WASTEWATER

By Charri Lou Garber

The total amount of water on Earth is fixed. The water available today is the same amount that was available five billion years ago, when the Earth was first formed. Every drop of water we use for washing, cooking, or drinking has been used countless times before. It is estimated that a drop of water from the source of the Mississippi River will be used *17 times* before it reaches the Gulf of Mexico. There are efficient, modern methods for purifying wastewater, and it's my job to keep one wastewater treatment plant operating smoothly.

Sewage—the very sound of the word turns my stomach and wrinkles my nose. I like the term wastewater because it defines what sewage really is. Wastewater is the water that flows down the drain of your sink, shower, and toilet. In towns and cities, it's collected by sewer pipes and transported to a wastewater treatment plant like mine. What's in wastewater? To find out what it is, and what happens to it, imagine you're a soap bubble floating in the bathtub.

Whoosh

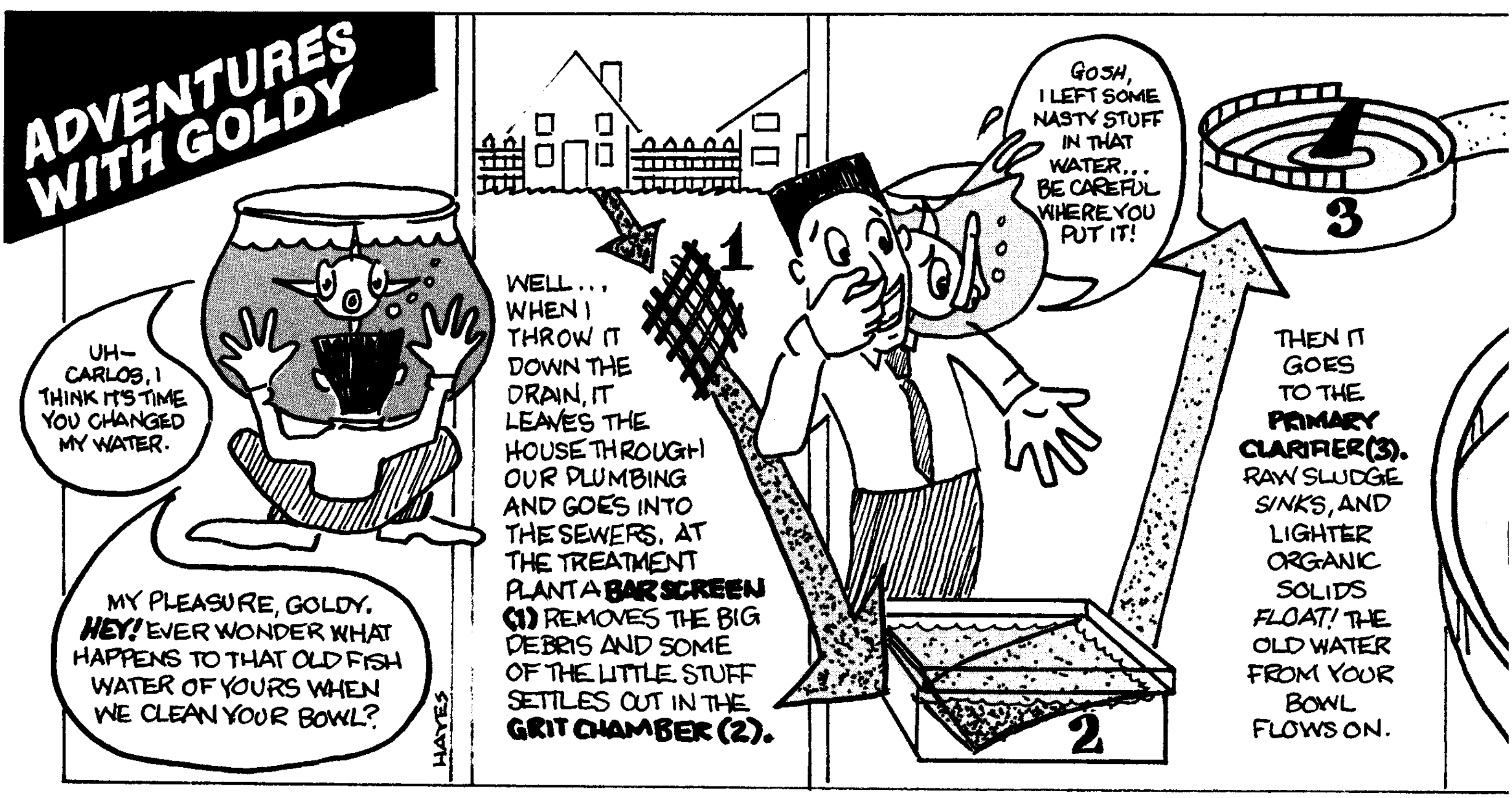
Suddenly the plug is pulled, and you're whirled down the drain. Once inside your house's drain pipe, you flow along to the street into a larger pipe. Here you're mixed with more wastewater from surrounding houses. Now you float along with material that is in solution (such as pancake syrup, urine); material that is colloidal (such as used dishwashing detergent); and solids that are temporarily suspended only because the water moves quickly, such as coffee grounds, lettuce leaves, feces (broken up and unrecognizable), toilet paper, and even the occasional sock from the laundromat down the street.

