Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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The Science & Technology of Water

Curriculum Unit 87.06.07
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In the seminar Science, Technology, and Society, headed by Dr. Charles Walker, we discussed the values and obligations that science and technology have to society. Such topics as the anatomy of power were examined and questions were raised as to whether or not scientists exercise power. If scientists exercise power, in what way do they exercise power? Another question raised during the seminar was, is our world getting too sophisticated that only a small elite will be able to understand and possibly control our society?

The main objective of this seminar, however, was to relate science and math into the students daily lives. Basically we are trying to satisfy a physical need "in their world." I first proposed a unit that would deal with the disposal of hazardous wastes and its effect on local water supplies. The unit, however, proved to be too long, so I have limited my unit to water; pure and impure, a limited resource, one which is slowly being contaminated by the waste products of technology.

Water is an essential constituent of all living matter, from vegetation, to animals and especially man. It is the most abundant compound in the human body, making up about 70% of our total body weight. Water is essential for all bodily functions, so much so that a person can survive longer without food than water.

As our most common resource, water covers 70% of the earth's surface. It can be found in our oceans, seas, lakes, rivers, streams, even glacial deposits, and of course, water is always present in our atmosphere. 97% of the earth's water is saline (salt) water with vast amounts of dissolved minerals. More than 70 elements have been detected in the mineral content of sea water. The world's fresh water comprises the other 3% of which two-thirds is locked up in the polar ice caps and glaciers. The remaining fresh water is found in ground water, lakes and our atmosphere.

Man uses water not only for drinking and cooking, but also for bathing, washing, laundering, heating, and air conditioning; for agriculture, raising stock and gardens; for industrial purposes, cooling, for water power and steam power; for fire protection; for disposal of wastes; and for recreational purposes such as swimming, fishing and boating.

Every activity of man involves some use of water. For many of these uses, the water must be drawn from a water source. Often, the water that is drawn is returned to the same water source, either with pollutants or increased temperature or both. If taken from large water supplies (i.e.,. rivers, lakes and streams), this water is used over and over again by downstream communities.

The quality of water suitable for man's needs varies widely, and what is satisfactory for one purpose may not be for another. Since water is such an important part of human life, this unit proposes to discuss the following:

I. physical properties of Pure Water
II. Physical Properties of Impure Water
III. The Water Cycle
IV. Purification Techniques of Natural Waters
V. Purification Systems in New Haven
VI. Drinking Water Quality & Protection
VII. Conservation
VIII. Appendix

I. Physical Properties of Pure Water

Objectives: Students will be able to: -describe The structure of a water molecule

-describe Hydrogen bonding

- *describe* the *physical properties of water*

A. Structure

A single water molecule consists of 2 hydrogen atoms and 1 oxygen atom. Each H-atom is attached by a single covalent bond to the oxygen atom. The water molecule is nonlinear and has a V-shape structure.

(figure available in print form)

electron distribution	bond angle & bond length	molecular orbital structure	dipole representation

The bond angle between the 2 H-atoms is approximately

105° Oxygen is the second most electronegative element, as a result, the two covalent 0-H bonds in water are polar. The two polar covalent bonds and the bent structure result in a partial negative charge on the oxygen atom and a partial positive charge on each hydrogen atom which repel each other 105°. The polar nature of water is responsible for many of its properties, including its behavior as a solvent.

B. The Hydrogen Bond

A *hydrogen bond* is a chemical bond that is formed between polar molecules that contain a hydrogen atom covalently bonded to a small, highly electronegative atom such as fluorine, oxygen or nitrogen. The high electronegative atom tends to have a negative charge while the hydrogen is positively charged. When a negatively charged atom from one molecule is attracted to a positively charge H-atom of another molecule. The hydrogen bond is actually a dipoledipole attraction of polar molecules.

The hydrogen bonding between water molecules give water physical properties that do not fit the trend relative to the molecular weights of similar compounds from the same chemical family. Water tends to have unusually high melting point, boiling point, heat of fusion and heat of vaporization. This is because hydrogen bonds are stronger than the intermolecular forces between other molecules.

Below is a table and graph that compares the physical properties of H20, H2S, H2Se and H2Te at STP.

for *mula*	*color*	Molecular *weight*	Melting Point C	Boiling Point	Heat of fusion	Heat of vaporization
H20	colorless	18.0 g	0.0 C	100 C	80 cal/g	540 cal/g
H 22S	colorless	34.1 g	-85.5 C	-60 C	17 cal/g	131 cal/g
H2Se	colorless	81.0 g	-65.7 C	-41 C	7 cal/g	57 cal/g
H2Te	colorless	129.6 g	-51.0 C	-2 C		43 cal/g

Temperature as a function of Molecular Weights in the Melting and boiling points of H 0, H2S, H2Se & H2Te

(figure available in print form)

C. Physical Properties

Water is a colorless, odorless, tasteless liquid with a melting point of 0° C and a boiling point of 100°C at 1 atm pressure. Two additional physical properties of matter are introduced with the study of water: Heat of fusion and heat of vaporization.

