TEACHERS GUIDE

Toxics Release INVENTORY

Activities to learn about the chemicals released into local watersheds and airsheds

TEACH WITH DATABASES

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TOXICS RELEASE INVENTORY

BY

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INTRODUCTION

Introduction to Toxics Release Inventory

Toxics: Chemicals that adversely affect the health and growth of an organism.

Teach With Databases: Toxics Release Inventory was jointly developed by the National Science Teachers Association and the U.S. Environmental Protection Association (EPA). It has been designed to help science classes take advantage of the wealth of environmental data available in databases, both on-line or in CD-ROM format. The focus is on EPA's Toxics Release Inventory (TRI), with classroom activities which allow students to learn more about the chemicals released into local watersheds and airsheds.

TRI activities are best done with students working with the database in small groups, although each student should have the opportunity to experience using the database on their own. In order to make the best use of one TRI CD-ROM, consider the following options:

▶ **Put it on a network:** It should be

USING TRI DATA

Many individuals and groups have used TRI during the past decade for a variety of purposes. For example, each of the following entities has used TRI in their own specific ways:

▶ **GOVERNMENT AGENCIES: Monitor environmental hazards, guide regulatory and legislative decision making.**

▶ **HEALTH CARE OFFICIALS: Build information databases on toxic chemicals and their effects, to become better prepared in an emergency.**

▶ **CITIZENS: Monitor environmental dangers. TRI encourages dialog between individuals and local companies on how to improve manufacturing processes to reduce releases. Media reports about TRI have served to inform the public and encourage use of this database.**

▶ **ENVIRONMENTAL GROUPS: Monitor toxics releases, press manufacturers for changes, promote regulatory action. For example, the Hudson River Sloop Clearwater uses TRI data to track chemical releases in the Hudson River basin. It has produced three reports and undertaken a public education effort.**

▶ **BUSINESSES: Monitor their releases of toxic chemicals, reduce emissions, and replace toxic chemicals with non-toxic substitutes. Businesses care about their public image; in many cases, manufacturers have substituted non-toxic or less toxic chemicals in order to improve their TRI performance. Many businesses have come to realize that producing and disposing of wastes is a costly undertaking. Producers have thus focused attention on reducing the amount of chemicals they release, and reusing and recycling when feasible.**

▶ **LABOR ORGANIZATIONS: Inform workers about dangers, press manufacturers for improvements, and lobby for government safety legislation.**

▶ **ACADEMIC RESEARCHERS: Categorize environmental hazards and devise alternative technologies to prevent toxic spills. Researchers are also coupling TRI data with other data, such as economic indicators, to study social policy and economic development.**

NOTE: As of the writing of this volume, EPA's Toxics Release Inventory database is still recorded in English system units. For ease of use, all references to TRI content have been maintained in this system, though lab preparations and activity sections not dealing directly with TRI are presented in metric units.

possible to place the contents on the CD-ROM on your school's computer network so students can access it from any port. If you have a local network, ask your system administrator for information on installation. EPA has TRI User Support available by telephone; consult the TRI User's Manual for contact information.

- **Order additional CD-ROMs:** EPA makes copies of the TRI CD-ROM available upon request. Consult Section 1.4 of the TRI User's Manual for ordering information.
- **Surf the Web:** The TRI database is located on the World Wide Web at http://www.epa.gov/opptintr/tri. The online database is more up-to-date than the CD-ROM, and the data are presented in an easy-to-read format. However, this database has fewer search parameters than the CD-ROM.

If none of the above options are possible, consider using computer projection equipment. If available, this will allow you to project the computer screen in front of the class, allowing students to follow as you move through the TRI database.

USING TRI IN THE CLASSROOM

This book is designed so that students can use TRI to conduct research into toxics releases in their local communities, and then apply the data to a series of activities that cover biology, chemistry, and environmental science. TRI's strength as a teaching tool is that the data are real, immediate, and of local origin. Your students will come up with both questions and answers that will be different from those found by students in other regions. Sample answers are designed to serve as examples only.

Each unit in this book is based on an independent theme in environmental chemistry. The "First Look at TRI" section will prepare you and your students to use the CD-ROM included with this package. Each of the following units can be used on its own, or in any combination that supports the classroom curriculum. The TRI database also offers an excellent source of ideas for independent student research, and the activities contained in this book may serve as a starting point for student-designed experiments.

This book uses the Chesapeake Bay (page vii) to provide sample context for the use of TRI, and as a location for comparison to your own region or community.

WHY A TOXICS RELEASE INVENTORY DATABASE?

During the past century, rapid industrialization has resulted in the increased use of industrial chemicals. Manufacturers use them in producing petroleum products that run our cars, or chemicals that are sprayed on our crops or used to make the plastic containers that hold our milk and soft drinks. Most products that we use in daily life are produced using chemicals, so they may be necessary; how can we use them safely?

The presence of human-made chemicals in our lives has raised serious safety and health concerns. What are proper exposure levels for workers? What are the impacts when these chemicals are released into the air, water, and ground? These concerns were brought to world attention in late 1984, when an industrial accident occurred at a Union Carbide chemical facility in Bhopal, India. The accident released a toxic gas called methyl isocyanate, killing more than 6,000 people. A short time later, a plant in West Virginia had a serious chemical release. The worldwide outrage over these events focused sharp attention on the issue of public exposure to toxic and hazardous chemicals.

EPCRA'S MAIN PROVISIONS

EMERGENCY PLANNING: Establishes a system on the state and local levels to allow for rapid, effective response to hazardous and toxic chemical releases.

EMERGENCY NOTIFICATION: Requires facilities to immediately notify local and state emergency planning committees if they release a hazardous substance into the environment in amounts that exceed allowable quantities.

COMMUNITY RIGHT-TO-KNOW REQUIREMENTS: Requires facilities to prepare Material Safety Data Sheets (MSDS) on materials they use. The sheets are submitted to state and local emergency planning committees and local fire departments.

TOXICS RELEASE INVENTORY (TRI): Requires facilities to establish an inventory of routine releases of toxic chemicals. The results are placed in a database that is available to the public.