You flow along (remember, you're the charming bubble, not that other disgusting stuff) at a speed of about 0.6 meters per second—fast enough to keep everything movng along. The water gets deeper and soon you pour into a larger pipe. Here you're mixed with more stuff: waste chemicals from a photo finishing business, plastic gloves. You name it, it's there.

It begins to rain, and, if you're in one of those cities that has just one network of pipes, water pours in from the storm drains. The water gets deeper and flows much faster. Rainwater isn't the only thing flowing in, though. There's dirt from the road, leaves and twigs from the trees, spilled gasoline and oil from service stations, and even gum wrappers and soda cans.

The water starts to slow down as you near a hill. To get over the hill you enter a lift station where large pumps lift you to a higher elevation. You continue your downhill flow. At last you see the light at the end of the tunnel. You've made it to the treatment plant.

The wastewater flows through a Parshall Flume, which measures the



quantity of water and tells the plant operators how many millions of gallons of wastewater they have to treat. Now the process of separating wastewater into waste and water begins.

Primary treatment

The first part, called primary treatment, is a simple physical process. The wastewater first flows through a bar screen (Step 1 in illustration), a set of vertical bars that catch the larger stuff—rags, twigs, plastic bottles, and the occasional dollar bill. The bar screen is raked periodically and the debris hauled to a landfill (after it's been checked for dollar bills).

If the wastewater has been in the sewer pipes a long time, decomposition has started. Because this is the first place the water has been exposed to the air, hydrogen sulfide (H_2S, from decomposition of proteins) is released, and its characteristic odor—rotten eggs—is present. Chlorine can be added to the waste water to control the odor because Cl_2 oxidizes H_2S.

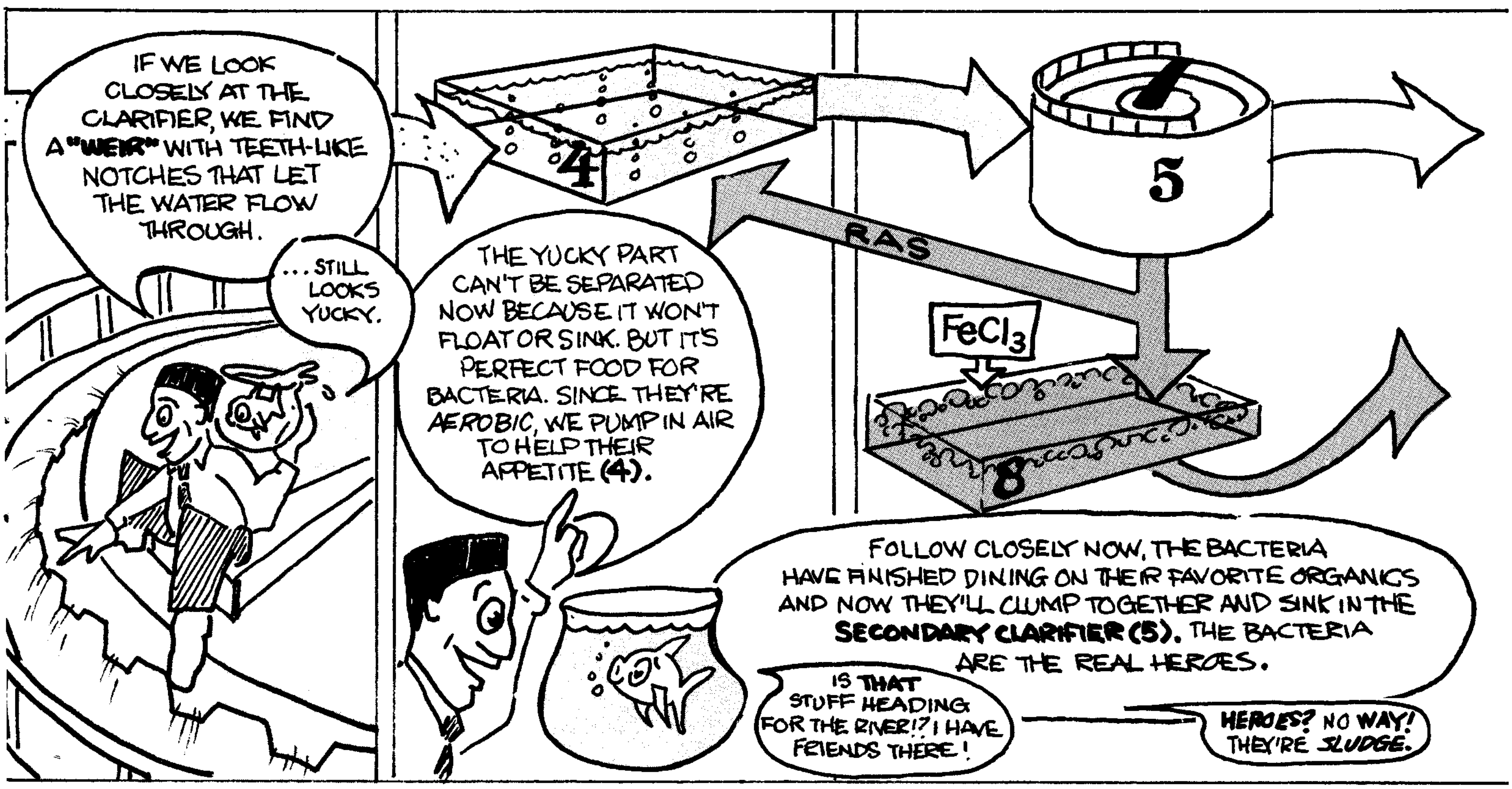
$$H_2S + 4\,Cl_2 + 4\,H_2O \rightarrow 8\,Cl^- + SO_4^{2-} + 10\,H^+$$