Heat of fusion is the amount of heat required to change one gram of a solid into a liquid at its melting point. The heat of fusion of water is 80 cal/g. The heat of fusion is the energy needed to breakdown the crystalline lattice of ice from a solid to a liquid.

Heat of vaporization is the amount of heat required to change one gram of a liquid into a gas at its boiling point. The heat of vaporization for water is 540 cal/g. The heat of vaporization is the energy needed to breakdown the inter- molecular forces (or hydrogen bonds) between molecules in a liquid to be unattracted to each other in a gas.

The *Specific Heat* of water is 1 cal/g°C. The specific heat is the amount of energy needed to raise one gram of water one degree Celsius.

ACTIVITY: (may be a demonstration or lab exercise, 30 min.)

Materials: hot plate, thermometer, 250 grams of ice, 500 ml beaker

Measure the temperature of the ice as time zero. Then begin heating ice and take temperature every 30 seconds. Once the ice starts to melt, the temperature no longer rises even though the hot plate continues to supply heat. Once all the ice has melted, the temperature again rises as the water heats up. The temperature of the water stops rising, once the water starts to boil even though the hot plate continues to supply heat at a constant rate.

DATA TABLE

time (seconds) temperature Heating Curves

(figure available in print form)

Problem Solving:

1. How many calories are required to change 20 grams of ice at 0.0° C to liquid water at 0.0° C? (the heat of fusion is 80.0 cal/gram)

 answer: Q = Hm Q = *80.0* cal/g x 20 g

 Q= 1600 *cal*

2. Calculate the number of calories required to vaporize 20 grams of liquid water at 100 C to gaseous water(steam) at 100 C. (The heat of vaporization for water is 540 cal/g)

 answer: Q= Hm Q=54O cal/g x 20 g

 Q= 10,800 cal

3. How much heat would be needed to raise the temperature of a 20 gram sample of water from 50° to 80° C?

 answer: Q = m Tc Q= 20 g x 30 C x 7 cal/g C

 Q = 600 cal

4. Calculate the number of calories required to melt 20 grams of ice at 0.0 C and convert the resulting water to steam at 100 C.

 answer: Q= Hfm + m *Tc* + Hvap m

 Q= *80* cal x 20 g + 20 g x 700 C x 7 *cal* + 540 *cal* x *2Og*

 g g C g

 Q= 1600 *cal + 2000 cal + 70,000 cal*

 Q= 74,400 *cal*

II. Physical Properties of Impure Water

Objectives: Students will be able to differentiate between suspended particles and colloidal particles in solution.

Impurities in water may be in one of the three phases of matter: solid, liquid or gas. These impurities are dispersed into three states: suspension, colloidal and dissolved. The state in which an impurity is dispersed is especially important in the methods required for its removal.

A. Suspended Particles

Particles in suspension can be seen by the naked eye or by a microscope. The diameter of suspended particles ranges generally from 100 to 200 micrometers.

Suspended particles contribute to the cloudiness or turbidity of water. The *turbidity* of water is its capacity for absorbing or scattering light.

Demonstration: a sample of suspended particles may be made by taking some clay and adding it to a beaker of water. Stir vigorously to suspend clay.

Students should observe that after some time the suspended particles eventually settle to the bottom of the beaker. Ask students how they might remove the sand from the water. Answer: by filtration or allow to settle and decant

B. Colloidal Particles

The fundamental difference between a colloidal dispersion and a suspension is the size of the colloidal particles between 1 to 5 millimicrons. They can be distinguished only by means of an ultramicroscope or an electron microscope.

There are many types of colloidal dispersions, the following table is a list of some colloidal dispersions.

TABLE OF COLLOIDAL DISPERSIONS

Type	Name	Examples
gas in liquid	foam	Whipped cream, soaps suds
gas in solid	solid foam	Styrofoam, foam rubber
liquid in gas	liquid aerosol	fog, clouds
liquid in liquid	emulsion	milk, vinegar in oil
		salad dressing
liquid in solid	solid emulsion	cheese, opals, jellies
solid in gas	solid aerosol	smoke, dust in air
solid in liquid	sol	india ink, gold sol
solid in solid	solid sol	certain gems (ex. rubies)

Colloidal dispersions that can be made in the classroom

1. india ink in water

2. add iron (III) chloride solution to boiling water

When colloidal solutions are observed in the path of an incident light beam, they appear perfectly clear. However, when at right angles to the beam many colloids appear turbid even to the naked eye. This phenomenon is known as the *Tyndall Effect* .