TRI REPORTING REQUIREMENTS

Manufacturing facilities covered by TRI must report:

1. **What chemicals were released into the local environment during the preceding year;**
2. **The type of ecosystem that was contaminated (air, water, land);**
3. **The disposal, treatment, recycling, and energy recovery methods used;**
4. **The methods of chemical treatment used on-site;**
5. **The efficiency of waste treatment;**
6. **Pollution prevention and chemical recycling activities;**
7. **The transfer of chemicals to other facilities.**

In response to the concern these events raised, Congress passed the Emergency Planning and Community Right-to-Know Act (EPCRA) in 1986. The act established requirements for industry and all levels of government, regarding emergency planning and reporting on hazardous and toxic chemicals (page v).

EPA manages TRI, one of the main provisions of EPCRA. It includes more than 600 chemicals that can be released into the air, water, and/or land. Private manufacturers and federal facilities which have more than 10 employees and manufacture or process over 11,312 kg of these designated toxics, must comply with EPCRA. Facilities also must report if they use more than 4,525 kg of any designated chemical or category.

TRI also contains information on pollution prevention and chemical recycling. All information in TRI is part of the public domain—EPA makes the information available to the public in print, microfiche, CD-ROM, and on the Internet.

TRI relies on a system of self-reporting by the manufacturers. Although TRI is currently limited to manufacturing operations, it is being expanded to include more industries and a broader range of chemicals. In accordance with TRI, companies report releases based on estimates rather than exact measurements, and they are not required to report releases smaller than one pound. In addition, the time frames of the releases are not reported either, meaning reported amounts could have been released evenly over the course of the year, or in one single burst.

Most toxics releases result from normal manufacturing of goods or the processing of materials, rather than from accidents. They may occur from refineries processing oil into gasoline, a furniture company producing desks, or other routine commercial activities that provide us with everyday goods and services. Students should understand that local companies and businesses listed in TRI have not necessarily done anything wrong by releasing toxics. A large majority of the toxics releases occur in permissible amounts, and in a manner that complies with environmental laws.

POINT SOURCE AND NON-POINT SOURCE POLLUTION

One important distinction for students to understand is the difference between point source and non-point source pollution. Point source pollution, which TRI covers, comes from easily identifiable, and regulated, sources. For example, point pollution comes from a factory's smoke stack, the discharge pipe of a waste treatment facility, or a leak in an underground storage tank. Environmental regulators can easily determine point sources and measure their emissions. They can also regulate these sources, for example, by requiring advanced scrubbers on smoke stacks, or that underground tanks be more leak proof.

Non-point source pollution comes from many different sources, which are not as easily identified when the impacts are recorded. Oil and other petroleum products may leak from any number of automobiles and other motorized vehicles, and then washed off into the street. Eventually these products may enter local waterways, and possibly the ocean. Other types of non-point source pollution include pesticides and herbicides, which are sprayed locally on lawns and on agricultural fields. Even lawn mowers and backyard grills release some emissions into the air. The variety of sources makes it difficult for regulators to determine the precise location and levels of emissions and, therefore, to pass regulations to limit or prevent them.

When students perform the following activities, they should understand that TRI measures only point source pollution. As a result, they will not be able to determine the full level of pollutants being discharged into a watershed or airshed. In fact, EPA has determined that a major percentage of the existing polluted bodies of water have become contaminated through non-point sources.

THE CHESAPEAKE BAY

The Chesapeake Bay is America's largest coastal estuary. (Please see map on back cover.) Located within Maryland and Virginia, the bay stretches 290 kilometers from near Havre de Grace, Maryland, south to the Atlantic port city of Norfolk, Virginia. Nineteen rivers and approximately 400 streams and creeks flow into the bay, which measures 48 kilometers at its widest point. Three rivers—the Susquehanna, James, and Potomac—provide the bay with about 80 percent of its fresh water. The bay includes numerous fresh and salt water estuaries that are home to many species of fish and wildlife.

The Chesapeake Bay has been used for centuries for commerce, military activities, and recreation. Census projections indicate that 16 million people will live in the Chesapeake Bay area by the year 2000, an increase from 13 million in 1980. Baltimore, Maryland and Norfolk, Virginia are two major port cities, playing host to commercial and military shipping. The bay is rich in fish and marine life, supporting major fishing and crabbing industries—the Maryland blue crab is a well-known delicacy. The city of Annapolis, which is located in the northern area of the bay, is both the state capital and home of the U.S. Naval Academy. On a nice summer day, a visitor will see thousands of recreational vessels as people sail and fish in the bay and its many tributaries.

As commercial and residential development has increased in the region, the Chesapeake Bay has come under increasing stress—the bay is becoming more and more polluted as a result of increasing human activities. This pollution has come from a wide range of sources, including toxics that are released into rivers that flow into the bay; air emissions that become part of rain that falls into the Chesapeake; and pesticide and herbicide runoff from farm fields.

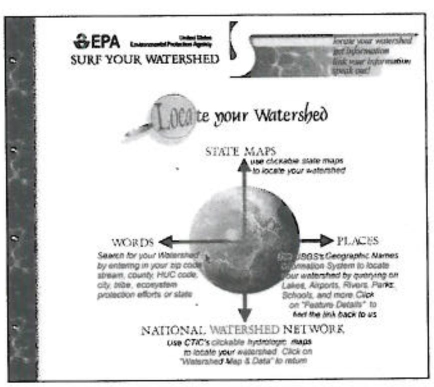
Efforts to preserve the Chesapeake Bay continue, and similar battles are being fought throughout the United States as we struggle to find a healthy balance between human activities and nature. In this book, students will use TRI to understand how toxics are affecting the water and air in their communities.

EPA'S ON-LINE WATERSHED SEARCH PAGE

EPA maintains extensive information about watersheds on its World Wide Web site. The "Surf Your Watershed" page features clickable state maps that allow you to identify watersheds anywhere in the United States. Users can obtain detailed information about the watershed, including a geographic description, maps, population data, land cover statistics, environmental conditions and trends, and discharge information from a host of EPA databases including TRI.