The water then flows into a long, narrow, knee-deep channel called a grit chamber (Step 2). Here the water is slowed to about 0.3 meter per second which allows what we call grit—the sand, rocks, coffee grounds, and diamond rings—to settle. The grit is periodically removed and hauled to a landfill. The stream should now be free of inorganic material.

The flow rate is still fast enough to keep the lettuce leaves, corn, and toilet paper moving. These are organic solids and can create a nuisance if not treated properly, so the next step in the wastewater treatment process removes the organic material that is either lighter or heavier than water. The water flows into a primary clarifier (Step 3), a large, circular, cement pond about three meters deep. The wastewater enters at the center of the clarifier and flows toward the edge. The lighter organic solids and scum float to the top of the tank. The heavier organic material—called sludge—sinks to the bottom.

Along the outer edge of the tank is a plastic (polyvinylchloride) barrier that has a series of W's cut from its top edge, forming a weir. The weir lets water flow out faster when the water level in the tank is higher, and slower when the level is lower. Thus the weir maintains a constant water level. At this point, the primary clarifier has separated the main water stream from the "floaters" and the "sinkers."

This is the end of the primary treatment, and 30% of the "pollution" has been removed. The main water stream continues to the next stage, carrying materials that are dissolved (sugar, etc.) and colloidal (very small particles). Secondary treatment turns these materials into larger solids that can settle out and be removed.



Secondary treatment

Secondary treatment is a biological process that relies on microscopic "bugs" to decompose the organic wastes. The action takes place in a deep, rectangular tank known as an aeration basin (Step 4). At the bottom, a series of pipes with small holes releases air into the tank. The churning action reminds me of blowing air through a straw into a glass of chocolate milk. At the head of the tank, microbe-rich sludge (obtained from one of the later stages) is added. This material is called RAS (return activated sludge) and is a brown mass, teeming with hungry bacteria, fungi, and protozoa.

Give these actors air, water, agitation, and some time, and they will feed on the waste, grow, and reproduce. These microorganisms contain all the building blocks of life: complex carbohydrates, proteins, nucleic acids, and lipids. As they consume the organic waste, the microorganisms grow and reproduce, forming a larger biomass. About 30% of the organic waste is converted into biomass, and 70% is oxidized into CO_2 and H_2O.

Urea, the primary compound in urine, and other organic nitrogen compounds are degraded to form ammonia.

$$\underset{\text{urea}}{(NH_2)_2CO} + H_2O \rightarrow CO_2 + \underset{\text{ammonia}}{2\,NH_3}$$

Much of the ammonia is "fixed" into proteins and nucleic acids by the growing biomass. Excess ammonia can be oxidized by certain bacteria to form nitrites.

$$2\,NH_3 + 3\,O_2 \rightarrow 2\,NO_2^- + 2\,H_2O + 2\,H^+$$

Different organisms can then oxidize the nitrites to nitrates.