Examples of the tyndall effect is to a colloidal dispersion like india ink in water and direct a flash light directly into the solution and then at a right angle. Also, ask your students if they have ever observed dust in air.

Although colloidal dispersions may appear to be turbid with the tyndall effect, colloidal particles contribute little to the normal turbidity of water; but they are largely responsible for the color of natural waters.

To describe Brownian movement, ask your students if they have ever observed dust in the air when the sunlight is coming in a window. Also ask your students to describe this effect. Hopefully you should elicit that the dust appears to be moving rapidly and randomly. This can lead you nicely into the discussion of Brownian movement.

Brownian movement, first reported by Robert Brown in 1827, is the random motion of colloidal particles. This motion is due to the continual bombardment of the colloidal particles with the medium in which it is in. The colloidal particles have a very small mass which allows them to have considerable velocity of translation.

If the Kinetic Molecular Theory has been discussed previously you may also want to tie the brownian movement as visual proof that matter at the molecular level is in constant random motion.

The stability of different dispersions varies with the properties of the dispersed and dispersing phases. Good colloidal dispersions will remain in suspension indefinitely for two reasons. One, because the particle are continually bombarded by the molecules of the dispersing phase, which keeps the particles in motion (Brownian movement) so that gravity does not cause them to settle out. Two, since the colloidal particles have the same kind of electrical charge, they repel each other. This mutual repulsion prevents the dispersed particles from coalescing to larger particles, which would settle out of suspension.

There are many applications for colloidal particles, charcoal is used to remove colloidal impurities from air and water. Another important application is dialysis. Thomas Graham found that a parchment membrane would allow the passage of true solutions but would prevent the passage of colloidal particles.

III. The Water Cycle

Objective; Students will be able to describe the hydrologic cycle

Only 1% of all the available water constitutes our freshwater. Where do we find it? Freshwater is found underground, in rivers, in lakes, in ponds and in the atmosphere. In New Haven, the majority of our fresh water comes from Lake Whitney, Lake Saltonstall, Lake Gaillard, West River and groundwater sources. But remember, water is continually evaporating, condensing, and falling as precipitation in what is called the *hydrologic cycle* .

(figure available in print form)

Because of the hydrologic cycle, enough precipitation falls each year to cover the entire surface of the earth 85 cm deep in water. However, the amount of water that evaporate, condenses, and returns as precipitation is not the same over the oceans as over the land.

During evaporation all salt and minerals are left behind, thus purifying sea water. Off all the water that evaporates approximately 84% comes from the oceans and approximately 16% comes from land sources. However, more precipitation over land occurs than evaporates, 23% precipitation on land and 77% over and oceans. Therefore, the hydrologic cycle is continuously replenishing the freshwater on land from the vast supply of water in the ocean.

What happens to water that falls on land? Basically three things happen to water that falls as rain. One, two-thirds may evaporate back into the atmosphere; Two, some soaks into the ground; Three, the rest flows across the surface of the land.

The amount of water that soaks into the ground depends on how dry the ground is and what kind of soil is present. Some soils have space in between the soil particles called a *pore space* . The more pore space a soil has, the more water it will hold.

The total amount of pore spaces in a volume of materials is called *porosity* . The porosity of rock layers is and important property to consider when studying groundwater. Another important property of rock layers is *permeability* . Permeability is a measure of how well water flows through the pores and cracks in rock layers. The amount of permeability depends on the size and shape of the pore spaces and how they are connected. Highly permeable rock layers are able to transport groundwater over great distances.

ACTIVITY 1 **POROSITY**

Materials: 4 large containers (beakers) they should be the same size, sand, clay, gravel, garden soil, 100 ml graduated cylinder, water

Fill each container with the same amount of soil (about three quarters full) then add water till the container is full. Be sure to measure the amount of water added to each container. This exercise show the porosity of each type of soil.

ACTIVITY 2 **PERMEABILITY**

Materials: 5 larger filters, sand, clay, gravel, garden soil, 4 beakers, and a watch with a second hand and filter paper

Put filter paper in each filter and fill 4 out of the 5 filters with different soils. Saturate each sample then add 30 ml of water into each filter successively and time how long it takes for the water to filter through each type of soil and the filter paper. This activity shows the permeability of each soil.

