolids is removed by either rotary press or solar drying. For rotary press operations, a polymer solution is added to aid the separation of solids from water. The liquid biosolids are passed through the rotary press, leaving the dewatered biosolids. Another option used for dewatering is solar drying. Nature does the work of dewatering the biosolids, using sun and wind. This reduces the cost of operation. The biosolids have a high nitrogen content and can be used as an agricultural soil conditioner, a feed stock for composting, or daily cover at a landfill.



WASTEWATER PROCESS FLOW
Raw Sewage (Primary Influent)
1
Primary Sedimentation
Primary Effluent
Solids
Grit Removal
Rotary Drum Thickener
Biological Treatment
2
Fixed Film Reactors
3
Aeration Basins
Return Activated Sludge
4
Secondary Clarifiers
Generates Plant Heat & Electricity
Cogeneration
9
Methane Gas
8
Digester
Waste Activated Sludge
Secondary Effluent
Gravity Belt Thickener
Filtration
5
Dual Media Filters
Sand
Anthracite Coal
10
Dewatering Process
Rotary Press
Drying Beds
Disinfection
Chlorine Contact Tank
6
Biosolids
Dechlorinate with Bisulfite
Final Effluent
7
Recycled Water
Landfill Daily Cover
Agricultural Reuse
Landscape Irrigation
San Francisco Bay

About Silicon Valley Clean Water

Silicon Valley Clean Water (SVCW) is a Joint Powers Agency established in 1975, creating a regional wastewater treatment facility to treat municipal and industrial wastewater from the cities of Redwood City, San Carlos, Belmont and the West Bay Sanitary District (servicing the city of Menlo Park, Atherton, Portola Valley, areas of East Palo Alto, Woodside, unincorporated San Mateo County and Santa Clara County).

Located at 1400 Radio Road in Redwood City, CA, the treatment facility is permitted to treat a daily wastewater flow of up to 29 MGD and wet weather peak flows of up to 80 MGD. Using many of the treatment processes described in this workbook, the water discharged to the San Francisco Bay meets all the regulatory requirements necessary to protect human health, wildlife, and the water, air, and land environments.

At SVCW we approach our work from a resource recovery perspective, protecting the environment by recycling water, using biosolids, and recovering energy in the following ways:

- **Recycled Water** - treated wastewater meets the current requirements for Recycled Water in the State of California. The City of Redwood City saves approximately 500 million gallons of drinking water every year by utilizing recycled water for landscape irrigation in Redwood Shores and other areas within the City.
- **Cogeneration** - SVCW's cogeneration process uses methane gas produced from one of the treatment processes to provide approximately 70% of the facility's electrical energy needs.
- **Heat Recovery** – the waste heat recovered from the cogeneration process provides all the heat needs for significant process heating and building heating system and offsets natural gas usage.
- **Biosolids** - biosolids from wastewater solids are land applied for non-food crops, used as alternative daily cover on landfills, converted to biochar or a feed stock for compost.

SVCW is currently implementing a $833 million Capital Improvement Program to update the treatment plant and equipment necessary to pump and treat the wastewater for the service area. SVCW and our staff are dedicated to the protection of the environment that we live in and to recovery of our precious water, energy, and biological resources. In every task we undertake, safety and environmental protection are our primary concerns.

Silicon Valley Clean Water, 1400 Radio Rd., Redwood City, CA, (650) 591-7121, info@svcw.org