$$2\,NO_2^- + O_2 \rightarrow 2\,NO_3^-$$

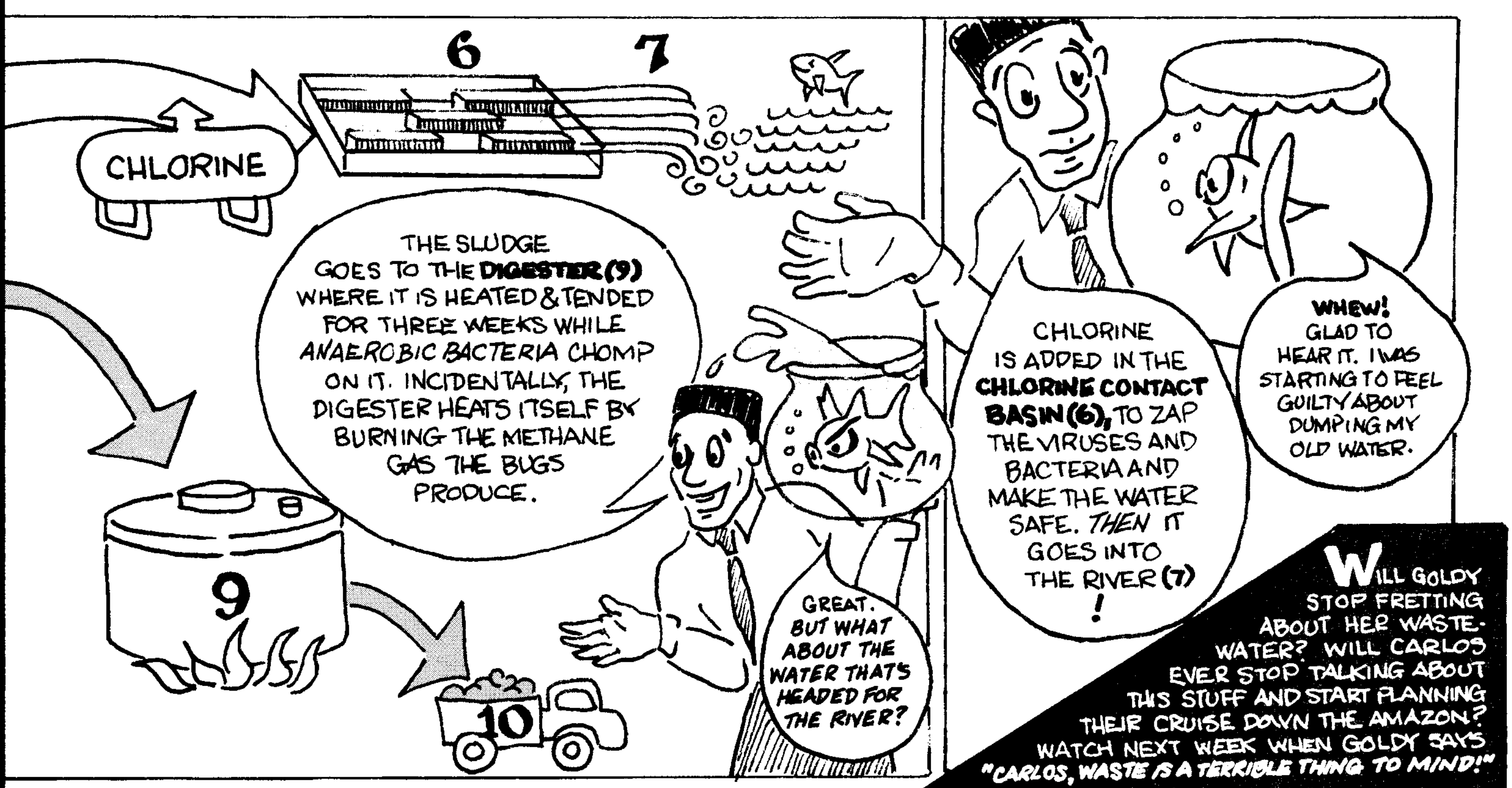
These two transformations are called nitrification. The treatment process has now removed 85% to 95% of the "pollution."

This chocolate-colored mass then leaves the tank and flows into a secondary clarifier (Step 5). It is deeper and larger than the primary clarifier because activated sludge particles are finer than raw sludge particles and need more time to settle. Here again, what will settle, settles. This settled sludge is called activated sludge because it contains active microbes. Some of it is taken out of the system and treated further. The rest is returned to the aeration basin as RAS.

Looks great, but...

The water that flows over the weir of the secondary clarifier is clear and sparkling. To the naked eye it looks pure and safe to drink, but it can contain pathogens—harmful bacteria, viruses, and protozoa. Some pathogens can cause typhoid, cholera, and dysentery, so the water must be disinfected. This is done in the chlorine contact basin (Step 6), which is long, narrow, deep, and shaped like a maze.

Chlorine gas, Cl_2, a powerful oxidizing agent, flows from a storage cylinder, is mixed with water to form a solution, and is injected into the treated wastewater at the head of the disinfection basin. When Cl_2 gas is dissolved in water, it undergoes a series of pH-sensitive equilibrium reactions. At a neutral pH, both the hypochlorite ion and hypochlorous acid are present, and both can kill pathogens.