When water moves across the earth’s surface, it is called *surface runoff* . Surface runoff occurs when the rain falls faster than the water can move through the soil, the water begins to collect on the surface. This water may move downhill across the surface of the land.

Surface runoff moves on land from high places to lower places. It collects in small streams and drains into larger streams and into major rivers. The area of land drained by a river is called the river’s *watershed* . It is this area that must be carefully guarded against contamination.

PROBLEMS:

1. The water source of a spring-fed lake is
2. A permeable rock layer containing water that is trapped between 2 impermeable layers is called a(n) .
3. A trapped aquifer will form a(n) .
4. One way to prevent water shortages is by damning rivers to form .
5. The hydrologic cycle continuously replenishes the freshwater on land from the supply of water

in:.

(A) wells (C) ice caps

(B) oceans (D) underground streams

6. Which of the following does *not* happen to water that falls as rain?

(A) It evaporates back into the atmosphere

(B) It soaks into the ground

(C) It condenses onto grass

(D) It flow across the surface of the land

7. The amount of water a rock layer can hold depends on its:.

(A) soil type (C) amount of precipitation

(B) pore space (D) texture

8. Wells are found in:

(A) reservoirs (B) watersheds (C) aquifers (D) lakes

answers:.

1. groundwater	5. B
2. aquifer	6. C
3. well	7. B
4. reservoirs	8. C

IV. Purification Techniques of Natural Waters

Objectives: Students will be able to describe the techniques in the purification of water.

Natural fresh waters are not pure, but contain dissolved minerals, suspended matter, and sometimes harmful bacteria.

The sources for water are often drawn from rivers and lakes for cities; and from groundwater wells in more rural areas. Such water is generally unsafe to drink without treatment. To make such water potable (that is, safe to drink), it is treated by some or all of the following processes:

1. The first process is *Screening* , which is the removal of relatively large objects, such as trash, fish and so on.

2. Coagulation: a chemical such as aluminum sulfate (Alum) is added to create small gelatinous particles (floc) which gather dirt and other solids.

This can be demonstrated by adding alum to water that comes from ocean or add some dirt and india ink to some tap water. You must adjust the pH to 8-10.

Coagulation is a very useful process for removing colloidal particles. The colloidal particles carry a negative charge and the aluminum sulfate surrounds each colloidal particle to overcome the negative charge.

3. Flocculation: is the gentle mixing of the water which causes floc particles to join and form larger particles.

This can be demonstrated if a stirrer and stirring bar is available.

4. Settling: floc and sediment fall to the bottom and are eventually removed as sludge.

5. Filtration: the water is passed through granular material such as sand and crushed anthracite coal.

A filter made of charcoal sand and gravel has been made and donated to the institute.

(figure available in print form)

To the left is a figure of the filter made for the institute. Filter water from many different sources and compare before and after filtering.

It is suggested that after use you attach the tubing to the nozzle of a faucet and force water up through the filter to clean the filter.

6. Disinfection: Chlorine gas is bubbled into the water and dissolves in it to kill bacteria and other microbes.

7. Corrosion Control: Chemicals such as quicklime, CaO, can be added to reduce acidity in water, which can be attributed by the addition of chlorine, and to also prevent corrosion in city and household pipes.

8. Fluoridation: fluoride is added in many municipal treatment facilities to help prevent tooth decay.

Water Hardness:

Although not a problem in New Haven, many water sources contains dissolved calcium and magnesium salts which makes the water *hard* . One drawback of hard water is that ordinary soap does no lather well in it; the soap reacts with the calcium and magnesium ions to form an insoluble greasy scum. However, synthetic soaps, known as detergents or syndets, are available; they have excellent cleaning qualities and do not form precipitates with hard water. Hard water is also undesirable because it causes “boiler scale” to form on the walls of water heaters and steam boilers, which generally reduces their efficiency.

There are four techniques used to “soften” hard water: distillation, chemical precipitation, ion exchange and demineralization. In distillation, the water is boiled off and the steam is condensed back to a liquid again, leaving the minerals behind in the distilling apparatus.

Calcium and magnesium are precipitated from hard water by adding lime and sodium carbonate. The insoluble calcium carbonate and magnesium hydroxide are precipitated and are removed by filtration or sedimentation.