PROCEDURE

1. **Using your web browser, go to the EPA Surf Your Watershed page (www. epa.gov/surf). You will be presented with four search options for identifying a watershed: State Maps, Places, Words, or the National Watershed Network.**



2. **Click on the option with which you are most comfortable. Conduct a search for the watershed in your area.**
3. **The watershed page will include a map and geographical information about the watershed, including population, counties, and nearby watersheds. It will also include a number of environmental indices, including information on toxics releases.**
4. **Click on the TRI link. You will be presented with a page listing all releases of toxics into the watershed. Students can analyze the data to determine the types and amounts of releases into the watershed.**
5. **If the database contains no TRI data for that watershed, then go back to Step 1 and choose another watershed in your area.**
6. **Your web browser will allow you to save the data to your computer or print it out. (A sample map of the Chesapeake Bay is printed on the back cover of this book.)**

ABOUT THE AUTHOR

Jay Barracato considers himself a science teacher. Over the past six years at Patuxent High School in Calvert County, Maryland, he has taught chemistry, biology, Earth science, physics, and environmental science. Jay does independent work at Chesapeake Biological Laboratory on trace level analysis of chlorinated compounds in marine environments, and has involved his high school classes in raising hyper-thermophilic *archaea* (bacteria similar to those found at hydrothermic vents). Jay has participated in the Maryland Governors Academy and the University of Maryland Graduate Fellows Program. His students use statistics to analyze real data they collect, and he uses on-line databases as a source of data in his classroom.

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Identifying a Local Watershed & Airshed

OVERVIEW

This activity allows students to focus on the TRI database by identifying a local watershed and airshed that can be used for subsequent activities. Once students have created a map, they will be able to determine what is released into the watershed and airshed by searching the TRI database by geographical subdivisions (state, county, city), ZIP code, body of water, or other relevant criteria–the TRI CD-ROM database will not perform searches by watershed or airshed.

This activity has two main benefits. First, the map will allow you to take a somewhat abstract concept–the release of toxics–and make it into something real and immediate. (If you are unable to obtain a topographic map, a road map of your specific area will also work.) Students will be able to use this map to determine precisely where a release occurs and to visualize its location on a map. Second, this activity will demonstrate to students that they are part of a larger community. The release of toxics in their area can have an impact many kilometers away, and their community can be affected by events that take place far away. The interconnected nature of life on Earth is an essential concept in biology, chemistry, and environmental science.

Before assigning this activity to students, you will want to identify a local watershed and airshed in your area, and perform a TRI search to determine if there are local manufacturing facilities releasing toxics into the region you identified. If TRI does not have any data for your watershed, or has a small data set, you should then identify another watershed from a nearby city that has industry. For example, a teacher in southern Maryland might find little or no data for the local area, whereas TRI has plenty of information for the city of Baltimore.

A watershed is generally defined as:

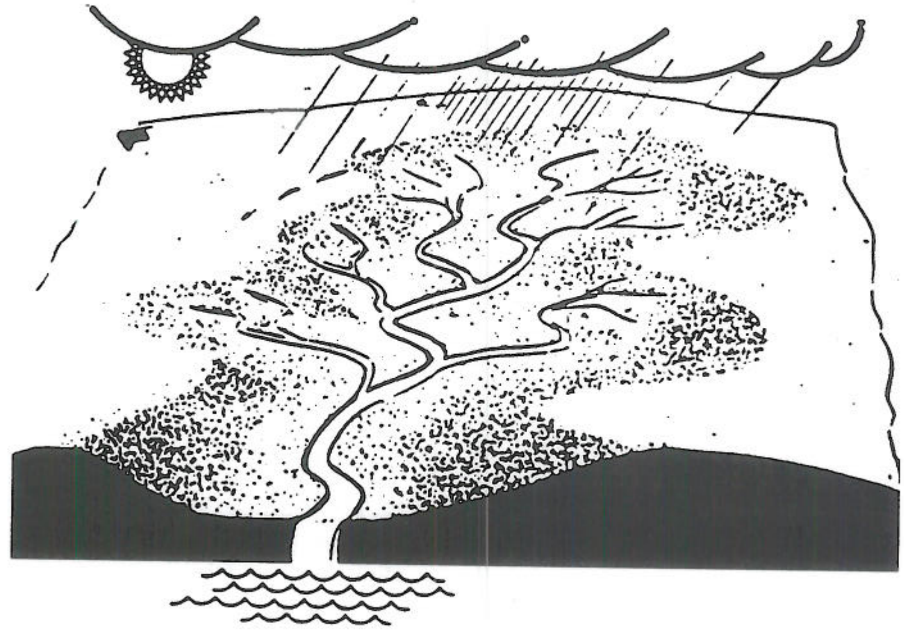
- an enclosed basin with a common drainage system
- a basin that forms a part of a larger drainage system
- the water supply for human drinking
- the water supply for farming
- the water supply for all other plant and animal life
- the water supply for cleaning, showering, toilet flushing
- the water supply for manufacturing

An airshed can be any size and shape and is generally defined as an area that you are interested in studying. It has no fixed boundaries, because seasonal variations and disruptive events, such as major storms, will cause an airshed's size and shape to change throughout the year. Airsheds are frequently the area surrounding a watershed. So, for the purposes of this activity, tell students that they are to consider the airshed and watershed to be the same area on their map.

ACTIVITY 1.1

You may wish to introduce students to database structure and organization by conducting *Database Basics* Activities 1 and 2.

Identifying a Local Watershed & Airshed



Watersheds come in all shapes and forms, but few are as large or as troubled as the Chesapeake Bay. In this activity, you will define watersheds and airsheds, and identify those in your community. You will then create a regional map, and use it to do the other activities in this book.

PROCEDURE

1. What is a watershed? What is an airshed? Conduct research using books, on-line databases, and maps. Using your research, come up with comprehensive definitions for a watershed and an airshed.

2. Identify a watershed and an airshed in your region. Sources of information include the EPA, United States Geological Survey (USGS), and the United States Department of Agriculture (USDA). You can also speak with USDA Cooperative Extension Service agents, the local department of natural resources, or other experts in your region.