Molecular chlorine | Cloride ion | Hypochlorous acid

$$Cl_2 + H_2O \leftrightarrow H^+ + Cl^- + HOCl$$

Hypochlorite ion

$$HOCl \leftrightarrow H^+ + OCl^-$$

As the wastewater flows through the basin, some of the bacteria and viruses are killed, depending on the concentration of hypochlorous acid and hypochlorite ion. If sufficient chlorine has been added, any and all bacteria will be killed, so a proper dosage must be maintained. This is accomplished through sampling and testing.

The disinfected wastewater then leaves the plant and is discharged into a nearby river, lake, or ocean (Step 7). Properly treated wastewater will have no detrimental effect on the receiving water.

We've made the main water stream safe, but we still must treat all that sludge that settled to the bottom.

Going DAFT

In secondary treatment, sludge settled in the secondary clarifier (Step 5). This sludge is thin and smooth. It contains only 1% pollutants, but these fine particles are difficult to separate from the water. Our goal now is to make the tiny solid particles clump together so they can be removed. This requires the chemical action of a coagulant and the physical action of air bubbles. First, some iron(III) chloride is added, and it reacts with the hydroxide present in the alkaline water.

$$FeCl_3(aq) + 3OH^-(aq) \rightarrow Fe(OH)_3(s) + 3Cl^-(aq)$$

The resulting precipitate, $Fe(OH)_3$, is fluffy and porous (flocculent) and physically entraps the tiny sludge particles. (Alum may be used instead, and lime may be needed to supply the alkalinity; some plants substitute an organic polymer.) The stream now flows into the Dissolved Air Flotation Thickener (DAFT), which is a deep, rectangular, concrete basin (Step 8). Water and air are mixed to make a foam that floats the sludge to the top of the tank. A portion of the water is recycled through a pressurized tank where compressed air is introduced. Under a pressure of five atmospheres, more air than usual dissolves in the water (an example of Henry's Law); when the water returns to the DAFT basin and atmospheric pressure, bubbles come flooding out of the water, forcing the flocculent precipitate and its trapped sludge particles to the surface. Another barrier holds the floating waste in place while the liquid stream flows on.

The surface of the DAFT basin now resembles dark brown cottage cheese. It is coated with sludge that is now 4% solids. These solids are skimmed and pumped to the digester.

The digester

To me, a digester (Step 9) is like a man-made stomach. It is an airtight tank where anaerobic microorganisms consume organic material (raw sludge, scum). The end product is a stable, black liquid that can be disposed of without causing odors or creating a nuisance. To speed up the process, the digester is heated to 37 °C (98 °F), the optimum temperature for methane-producing bacteria.

Where do we get the heat to keep the digester warm? One of the digester byproducts is methane gas, CH_4 (the compound in the natural gas that you may use to fuel your kitchen stove). The methane is burned under boilers; the hot water is used to heat the digester. Raw sludge is fed continuously, and the process takes about 20 days. When it's all over, the treated sludge can be applied to land as a fertilizer (Step 10).

The sludge digestion process is actually done by two groups of bacteria. The first digests organic compounds into organic acids, causing the pH to drop as low as 4.8. The acids formed are then consumed by a second group of bacteria called methane formers. The methane formers feed on the organic acids and produce digester gas, a mixture of CH_4, CO_2, H_2S, and H_2O. Without the methane formers to consume the acids, the pH would soon be too low to effectively operate the digester. The methane formers are very sensitive to pH and temperature. Both groups of bacteria are growing at the same time and in the same place, and the process must be monitored through laboratory tests. A healthy digester has a pH of 7.0 (neutral).

Upset stomach?

The digester is huge, but it is closed and sealed. I can't see through its solid concrete walls (like Superman!). How can I tell whether it is healthy? I rely on a set of chemical tests to see what's happening on the other side of the wall. I measure pH, alkalinity, and volatile fatty acid content to keep my digester in control.

Many chemical tests help me purify your wastewater. I know how much Cl_2 to inject by calculating chlorine demand, then confirming that it was sufficient to do the job by testing for the presence of fecal coliform bacteria. How do I know if a toxic industrial contaminant is present? By running a BOD (biochemical oxygen demand) or COD (chemical oxygen demand) test. How much nitrogen is in there? I'll run the TKN (total Kjeldahl nitrogen) test. Heavy metals? I'll use atomic absorption spectroscopy.

That's why I don't turn up my nose when someone says wastewater. To me, wastewater doesn't represent smelly sewage; it represents a great opportunity to run a chemistry lab, operate a major processing plant, and help other people by keeping their water clean and taking care of their waste.

Keep it coming!