In the ion-exchange method, used in many households, hard water is effectively softened as it is passed through a bed or tank of zeolite. Zeolite is a complex of sodium aluminum silicate. In this process sodium ions replace objectionable calcium and magnesium ions, and the water is thereby softened:

Na2 Zeolite(s) + Ca $^{+2}$ (ag) ————-CaZeolite(s) + 2Na $^{+}$ (aq)

The zeolite is regenerated by back-flushing with concentrate sodium chloride solution, reversing the foregoing reaction. The sodium ions that are present in water softened either by chemical precipitation or by the zeolite process are not objectionable to most users of soft water.

In demineralization both cations and anions are removed by a two-stage ion exchange system. Special synthetic organic resins are used in the ion-exchange beds. In the first stage metal cations are replaced by hydrogen ions. In the second stage anions are replaced by hydroxide ions. The hydrogen and hydroxide ions react, and essentially pure, mineral free water is produced.

LAB ACTIVITY:.

Purpose: To determine the sudsing action in samples of hard and soft water.

Materials: 4 250m1 flasks, a 10 ml graduated cylinder and a 100 ml graduated cylinder, soap solution (use 100 ml ivory liquid soap and dilute to one liter BE SURE TO DO THIS SLOWLY TO MINIMIZE SUDSING) water samples: distilled water (control), tap water, Ca $^{+2}$ (aq) water (calcium dilution 200 mg/L) Mg $^{+2}$ (aq) water (magnesium dilution 200 mg/L)

Procedure:

1. Measure exactly 100 ml of each water sample into each of the flasks and label.
2. Add 10 ml of soap solution to the distilled water Cover flask with hand and shake *gently* for 5 seconds
3. Measure the height of bubbles + water in centimeters Measure the height of the water and then subtract to get the actual height of the suds. In measuring bubbles use judgement to

determine height, disregard an odd bubble that may be a lot higher then the majority

4. Repeat steps 2 & 3 for the other water samples, be sure to shake the flasks as similarly as the first.

Data Table:

Sample	height of suds	-	height of water	=	height of suds
distilled		-		=	
tap		-		=	
Ca^{+2}		-		=	
Mg^{+2}		-		=	

Questions:

1. Why is distilled water used in this experiment?
2. How did the different samples compare in sudsing action?
3. What effect do you think hard water, or water with a high concentration of dissolved minerals, has on washing clothes? Bathing?
4. What is often done to water containing a large amount of dissolved minerals before it is used by people?

Answers:

1. The distilled water acts as a control because the tap water may have some minerals dissolved in it.
2. The distilled water should have the most sudsing action followed by the tap and then the Ca+2 and Mg+2 water samples showing that the last to are the hard water samples.
3. Hard water does not wash clothes as well as soft. Extra soap is needed to produce lather in the hard water.
4. Softeners can be added to water or an ion-exchanger can be installed in a house where there is hard water present. Water treatment plants can also soften the water *before sending the water into the system.*

LAB ACTIVITY 2

Purpose: To determine the amount of extra soap needed for hard water samples.

Materials: four 250 ml flasks, a buret and buret stand, soap solution (see instruction in previous lab) water samples: distilled, ta[, Ca $^{+2}$ (aq) and Mg $^{+2}$ (aq)

Procedure:

1. Measure exactly 100 ml of each water sample into a flask and label.
2. Fill Buret with soap solution to zero.
3. Titrate soap into flask containing distilled water while continually swirling the flask consistently. When soap bubbles begin to appear, stop titrating and measure the amount of soap delivered into the flask.
4. Repeat steps 2 & 3 and be sure to swirl the flask at the same rate as you did previously to minimize error.

Data Table

Sample	*amount of Soap (ml)*
distilled	
tap	
Ca+2(a)	
Mg $^{+2}$ (aq)	

Questions:

Same as first lab.

ACTIVITY; Taste Test

Give students samples of tap water, bottled water, boiled water and distilled water and ask them which tastes the best and water are some of the subtle differences between the samples.

V. Purification Systems in New Haven

Objectives: Students will be able to describe the water treatment plants in New Haven.

The South Central Connecticut Regional Water Authority is a non-profit public corporation that supplies water to the greater New Haven area. If you live in New Haven, your water probably comes from one of the following systems: Lake Whitney, Lake Saltonstall, Lake Gaillard or The West River Water Treatment plants. All of the systems are very similar, there are only subtle differences between them.

Up until 1903, New Haven's water supply came directly, untreated, from local water sources such as Lake Whitney. In 1901 there was a great outbreak of typhoid which sickened more than 400 people. Epidemiologists traced the out break to the untreated water. This event led to the construction of the Lake Whitney Slow Sand Filtration Treatment Plant. The filter was the first "modern" functionalist structure in Connecticut, by using reinforced concrete.