3. Mount a topographical map of your local area on the bulletin board. Cover the topographical map with an acetate overlay so it can be marked with different colored markers.

3. Locate and mark your school on the map. (You may also want to locate and mark your individual homes.) Then, using the information you derive from looking at maps and consulting other resources, draw an outline of your local watershed on the acetate.

4. Identify specific watershed components. Use different colored markers and pushpins to mark them on the acetate overlay.

5. Identify residential and commercial development in the watershed, then mark them on your map or acetate. You can refer to your road and topographic maps—as well as to other resources (such as Geographic Information Systems (GIS) and county planning department maps, phone books, etc.)—to identify and locate major development. You may want to color code the developments by type—such as industrial, commercial, recreational, and residential. How many towns draw water from the river or stream being studied? Where is the intake? Where is the discharge for local water and sewer treatment facilities?

FIRST LOOK AT TRI

In this section, students will use the TRI CD-ROM to obtain an overall understanding of the TRI database and its uses. The first activity asks students to search for toxics releases in their hometown or region. In the follow-up activity, students use the TRI database to learn about the hazards posed by these releases. Extensions at the end of this section ask students how they might redesign the databases to be more useful for residents living near a manufacturing facility.

SECTION 2 GOALS

2.1

FOCUS

TRI is the citizens' resource for determining which toxic chemicals are released into the community. This section provides the tools necessary for using TRI.

OBJECTIVE

To become familiar with the types of data and the database tools used in TRI.

2.2

FOCUS

Each chemical included in the TRI database has a Chemical Substance Fact Sheet. These provide crucial information, for citizens as well as health and safety professionals, about the chemicals.

OBJECTIVE

To search TRI for specific Chemical Substance Fact Sheets. To learn about chemicals in local areas.

Identifying Toxics Releases in a Region

ACTIVITY 2.1

You may wish to introduce students to data analysis and basic statistics methods by conducting *Database Basics* Activities 6 and 7.

This activity can be used in concert with Activity 1 or on its own. This exercise leads naturally into Activity 2.2, in which students will learn what toxics are being released into the area they have chosen.

This activity uses a map and pins. An alternative would be to use a laminated map and alcohol pens to mark release locations.

As with Activity 1, you should conduct the search prior to leading the class in this activity. This will allow you to become familiar with the database, and ensure that the area your class will search has TRI listings—some communities are not covered by TRI.

If you expand the search to cover the entire watershed, you might want to use maps that include ZIP codes. It is likely that many watersheds will only cover parts of counties or cities. Having a ZIP code map could help students to narrow the search considerably.

Answers will vary by area.

EXTENSIONS

1. Ask students to search TRI's treatment database. Identify how manufacturers are treating toxics and managing their waste flow.

2. Have students broaden or refine the search as desired. Possible options include:

a. Expand the search to include the entire watershed you identified in Activity 1. You can do that by searching any additional areas (by town, county, or ZIP code) not included in the original search. You can then combine those results with the rest of the data you collected by using Step 6.

b. Narrow the search by type or category. For example, you could identify only water releases that take place in your study area. Or, you could limit it to a particular chemical such as styrene or chloroform.

Identifying Toxics Releases in a Region

In this activity, you will use the TRI database to investigate which chemicals are being used by manufacturing facilities in a specific area. In the process, you will learn the basics of searching a database.

PROCEDURE

1. Determine a geographic area that you want to search. If this is the watershed or airshed you identified in Activity 1, then choose a county or city located within this area. If you did not do Activity 1, then choose a city or county that you live in or near.

2. Obtain a map of the area that you are searching and place it on a bulletin board. This activity works best if you have a street map of the area.

3. From the main TRI menu, choose the TRI 1987-1990 database. (Make sure you have the CD-ROM in the drive.) Choose **Release** when prompted. This will allow you to search for toxics released during this time period.

4. Under **Select**, conduct a search for toxics releases in the area you have chosen. Scroll down to **Facility City** or **Facility County** and hit return. Type in the name of the city or county you are searching. The computer should show a tally of toxics releases in that area.

5. Under **Select**, choose **Facility State** and type in the name of the state in which the county or city is located. The computer should show a tally of toxics releases for your state.

6. Choose **Combine Sets** and type in "1" and "2" to combine the two searches. This combined list will have the number of toxics releases for the city or county you searched.

7. To display the information, choose **Sets** and then scroll down to **Display Sets**. Type in the number "3" and hit return. You should see the first record in the combined list.

8. Scroll through the records. (Print them out if that makes them easier to examine.) Which chemicals were most frequently released? Where were the releases occurring? Did they increase or decrease over the years? What other patterns do you see?

9. Using pins, mark on the map where releases occurred in the community you are studying. You could use colored pins to designate different types of releases (air vs. water) or the releases of specific chemicals.

10. Look for patterns in the data. Are the releases clustered in particular areas? Do specific types of facilities release particular toxics? Are there more water than air releases? What other trends do you see?

QUESTIONS

1. Analyze the results of your search.

a. Are the releases evenly distributed, or localized in specific areas?

b. What bodies of water are being affected by discharges?

c. Are the areas where many releases take place heavily or lightly populated?

Learning More About a Toxic Chemical

Depending on the number of chemicals identified in Activity 2.1, you may wish to have students perform a second search of additional areas, thus increasing the number of chemicals they can research for this activity. If possible, ensure that no two students research the same chemical. Answers will vary by chemical.

EXTENSIONS

1. Chemical Substance Fact Sheets are written primarily to cover workplace exposure. Ask students to rewrite the sheets considering the following questions about the impact of releasing the chemicals. How large of a concentration would be needed to cause serious injury or death? How is the chemical diluted in open air or water?

2. Every facility that reports TRI data is required to have a contact who can answer questions from the public. Invite the Public Information Officer from a local manufacturing facility to visit class to discuss TRI. Other sources of information include your local fire department, emergency planning committee, or a union that represents workers at a local facility.