***Charri Lou Garber** is the lead operator at a 29-mgd (million gallons per day) water pollution control facility in Bremerton, WA. She entered the water treatment field through the C.E.T.A. program in 1979 and was trained both in the classroom and on the job.*

References

Proctor, D. E.; Proctor, J. *Chemistry for Water/Wastewater Utilities*; Proctors' Enterprises, Auburn, WA. 1975. [Available from Proctors' Enterprises, 431 12th Street, S.E., Auburn, WA. 98002.]

Wastewater Treatment Plant Operations, Volumes I, II, III; prepared by California State University–Sacramento, Department of Engineering; Ken Kerri, project director. 1980.

ChemMatters

April 1992

Classroom Guide

A Supplement to *Chem Matters* Magazine

Edited by Frank W. Darrow, ICE Affiliate, Associate Professor, Department of Chemistry, Ithaca College, Ithaca, NY 14850

ADDITIONAL INFORMATION ABOUT THE ARTICLES

Camping Stoves

Peter Moskaluk, Grosse Pointe North High School, Grosse Point Woods, Michigan, likes to demonstrate the density of propane by measuring the mass of a balloon, filling the balloon from a propane tank, and then measuring the mass of the balloon again. The balloon is then submerged in a tank of water to get an approximate volume by displacement. Using room temperature and pressure, and the volume and mass of propane, Peter calculates the formula weight and reports that he usually gets values between 40 and 48 grams per mol. Peter says, "You can do the experiment more accurately if you bubble the propane into a large cylinder and take the vapor pressure of water into account, but I like the fun of submerging the balloon, and talking about Archimedes, and then lighting the balloon afterwards."

Another procedure for demonstrating gas densities is given by Lee R. Summerlin and James L. Ealy, Jr., in *Chemical Demonstrations, A Sourcebook for Teachers*, Volume 1, Second edition (American Chemical Society, 1988, ISBN 0-8412-1481-6). Large bubbles are formed by bubbling gas through a soap solution. If natural gas is used they will generally rise in the air; with propane or butane they will sink. The bubbles are ignited with a candle attached to a meter stick before they strike a surface. Incidentally, compressed natural gas (CNG) is slowly gaining in popularity on boats because it is less dense than air and will not collect in the bilge in potentially explosive mixtures as will propane or butane.

Blood Markers

Be certain to refer your students to "Mystery Matters: DNA Fingerprinting" by Richard Saferstein in *Chem Matters*, October 1991, for a discussion of the forensic use of DNA electrophoresis. Additional background information on electrophoresis can be found in *The McGraw-Hill Encyclopedia of Science and Technology*, and in "Analyzing DNA–Protein Interactions by Gel Electrophoresis" by Arnold Revsin, Department of Biochemistry, Michigan State University, in "Concepts in Biochemistry," *J. Chem. Ed.*, September 1990, *67*, 749–753.

The isoelectric focusing method uses a pH gradient in the gel. Because each protein has both positive and negative groups, its net mobility will depend on the relative excess of one over the other for net excess charge. There will be one pH where the net charge on the protein surface is zero and this pH is called the isoelectric point. In the electric field of the electrophoresis instrument each protein will migrate to its isoelectric pH and then become stationary. Thus all molecules of a particular isoelectric pH will migrate to the same region on the gel, leading to the term isoelectric focusing.

Electrophoresis kits are available from several major equipment suppliers. For those who are handy with tools and a little ambitious, methods for making very inexpensive systems that use 9-V transistor radio batteries are described by four high school biology teachers in "Bargain Basement Electrophoresis," *The Science Teacher*, October 1988, *55*, 22–25, and by T. R. Hopkins and K. Sreekrishna in "Gel Electrophoresis in a Covered Butter Dish," *J. Chem. Ed.*, March 1987, *64*, 279–280.

Simple methods for demonstrating the migration of ions in an electric field are given by John G. Little and Ronald Strothkamp in "A Simple Demonstration of Ion Migration" in "Tested Demonstrations," *J. Chem. Ed.*, December 1990, *67*, 1063–1064, and by Juan A. Llorens Molina in "Electrolytic Migration of Ions" in "Overhead Projector Demonstrations," *J. Chem. Ed.*, December 1988, *65*, 1090. Both articles describe the use of a thin layer of supporting gel in a Petri dish. The migration of colored ions such as Cu^{2+} and CrO_4^{2-} is evident several minutes after power is applied. Nine-volt transistor batteries can be used as the power source.

Wastewater

Four videotapes from the Environmental Protection Agency Water Quality Standards Program are available on loan from EPA. They include "Introduction to Water Quality Standards," "Antidegradation Policy: A Means to Maintain and Protect Existing Uses and Water Quality," "Development of Water Quality Criteria and Its Relationship to Water Quality Standards," and "Enumeration Methods for E. Coli and Enterococci." To borrow them, contact the Criteria and Standards Division, EPA, Frances Desselle, phone 202-475-7320, or the EPA Water Quality Standards Coordinator in your region.