There are 12 sand beds at Lake Whitney. The bottom of the beds are covered to a depth of 8 inches, with a layer of gravel or broken stone from 1 to 3 inches in diameter; on top of this layers of gravel and course sand of gradually increasing degrees of fineness are place successively to a depth of 16 inches. Filter sand is on the very top vary in depths between 2 and 3 feet.

Raw water comes into the plant and travels up through the layers of gravel and sand. It is then allowed to filter back through the sand and gravel virtually free all contaminants. Bacteria is also encouraged to grow on top of the sand. This bacteria is "good" bacteria because it destroys "bad" bacteria such as those responsible for the typhoid epidemic in 1901.

In the Lake Saltonstall system, located in Branford just off of I-95. Untreated water is first pumped into the plant and then into the flash mixing tank. Chemicals may be added to the flash mixing tank to disinfect the water. Alum is also added to help remove solids, dissolved particles and colloids.

The alum which form a gelatin film is clumped by adding a polymer which acts like a glue to make larger floc particles which can be more easily filtered out of the water. Chlorine can be added again to the system before filtering.

Each of the dual filters has approximately 20 inches of anthracite (coal), 10 inches of sand, and 12 inches of support gravel. Activated charcoal has an enormous surface area, approximately one million square centimeters per gram in some samples. Hence, charcoal is very effective in selectively adsorbing polar molecules from water. Bacteria and other organisms are removed by organisms that are attached to the gravel.

After filtration, the water is treated again with chlorine to disinfect, and the pH is also adjust by the base NaOH. The water is then stored until it is ready to be pumped into the system.

Before going into the system, the water is first treated with fluoride, to prevent tooth decay; and phosphates are also added to help prevent corrosion in the pipe lines and in our homes.

The Lake Gaillard Plant is located in North Branford and supply approximately two-thirds of South Centrals water. Lake Gaillard is the largest reservoir system. Water in Lake Gaillard may come from Lake Hammonasset or Lake Menunkatuc; the water travels through tunnels cut through nearby mountains.

The Gaillard system has a few variations from the Saltonstall plant. First raw water comes into the plant and flows through a turbine to generate approximately 10 percent of the power needed to run the plant.

Alum and chlorine are added just before the water goes into the static mixer. The static mixer disperses the treatment chemicals throughout the water. Fixed baffles inside the mixer stir the water as it flows through. Mixing continues in the flocculation chambers. Here, chemical coagulants draws particles together to form larger particles which are removed in the filters.

Note: all filters are cleaned by backwashing or sending water backwards up through the filter bed. Solids removed from the filters go into the sanitary sewer while water is recycled.

From the filters, water is stored and treated similarly to Saltonstall's method prior to leaving the plant (see diagram)

The West River Water System draws water from a network of reservoirs in Bethany and Woodbridge, and the system supplies an average of 15 percent of South Central's water.

At West River, raw water comes through an intake pump, chemicals such as alum and chlorine are added, which then goes into the contact tank. The contact tank is made up of a dynamic mixer and two static mixers. Potassium permanganate is often added to remove metals such as iron and magnesium. Sodium hydroxide is also added to raise the alkalinity of the water which helps the alum react.

The water then enters the flash mixing tank, also known as the rapid mix, alum and two types of polymers are added here so that large floc particles are mad and then the water enters the filters (see diagram).

If you wish to visit one of these plants I recommend West River because it is completely enclosed and they also have a working miniature of the plant just call the Water Authority to set up a tour.

Problem:

A resident in New Haven received a bill from the water company recently. A man and his wife used 2800 cubic feet of water in three months. How many gallons of water did they use each day? Note: one cubic foot of water contains 7.48 gallons.

answer: *lcubic foot = 1.48 gallons* 1 *month* = 30 *days*

(figure available in print form)

Locate the water meter in your house or apartment building Find out how to read your meter by asking someone from the utility company. Heat the water meter in your house or apartment. After 24 hours reat the meter again. By subtracting the two sets of numbers, you will find out how many gallons of water your household uses a day. How many liters of water does your household use a day?

(figure available in print form)

(figure available in print form)

(figure available in print form)

VI Drinking Water Quality & Protection

Objectives: Students will be able to:

— list sources of contamination

— describe the federal laws that are designed to protect our water supplies

— discuss some of the health hazards associated with contamination

You may wish to begin this section with a slide presentation available from the water authority. Contact Rosemary Marcionus 624-6671 Ext 263 Also there is a script of the slide show available at the Yale-New Haven Teachers Institute.