3. Research one chemical found in your area, and write a report which documents the history of the chemical—how it got there, what are the associated health and environmental impacts, what is the local response, and how is it being dealt with.

ACTIVITY 2.2

If students will be writing reports on a specific chemical, you might want to first introduce them to data graphics using *Database Basics* Activity 9. You might also introduce toxicity and measurement with *Database Basics* Activities 4 and 5, and TRI Activity 6.1.

Learning More About a Toxic Chemical

In Activity 2.1, you learned about the release of chemicals in your home area. The information you used, however, did not tell you very much about the chemicals involved or the dangers they pose. Fortunately, the TRI database includes Chemical Substance Fact Sheets that contain extensive health and safety-related information for each of the compounds on the EPA's toxic substance list. The fact sheets provide information about toxicity, acceptable exposure levels, health effects, protection methods, and other important matters. You can use the data to learn more about chemicals released in your community.

In this activity, you will use the fact sheets to study one of the chemicals you identified in Activity 2.1.

PROCEDURE

1. Choose a common chemical from the list of chemicals you found in Activity 2.1.
2. From the main TRI menu, choose Chemical Substance Fact Sheets.
3. Type in the name of the chemical you want to research and hit return.
4. Review the information on the fact sheet.
5. Answer the Chemical Substances Questionnaire.

CHEMICAL SUBSTANCES QUESTIONNAIRE

1. Which chemical did you select?

2. What is one non health-related hazard associated with this chemical?

3. What is the workplace exposure limit?

4. What is the difference between an acute health effect and a chronic health effect?

5. What are the health hazards associated with the chemical?

6. What personal protective equipment should be worn when working with this chemical?

7. What is the most common treatment method for the chemical?

QUESTIONS

1. Examine the Chemical Substance Fact Sheets from different perspectives. How might a factory employee use the data? A plant manager? The director of the local emergency response committee? A local fire chief? A paramedic?

2. How you would rewrite the fact sheets so that they would be useful to a person living near the facility? What sorts of information would they need? How would you obtain it?

RELEASES

SECTION 3 GOALS

3.1

FOCUS

The main purpose of the TRI database is to tabulate the releases of hazardous chemicals by industry into the environment. To understand the chemistry of the environment, you need to determine the amount and identity of the chemicals added to the environment by humans.

OBJECTIVES

To use TRI to locate sources of point and non-point pollution in your community. To find trends in chemical releases by tabulating, summing, averaging, and graphing chemical releases.

3.2

FOCUS

Engineers often use the Law of Conservation of Mass to determine the amount of chemicals released into the environment.

OBJECTIVE

To demonstrate the Law of Conservation of Mass by analyzing a reaction in a closed system.

3.3

FOCUS

Sulfates persist in many aquatic habitats. Careful chemistry can reveal trace levels of this ion.

OBJECTIVE

To analyze samples for trace levels using spectrophotometry.

3.4

FOCUS

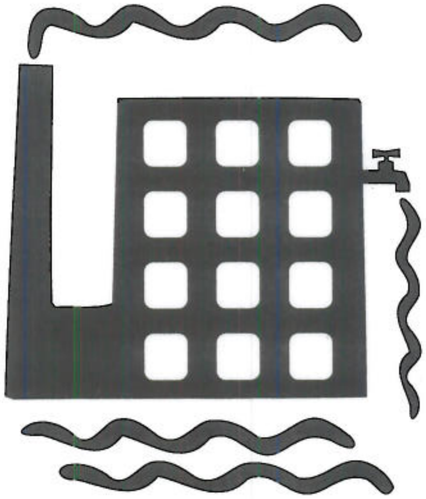
The chloride ion is prevalent in different water sources throughout the environment. Careful chemistry can reveal how much is present.

OBJECTIVE

To use the technique of titration to determine the amount of solute present in a sample.

Students may wonder how manufacturers determine how much of a chemical they are releasing. In some cases, facilities can directly measure their emissions by monitoring their solid and liquid wastestreams.

In other instances, manufacturers use mass balances as an estimation method. Mass balances are based on the Law of Conservation of Mass, which states that mass cannot be created or destroyed in an ordinary chemical reaction. In essence, if a manufacturing plant creates a chemical reaction and ends up with less mass than they expect, they have "lost" something along the way. The lost material is an emission that the manufacturer must report to EPA.



Sulfuric acid is an excellent example. It is a primary product of the chemical industry, and a byproduct of its production, sulfur dioxide, is a main cause of acid rain. The scientific equation for producing sulfuric acid is shown in Figure 3.0: (a) Sulfur (S_8) is burned to form sulfur dioxide (SO_2); (b) the sulfur dioxide is converted by a catalyst to sulfur trioxide (SO_3); and, (c) the addition of sulfur trioxide to water forms sulfuric acid.

Using these equations, engineers working for the manufacturer can predict how much sulfuric acid can be made from the amount of sulfur used. Sulfuric acid is 33 percent sulfur by mass. The production of 1 kilogram of H_2SO_4 requires 330 grams of sulfur. If the facility uses 330 grams of sulfur but only produces 950 grams of H_2SO_4, where did the remaining 50 grams go? Plant workers assume that the 50 grams of sulfur was lost to the air in the form of SO_2 or SO_3, both of which are gases. These gases must be reported to EPA as a release. EPA is concerned about these releases because they can have an impact on the environment. SO_2 is oxidized in the atmosphere into SO_3, which causes the formation of H_2SO_4. This compound contributes to acid rain, which pollutes the environment.

POINT SOURCE POLLUTION

Pollution that can be directly measured at its source. Examples: Smokestack emissions, and direct discharges from facilities into rivers and streams.

NON-POINT SOURCE POLLUTION

Pollution that comes from many different sources, and cannot be easily measured at its source. Examples: Chemical runoff from farm fields, and emissions from automobiles.

FIGURE 3.0

a. $S_8(s) + 8O_2(g) \rightarrow 8SO_2\ (g)$

b. $2SO_2\ (g) + O_2(g) + \text{catalyst} \rightarrow 2SO_3\ (g)$

c. $SO_3\ (g) + H_2O \rightarrow H_2SO_4$

Toxics Trends

ACTIVITY 3.1

Before conducting this activity, you may wish to use *Database Basics* Activity 8 to introduce students to graphing techniques. This activity also presents an opportunity to introduce students to decision-making. *Database Basics* Activity 10 in conjunction with the third extension suggestion can help students draw connections between data collection and real-world problems.