The October 1991 issue of *Chemecology*, published by the Chemical Manufacturers Association, was a special issue devoted to "Cleaning Our Water." You can obtain a copy by contacting Alison Bohn at 202-887-1236. Be sure to ask about a free subscription to *Chemecology*.

Some of the steps in water treatment can be quickly demonstrated. A little solid material such as dirt, coffee grounds, and so on can be mixed with some water in a beaker to demonstrate that some floats, some sinks, and some remains suspended. Simple filtration through coarse filter paper (or coffee filter paper) will remove much of the solid material. If there is a little salt in the solid material it will remain dissolved and conductivity of the solution can be demonstrated, showing that clean-looking water is not necessarily clean. The first unit in the ChemCom curriculum developed by ACS is devoted to water, and an early laboratory activity involves purification of a sample of highly impure (frankly foul) water to the point where it could be used to wash hands. For more information about ChemCom contact K. Michael Shea, Staff Associate, ChemCom, American Chemical Society, Education Division, Room 814, 1155 Sixteenth Street, N.W., Washington, DC 20036, phone 202-872-6383.

Related software: Three Project SERAPHIM computer programs are particularly suited to this article. The first, WAQUAL by John Estell, simulates a wastewater treatment plant. Students must choose the fractions of waste that will receive primary, secondary, and tertiary treatment. The effect on the pollution level of a river is shown. The disk is available in Apple II ProDOS format as disk AR801 (3.5 inch IIgs disk, ProDOS, IIgs required, $15), in Apple II DOS 3.3 format as disk AP802 ($12), and in IBM PC and PC-compatible format as disk PC3703 ($20). The second program, LAKE STUDY by David Whisnant, is a two-part simulation in which students sample lake water and then analyze the sample to suggest a reason for recent fish kills. The disk is available in Apple II ProDOS format as disk AR802 (3.5 inch IIgs disk, ProDOS, IIgs required, $15), in Apple II DOS 3.3 format as disk AP804 ($12), and in IBM PC and PC-compatible format as disk PC3704 ($20). The third program, also by David Whisnant, is titled BCTC. It simulates the study of a potential industrial pollutant and profiles a situation in which science simply does not have all the answers. It will take about an hour to run for most students. It is available in Apple II ProDOS format on the same disk with WAQUAL described above, disk AR801 (3.5 inch IIgs disk, ProDOS, IIgs required, $15), by itself in Apple II DOS 3.3 format as disk AP805 ($12), and in IBM PC and PC-compatible format as disk PC3705 ($20). Memberships in Project SERAPHIM are $20 per year and bring the member a catalog and *Project SERAPHIM News,* a periodic newsletter about workshops, hardware and software, and other items of interest to persons using personal computers in chemical education. The catalog only is available for $10. Subscriptions or orders must be prepaid, with checks made payable to Project SERAPHIM, and sent to: Project SERAPHIM, Department of Chemistry, University of Wisconsin–Madison, 1101 University Avenue, Madison, WI 53706; phone 608-263-2837.

For the Macintosh, Software Excitement offers a Hyper Card stack titled Wastewater Ass't which is described as "a technical look at the aspects of waste water management; covers definitions of terms, calculations of volume, and conversion calculations for the different aspects of flow/work processes." It is on their Education X disk (number 2838), along with a second stack titled Chemist's Helper. For further information call 800-444-5457. Wastewater Ass't sells for $4.99 each, with a discount for multiple copies.

Flameless Ration Heaters are now available for classroom use

The "Hot Meals" feature in the February 1992 issue of *Chem Matters* took a look inside the Army's Flameless Ration Heater (FRH). Surplus FRHs are available (now that Operation Desert Storm is over), and they are excellent for classroom experiments. The FRHs are being distributed by Ed Escudero at Summit Country Day School, 2161 Grandin Road, Cincinnati, OH 45208. They may be purchased in groups of 10 for $12.50. A check or money order made out to Ed Escudero must accompany your order. This price includes shipping within the U.S. and Canada (if ordering from another nation, first send a note inquiring about price).

Canned Heat Lab: Notes for teachers

1. The ethyl alcohol should be handled with care because it is flammable, and burns with an almost colorless flame. Have a fire extinguisher available.
2. You can demonstrate the volatility of the ethyl alcohol in the gel by letting a beaker of gel remain open to the air for a day.
3. Calcium acetate is less soluble in hot water than in cold (37.4 g/100 mL at 0 °C, 29.7 g/100 mL at 100 °C; CRC Handbook, 69th ed.), so this is a case where warming the solution does not increase solubility.
4. The gel can be dissolved in water and rinsed down the drain.

Canned Heat

An Alcohol Gel

Chem Matters
April 1992

Mixing a saturated calcium acetate solution with ethyl alcohol produces a semisolid gel that will burn. The product will be similar to Sterno™, the gelled alcohol often used in food warmers or under chafing dishes.