The number and types of contaminants in drinking water have been growing faster than the ability to detect and treat them as well as being able to set standards for. One hundred years ago the major contaminant of our water supply was a bacteria called Escherichia coli as well as some other common bacteria found in human feces. This problem was easily removed by the addition of chlorine, and therefore, the control of such diseases as typhoid and cholera.

Today we face contaminant from “point” sources such as industrial or municipal discharge pipes, or “nonpoint” sources, such as farmland, urban runoff, disposal and construction sites. Substances such as bacteria, nutrients, minerals, salts, trace metals and organic matter are normally found in water. At elevated levels some of these such as salt, selenium, fluoride, and radioactive elements become contaminants which at certain levels may be toxic.

Certain common industrial operations, such as mining, drilling, construction and forestry can contaminate water as part of their “normal” activities. There are other industries such as the chemical, medical, oil, which are more readily recognized as waste producing sources.

The disposal of industrial wastes has led to widespread contamination of many water sources due to the method of disposal. Landfilling, the most widely used method (although now illegal in Connecticut) has resulted in the ground water contamination from over one-third of the hazardous waste sites studied by the Environment Protection Agency (EPA) in 1982. Although safeguards are made to protect our water supplies, all landfills are subject to leaks.

As controls on liquid disposal in landfills have tightened, underground injection of wastes into deep wells has become more prevalent. Concern over contamination of aquifers has led to bans on the injection of hazardous waste in all of New England.

Many industries discharge their effluents into local sewage systems that then contaminate rivers and other water sources. Although there are laws that govern the discharge of industrial wastes very few industries are in compliance.

The disposal of radioactive wastes is a serious problem, not only to our water supplies but because of the potential threat of radioactive contamination. The volume of highlevel radioactive waste from nuclear power plants is supposed to quadruple in the next 15 years.

Pesticides and fertilizers from agricultural processes as well as lawn services have been detected from coast to coast. The true extent of pesticide contamination is only now being revealed. Certain conditions such as soil type, crops, irrigation practices, weather and other geological conditions as well as the properties of the pollutant influences the extent of contamination.

Eroding soil carries accumulated nutrients and pesticides into streams, rivers, and lakes causing contamination in sedimentation. Because there are few requirements to test for them, most of the chemicals go undetected by water treatment plants.

Municipal landfills which are designed to accept only solid wastes, not toxic, receive many toxic materials from household, municipal, commercial and even industrial wastes. These toxic materials eventually leach into our water supplies.

As mentioned previously, industrial wastes are often dumped into sewage systems. The sewage plants are not equipped to treat such wastes which then releases toxic materials into surface waters.

Urban runoff has contaminated many of out nation's rivers and lakes. Urban runoff may contain heavy metals such as cadmium and lead, inorganic chemicals, petroleum products, de-icing salts, pathogens and animal wastes.

Further contamination of drinking water occurs in your own home. The improper disposal of such household products as cleaners for your oven, sink, rug, furniture, and bathroom. Automotive products such as oil, anitfreeze, and rust removers, paint removers and solvents, garden and lawn products, the list seems to be endless are all possible contaminants to our water supplies if they evaporate or do not biodegrade.

Governmental operations also generate toxic wastes, and the disposal of these wastes have been generally under- estimated because security regulations have made it difficult for states to make accurate on-site investigations. Metal-plating solvents, spent fuel, heavy metals and other toxic chemicals, such as nerve gas have been stored unsafely and dumped regularly at many federal sites.

Until 1974, there was no federal legislation protecting our water supplies. It had been assumed that chemicals like chlorine took care of any contaminants, but the contaminants that the country faces now are far more threatening than the bacteria and viruses that chlorine is designed to remove.

The Safe Drinking Water Act (SDWA) of 1974 is intended to protect drinking water through the setting, monitoring and enforcement of standards and to a certain extent, to prevent contamination of underground water supplies.

The federal water management has been hampered by the conflicting legal, regulatory, and administrative actions of numerous agencies. There is no single body to coordinate water management. There are agencies such as the US Geological Survey that collect data and make assessments of water supplies and their quality.

The regulation of water quality and quantity as well as the management of these supplies is divided among many different agencies. The Environmental Protection Agency (EPA) has the primary responsibility for regulating pollution control and water quality. The Federal Food and Drug Administration, however, regulates bottled water and the water used in the packaging and processing of food. Other agencies that play a dominant role in the management of water are: the Army Corps of Engineers, the Department of Interior's Bureau of Reclamation, the Department of Agriculture's Soil Conservation Service, and the Tennessee Valley Authority.