The main purpose of this exercise is to allow students to learn more about data analysis by looking at a specific chemical released into the environment. This activity requires at least 40 total releases for the eight years, so students may need to expand the search beyond the original search area.

EXTENSIONS

1. Have students survey their home for sources of point and non-point pollution.

a. What happens to your waste water? Where does it go?

b. What energy source heats your home? Where is it stored? What, if any, emissions does it produce?

c. How do you dispose of solid waste, such as trash? Where does it go?

2. Have students research the history of their community in regards to laws regulating sewage and other waste removal. Have the laws changed? If they had lived in their home 10, 25, or 50 years ago, how would their answers to Extension 1a, b, and c change?

Toxics Trends

In this activity, you will analyze the results of your earlier watershed search to learn about trends in toxics releases. You will find total and average releases for a particular chemical over an eight-year period.

PROCEDURE

1. Use the procedures stated in Activity 2.1 to search for the release of chemicals in your local watershed or area. Identify the toxic chemical most often released in that area. This activity works best if you have a data set with 20 to 40 releases. If the total number is below 20, you might want to expand your search area; if over 40, narrow your search.

2. Display the data sets by Reporting Year.

4. Analyze the records to determine which type of ecosystem—air, water, land, or underground—has had the greatest amount of chemicals released. Label your first data chart (Table 3.1) with that type. Label the second data chart (Table 3.2) with total releases. For each year and facility, complete the data chart with the amount released from the TRI data.

5. For each year, total the releases and find the average releases per facility.

6. Repeat your search in the 1991–1993 TRI, again obtaining data on 20 to 40 releases of the chemicals. Add these data to your data chart. You should have between 40 and 80 data points on each of your data tables as well as eight yearly totals and eight yearly averages.

7. Graph the year vs. the total releases (Graph 3.1) and the year vs. the average releases (Graph 3.2).

8. Express the release by type as a percentage of the total releases.

Percent of ____________________ released to the ____________________.
(chemical name) (type of release)

	1987	1988	1989	1990	1991	1992	1993	1994
Sum of (air, water) releases								
Sum of all releases								
Percent								

ANALYSIS QUESTION

1. How does the percentage of the chemical released by type change over time?

TABLE 3.1

Data Table for Releases of ______________ into ______________ by year.
(chemical name) (type of release)

FACILITY	1987	1988	1989	1990	1991	1992	1993	1994
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Total								
Average								

ANALYSIS

1. What year has the maximum total release? How much was released?

2. What year has the minimum total release? How much was released?

3. What year has the maximum average release? How much was released?

4. What year has the minimum average release? How much was released?

TABLE 3.2

Data Table for Releases of ____________________ by year.

(chemical name)

FACILITY	1987	1988	1989	1990	1991	1992	1993	1994
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Total								
Average								

ANALYSIS

1. What year has the maximum total release? How much was released?

2. What year has the minimum total release? How much was released?

3. What year has the maximum average release? How much was released?

4. What year has the minimum average release? How much was released?

GRAPH 3.1

Graph of Total Releases of ______________________ **into** ____________________.
(chemical name) (type of release)

ANALYSIS QUESTION

1. Describe any trends evident in your graph.

GRAPH 3.2

Graph of Average Releases of ______________________ **into** ________________.
(chemical name) (type of release)

ANALYSIS QUESTION

1. Describe any trends evident in your graph.

Conservation of Mass

ACTIVITY 3.2

You may wish to conduct *Database Basics* Activity 3 to explore sources of error in a survey and/or data set. *Database Basics* Activity 4 can be used to help prepare students for working with titrations and dilutions. Additionally, you may wish to introduce mass and scales with *Database Basics* Activity 5.

This activity is designed to model the procedure most commonly used in determining the amount of material released by industries. The products of the reactions include precipitates and a gas. It should be noted that the reaction most likely to lose mass is the one that produces a gas. Gases are the hardest phase of matter to contain, and many of the releases that occur during the manufacturing process happen when the materials are in the gas phase.

Each reaction consists of a solid reagent and a solution. These are:

0.1 M hydrochloric acid (HCl) (8 ml conc. HCl diluted to 1 L) and solid sodium bicarbonate (Na_2CO_3)

0.1 M lead nitrate ($(PbNO_3)_2$ (33.1 g diluted to 1 L) and solid potassium iodide (KI)

0.1 M silver nitrate ($AgNO_3$) (17 g diluted to 1 L) and solid sodium chloride (NaCl)

Be sure to dispose of lead nitrate and silver nitrate properly.

ANSWERS TO QUESTIONS

1. Mass cannot be created or destroyed in ordinary chemical reactions.

2. In a reaction, atoms are neither created nor destroyed, but they may be rearranged into new molecules.

3. Yes, the Law of Conservation of Mass is proven, because although there was a change in the phase of matter, there was no change in overall mass. This is shown by the almost zero percent change. (Small changes may be attributed to error in measurement.)

4. Gases are the most difficult to contain.

5. It doesn't tell exactly how the material was released or into what waste stream. Industries would have to monitor amounts at every step in a manufacturing process.

EXTENSIONS

1. As an out-of-class, or extra credit assignment, have students learn about EPA Superfund sites.

a. What are they?

b. What chemicals contaminate them?

c. What methods are being used to clean them?

d. Are there any sites near your home or school?

2. If there is a Superfund site near your home, invite a local EPA representative to speak to your class.

a. What is the history of the site?

b. What chemicals are present in the site?

c. What has been, and is being, done to remediate the site?

d. Can the site be used in the future? If not, why?

3. Have students use the TRI database to locate 10 nearby manufacturers, and compare their emissions in terms of states of matter. Do the companies release higher levels of solids, liquids, or gases? Ask students to graph their findings using stem-and-leaf plots, line graphs, or pie charts. (Instructions for these data analysis methods are in *Database Basics* Activity 7.)