Materials

safety goggles	ceramic pad, watch glass, or wet paper towel
apron	40 mL 95% denatured ethyl alcohol
two 100-mL beakers	1.5 g calcium acetate monohydrate, $Ca(C_2H_3O_2)_2{\bullet}H_2O$
5 mL water	a few drops of food coloring (optional)
stirring rod	50-mL graduated cylinder
matches	10-mL graduated cylinder

Procedure

1. Put on your goggles and a protective apron.

2. Prepare the saturated calcium acetate solution by dissolving 1.5 g of calcium acetate monohydrate in 5 mL of water in one of the beakers (measure the water with the graduated cylinder).

3 Measure out 40 mL of the 95% denatured ethyl alcohol and pour it into the second beaker. (Optional: add a few drops of food coloring to the ethyl alcohol to make it more visible.)

4. Pour the alcohol into the calcium acetate. If a gel does not form immediately, pour the solution back into the alcohol beaker. Repeat until the semisolid gel makes pouring impossible.

5 Light the gel. CAUTION: don't burn yourself. The flame will be difficult to see. You may want to turn off some lights, or do the experiment in a darkened area, to make the flame more visible.

6. You can also make the flame more visible by sprinkling a little salt, NaCl, on the burning gel. What causes the yellow color?

7. Put the flame out by covering the beaker with a ceramic pad, watch glass, or wet paper towel. The flame will go out before the cover will burn (why?).

The addition of ethyl alcohol to a saturated calcium acetate solution forms a gel similar to the commercial product Sterno. The exact structure of the gel is unclear, but the reduced solubility of the calcium acetate caused by the addition of the alcohol may result in a network of solid that traps the ethyl alcohol within it. Because the gel does not spill, it is safer than using pure alcohol as a heat source.

This lab activity was adapted from Mickey and Jerry Sarquis, Fun With Chemistry: A Guidebook of K–12 Activities, *from the Institute for Chemical Education. Volume 1, Institute for Chemical Education, The University of Wisconsin–Madison, 1991; Bassam Z. Shakhashiri,* Chemical Demonstrations, *Volume 3, University of Wisconsin Press: Madison, WI, 1989, 360-361; and G. B. Kauffman and P. S. Chin Song, "Calcium Acetate Ethanol Gels,"* J. Coll. Sci. Teaching, ***1987***, 15, *410.*

CHEMMATTERS

April 1992

QUESTIONS ABOUT THE ARTICLES

Camping Stoves

1. Why are open campfires no longer allowed in many areas?
2. What are the products of the burning of hydrocarbons in air?
3. Write and balance the chemical equation for the complete combustion of propane, C_3H_8, by the oxygen, O_2, in air.
4. Given that the density of white gasoline is 0.70 g/mL and its heat of combustion is 11.1 kcal/g, calculate the heat produced by burning 25 mL of white gasoline. Repeat the calculation for alcohol, with a density of 0.79 g/mL and a heat of combustion of 7.1 kcal/g.
5. Why does propane need sturdier and heavier cartridges for storage than those needed for butane?
6. Why does alcohol score well for safety, especially on boats, compared with other camping stove fuels?
7. What is the function of the "generator tube" on liquid fuel stoves?
8. Give one advantage and one drawback for each of these fuels: butane, propane, alcohol, and gasoline.

Wastewater

1. What is wastewater?
2. What is the purpose of the "Parshall Flume" at the entrance to the wastewater treatment plant?
3. Write and balance the chemical equation for the reaction of chlorine gas, Cl_2, with water, H_2O.
4. What odor is associated with the presence of hydrogen sulfide gas, H_2S?
5. Write and balance the chemical equation for the oxidation of H_2S by HOCl.
6. How does "Secondary Treatment" differ from "Primary Treatment"?
7. Before being returned to the environment, wastewater is usually treated with chlorine gas. What is the purpose of this final step?

Mystery Matters: Blood Markers

1. Why was simple blood type not enough to distinguish the blood stains as being from James or Joan?
2. Where in blood cells are the proteins associated with major blood type found?
3. Where in blood cells are the proteins associated with genetic blood markers found?
4. Name the technique used by forensic scientists to analyze blood samples for genetic markers.
5. The structure of a protein depends on the sequence of amino acids that the protein contains. Draw the generalized structure of an amino acid, and identify its amino group, its carboxyl group, and its side chain.
6. If a protein carries some positive and some negative charges, what effect would a decrease in pH have on the protein's net charge?
7. What are two factors that affect the way proteins move in the electric field produced when the power pack is turned on?
8. Why must the gel be kept cool during the separation of the proteins?
9. Why did the forensic scientists need to compare several different genetic markers in the blood samples?