The Safe Drinking Water Act requires the EPA to set national primary drinking water standards known as Maximum Contaminant levels. These standards are based on the health risk assessments and the feasibility of attaining those standards. Revised standards which were to go into effect in 1977 are only now being put into effect as a result of the 1986 amendments to the SDWA.

There are many deficiencies in the law because certain items are not covered such as private wells, systems serving under 10,000 people, underground injection of certain brines from oil and gas mining, and there is also no support for research on alternative treatment technologies.

The Clean Water Act as amended is designed to restore and maintain the quality of surface waters. States have been required to develop water quality standards for rivers and streams. Contaminant levels in effluents discharged directly into these bodies are regulated by a permitting system, the National Pollutant Discharge Elimination System (NPDES), on a basis of the “best technology generally available” for municipalities and industries. For effluents discharged by industries into public sewer systems, pretreatment standards are required. However, thousands of companies have expired NPDES permits and there are thousands more who are illegally discharging into public sewer systems.

The Resource Conservation and Recovery Act (RCRA) regulates the storage, transportation, treatment and disposal of hazardous wastes to assure minimal effects on human health and the environment. A manifest system is responsible for tracking waste. Treatment, storage, and disposal facilities must have permits and must state the potential for public exposure to hazardous wastes. Certain restrictions on the disposal of liquid waste in landfills were also adopted.

The EPA has given enforcement powers to most of the states which have responsibility for conducting site inspections. However, there are numerous deficiencies in the enforcement of this law.

The Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA or Superfund) authorizes government cleanup of chemical spills and inactive hazardous waste sites that may pose threats to human health or the environment. The current “cleanups” are temporary rather than permanent solutions, and the available sites for disposal of Superfund waste are lacking. For this reason the 1986 Superfund amendments require cleanups that necessitate permanent solutions and the compliance with other environmental laws.

Another federal law is the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) is intended to protect public health and the environment through the regulation of pesticide registration, re-registration, marketing and the use in the US. EPA recognizes that pesticide residues in groundwater present a potential risk to human health. When evaluating a pesticide’s risks, EPA takes into consideration both its inherent toxicity and the potential routes of human exposure to such compounds.

VII. Conservation

Until the 1970’s scientists believed that water would be purified of contaminant as it trickled down through the various layers of soil. But many of the hundreds of commercial chemicals developed before and since World War II are not filtered out. Many solvents and pesticides pass through aquifers. Contaminated groundwater supplies have been increasing at alarming rates.

Aquifers have become a dumping ground for leaching landfills, runoffs from fertilizers and pesticides, leaking gasoline storage tanks not to mention the toxic wastes that have been injected directly into the ground. The injections are supposedly beneath water tables but water tables change and can be vulnerable to buried wastes.

Even common chemicals can ruin your drinking water. One pint of a common degreaser found in some household cleaners can pollute 10 million gallons of water. One cup of trichloroethylene, a chemical found in products such as septic tank cleaners, furniture strippers and dry cleaning fluids, can contaminate more than

3 million gallons of water. A few drops of some synthetic organic chemicals found in products used in industry, homes and businesses can contaminate enough water to fill a swimming pool.

What can you, the individual do about this potential threat to our water supply?

We can find ways to cut down our use of chemicals whenever possible, (copies of a list of alternative household products are available at the Yale New Haven Teachers Institute. When using chemicals only use what you need to do the job, a case of “overkill” can cause contamination.

Buy only what you need and estimate amounts before buying. This reduces storage problems and saves you money

Mix only what you need for a given job.

Avoid spills. Be extremely careful in the transportation and transfer of chemicals. Collect and reuse any spilled chemicals.

Remember chemical rinses are hazardous waste. They should be put back in the tank and used up.

Check for floor drains near chemicals. If you have one, either seal it or obtain a permit from the Water Compliance Unit of Connecticuts Department of Environmental Protection.

Store all chemicals in protected areas. Your storage area should be secured, well ventilated, leak proof, and if at all possible fireproof.

Never store chemicals outdoors. Exposure to the elements could cause chemicals to be carried off into ground or surface waters.

Label stored chemicals clearly, to avoid a mistake in the future. Never reuse chemical containers to store a different product.

Follow the manufacturer’s instructions for all phases of product handling. This includes instructions for disposing of containers. If a products’s label lacks specific information, call your supplier for instructions.

DON’T POLLUTE! Watch out for any suspicious dumping or other potential problems in your neighborhood and town. You can also get involved in local hazardous waste collection day.

EDUCATION IS THE ANSWER, THE MORE *YOU* KNOW AND INFORM FRIENDS AND FAMILY THE SAFER OUR SUPPLY OF WATER WILL BE.

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