Conservation of Mass

In this activity, you will explore the principle of mass balance. The principle is based on the Law of Conservation of Mass, which states that mass cannot be created or destroyed in an ordinary chemical reaction. Manufacturers use similar procedures to estimate chemical releases from their facilities when direct measures are not possible.

MATERIALS

Ziplock bag
Medicine cup
Scale
Reagents and solutions

PROCEDURE

1. For each reaction, place the liquid in the medicine cup and the solid in the bag. Place the medicine cup inside the Ziplock bag so it will not spill. Seal the bag.

2. Weigh the Ziplock bag and its contents as precisely as possible. Record the mass.

3. Spill the medicine cup so the compounds mix and react. Be sure the bag remains sealed.

4. Weigh the Ziplock bag again.

5. Calculate the percent change in mass for each reaction.

REACTIONS

$HCl\ (aq) + Na_2CO_3\ (s) \rightarrow$

$Pb(NO_3)_2\ (aq) + KI\ (s) \rightarrow$

$AgNO_3\ (aq) + NaCl\ (s) \rightarrow$

STUDENT DATA REPORT: Conservation of Mass

REACTION	STARTING MASS	FINISHING MASS	CHANGE IN MASS	PERCENT CHANGE
$HCl + Na_2CO_3$				
$Pb(NO_3) + KI$				
$AgNO_3$ +NaCl				

RELEASES

QUESTIONS

1. State the Law of Conservation of Mass in your own words.

2. Explain the Law of Conservation of Mass on a molecular level.

3. Do your results prove the Law of Conservation of Mass? Why or why not? (Hint: how much of a percent change did you get?)

4. Which phase of matter is the most difficult to contain?

5. What are the possible shortcomings in this method for estimating chemical emissions from manufacturing facilities? What could industry scientists do differently?

Determination of Sulfates in Aquatic Habitats: Spectrophotometer Model for Trace Level Analysis

This activity requires the collection of environmental samples. You can collect these samples yourself, using the sample description in the Student Section as a guide, or you can involve students in the collection process.

A calibration curve is needed for this Activity. Depending on your class size and available time, you should either prepare a curve prior to class, or have students perform this task as part of the activity. The standard solutions of sulfate ion can best be made by the following series of dilutions:

1000 ppm = 1000 mg/L SO_4^{2-}, the molar mass of $SO4^{-2}$ is 96 g/mole

1000 mg/L SO_4^{2-} = 1000/96 = 1.04×10^{-2} mole SO_4^{2-}/L

if the standard solutions are made from Na_2SO_4, then

1.04 x 10-2 mole Na_2SO_4 (142 g/mole) = 1.48 g Na_2SO_4

Make the standard solution by adding 1.48 g of Na_2SO_4 to 1.0 L of water. This standard solution can be diluted to give stock solutions, ranging from 100 to 1000 ppm.

ANSWERS

1. $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

2. To compare the unknown concentration with known values.

3. No it should not. The calibration curve may not stay linear.

4. Either collect more points to extend the calibration curve, or dilute/concentrate the sample to be in the range of the curve.

5. To remove suspended particles that would interfere with the measurement.

6. Sample answer: 500 ppm = 5×10^{-7} g/L = 5.2×10^{-9} moles/L.

EXTENSIONS

1. Have students research the area from where the environmental sample was taken. If they accompany you to collect the sample, have them record information about the site. For example, what does the water look like? What kind of vegetation is growing near the water? Are there buildings or roads nearby? If they do not accompany you, or if the site is too far for them to visit on their own, have them look up that area in the TRI database. Can the presence of sulfates, or lack thereof, be related to any toxics that are being released in that watershed? Why, or why not?

2. Ask students to use the TRI database to identify all companies that release a particular chemical. Have students contact one of these companies. What equipment do they use to test their emissions for that chemical? Do they test samples from their surrounding environment? How do the companies determine between the chemical not being present in their emissions and when it is present in levels that they cannot detect?

ACTIVITY 3.3

Before conducting this activity, you may wish to use *Basics* Activity 4 to introduce chemical detection, relative concentration, dilutions, toxicity, parts per million, and data indicators. To teach students how to plot data, and determine line equations, you may wish to use *Database Basics* Activity 7, Appendix C, or the section on "Finding the Line of Best Fit" in Appendix A.

Model for Trace Level Analysis: Concentration of Sulfate in Environmental Samples

INTRODUCTION

The spectrophotometer is an instrument found in many chemistry labs. It operates on the principle that chemical solutions absorb light. When the isolation is placed in a test tube which is then placed in the instrument, light of a known wavelength passes through the solution and onto a detector; and the detector tells us either the amount of light absorbed or transmitted by the sample.

The amount of light absorbed by the sample is related to its concentration: this is known as Beer's law. At low concentrations, this relationship is linear. A typical way of using the spectrophotometer to provide quantitative data involves creating a calibration curve. Samples of known concentrations of the compound of interest are carefully made, the absorbency is measured, and the data are graphed to determine the equation of the line. A sample of unknown concentration is then measured for absorbency, and the concentration is determined by comparing the line of the unknown to that of the known concentration.

TRACE LEVEL ANALYSIS

For many years, the common attitude toward chemical releases was: "The solution to pollution is dilution." Many engineers and scientists believed that the great amount of water flowing through the rivers was sufficient to dilute chemical waste to the point of harmlessness. However, scientists have discovered that this is not necessarily true.

The Baltimore Inner Harbor is an excellent example. This area, once full of factories and warehouses, has been redeveloped into a popular recreational area. It now includes an aquarium, shops, restaurants, and other attractions. But, if you visit the Inner Harbor, you will notice that not all the property has been redeveloped. For example, there is a large factory site near the center of the Inner Harbor that is still vacant.

You might suspect that this property is worth millions of dollars. However, during World War II, this was the site of a metal factory that produced alloys of chromium, a toxic substance that makes redevelopment difficult. The soil on this site is still heavily contaminated. Large amounts of chromium were also dumped into the harbor, where it remains buried in the sediment today. When these soils and sediments are disturbed by drilling or dredging, the chromium is resuspended in the water.

Scientists who monitor the harbor need to accurately measure very low levels of these concentrations. This process is referred to as trace level analysis. Scientists use a series of units to express these very low concentrations:

Parts per million (ppm) - number of milligrams of contaminant per liter of water

Parts per billion (ppb) - number of micrograms of contaminant per liter of water

Parts per trillion (ppt) - number of nanograms of contaminant per liter of water

Let's say a scientist finds that a local pond has a concentration of mercury that is 10 ppm. To picture this small amount, imagine one million jelly beans. If the red ones represent mercury, there would only be 10 red jelly beans in the entire pile. Trace level analysis requires careful work by the scientist, as samples from the environment could easily be contaminated in the laboratory. In addition, scientists need to be constantly aware of their level of detection, the lowest amount they can detect. This is especially important if the level of detection is greater than the level at which a chemical has adverse affects. They must determine if their equipment is sensitive enough to detect harmful levels of a certain chemical. For example, a method which detects metals only in the ppm range, is of no use if a metal is present in the ppt range.

Trace level analysis is important because it serves as a model for the relative concentrations that these releases create. Students are not used to dealing with these extremely small numbers. Activities 3.3 and 3.4 help reinforce the difference between a "nondetect"—meaning the chemical is present, but the equipment is not sensitive enough to detect it—and the chemical substance actually not being present.

Determination of Sulfates in Aquatic Habitats: Spectrophotometer Model for Trace Level Analysis

An environmental sample was collected from a river. The water was allowed to settle and was filtered to remove any insoluble particles.

PROBLEM

What is the concentration of sulfate in the environmental sample measured in ppm?

MATERIALS

Spectrophotometer
Curet
20 ml environmental sample
0.06 g barium chloride ($BaCl_2$)

PROCEDURE

1. Turn the spectrophotometer on, then allow it to warm up for 15 minutes. Next, adjust the wavelength to the desired value. For this activity, it should be set at 500 nm. With the door closed and nothing in the chamber, adjust the left knob until the needle reads 0. Place a curet filled with distilled water into the chamber (the outside of the tube should be clean and dry). Adjust the right knob until the dial reads 100. The instrument should be ready to take your measurements.

HINT: Take as many measurements at once as you can. If someone else uses the instrument, it must be zeroed again.

2. Create a calibration curve to compare your unknown samples to a series of known samples. In this activity, the calibration curve should be created by making a series of sulfate ion (SO_4^{2-}) solutions, and measuring their absorbance in a spectrophotometer. The absorbance is linear with the concentration over the range of samples in this activity–the concentration is graphed on the independent axis, and absorbance is graphed on the dependent axis. The best fit line is drawn or determined algebraically, and the concentration of the unknown sample is determined by measuring the absorbance in the spectrophotometer and interpolating from the graph.

3. Prepare your environmental sample by adding 0.06 g $BaCl_2$ to 20 ml of it. This forms the white precipitate that you will be measuring. Stopper the curet and shake three times to evenly mix the $BaCl_2$. Measure the sample in the spectrophotometer.

STUDENT DATA REPORT: Sulfates

Sample calculation for determining mass necessary for the standard solution:

100 ppm SO_4^{2-} is 100μg/L SO_4^{2-}

Assigned standard solution ______________________

Calculate the mass of assigned concentration:

CLASS DATA FOR STANDARD SOLUTIONS

CONCENTRATION	ABSORBENCY	CONCENTRATION	ABSORBENCY
50 ppm	______	450 ppm	______
100 ppm	______	500 ppm	______
150 ppm	______	550 ppm	______
200 ppm	______	600 ppm	______
250 ppm	______	650 ppm	______
300 ppm	______	700 ppm	______
350 ppm	______	750 ppm	______
400 ppm	______	800 ppm	______

The data should be plotted on graph paper, showing concentration vs. absorbency. Determine the equation of the line.

Equation of the best fit line ______________________

Correlation coefficient ______________________

COLLECTION POINT #1	COLLECTION POINT #2
SAMPLE ABSORBANCY	**SAMPLE ABSORBANCY**
1 ______	1 ______
2 ______	2 ______
3 ______	3 ______
Average ______	Average ______

Calculate the concentration of the sample from the equation of the calibration curve.

Concentration ______________ Concentration ______________

QUESTIONS

1. Write a balanced equation that describes the reaction of the sulfates and the barium chloride.

2. Describe the purpose of a calibration curve.

3. Can the calibration curve be used to determine points that are larger than your highest point or lower than your lowest point? Why or why not?

4. If the absorbency of the unknown is not within the limits of your calibration curve, what should you do?

5. Why must the environmental sample be filtered before processing?

6. Express the concentrations of the sulfate ion determined in the lab as molarities (moles/liter).

Determination of Chloride in Water: Titration Model for Trace Level Analysis

This activity requires the collection of environmental samples. You can collect these samples yourself, using the "Background" part of the Student Section as a guide, or you can involve students in the collection process. The sample should be filtered to remove any suspended materials.

A silver nitrate solution and fluorescein indicator are required for this activity. A 0.001 M $AgNO_3$ solution can be made by adding 0.17 g $AgNO_3$ to 1 L distilled water, and should be used if the environmental sample is fresh water. (See Extension 1.) The fluorescein indicator can be made by adding a small pellet of solid fluorescein to 100 ml of a 50% water/methanol solution.

Be sure to dispose of silver nitrate properly.

ANSWERS

Calculations:

1. Answers will vary according to sample. Total salt can be determined from the mass remaining after evaporation and the initial volume of the sample.

2. Answers will vary according to sample. The chloride ion may be determined by:

(M Ag) (ml Ag) = (M Cl) (ml Cl).

3. Answers will vary according to sample. Molarity may be converted to mass using the molar mass of Cl, 35 g/ml.

4. Answers will vary according to sample. Use answers from questions 1 and 3 to calculate the percentage.

Questions:

1. $AgNO_3 + Cl^- \rightarrow AgCl + NO_3^-$

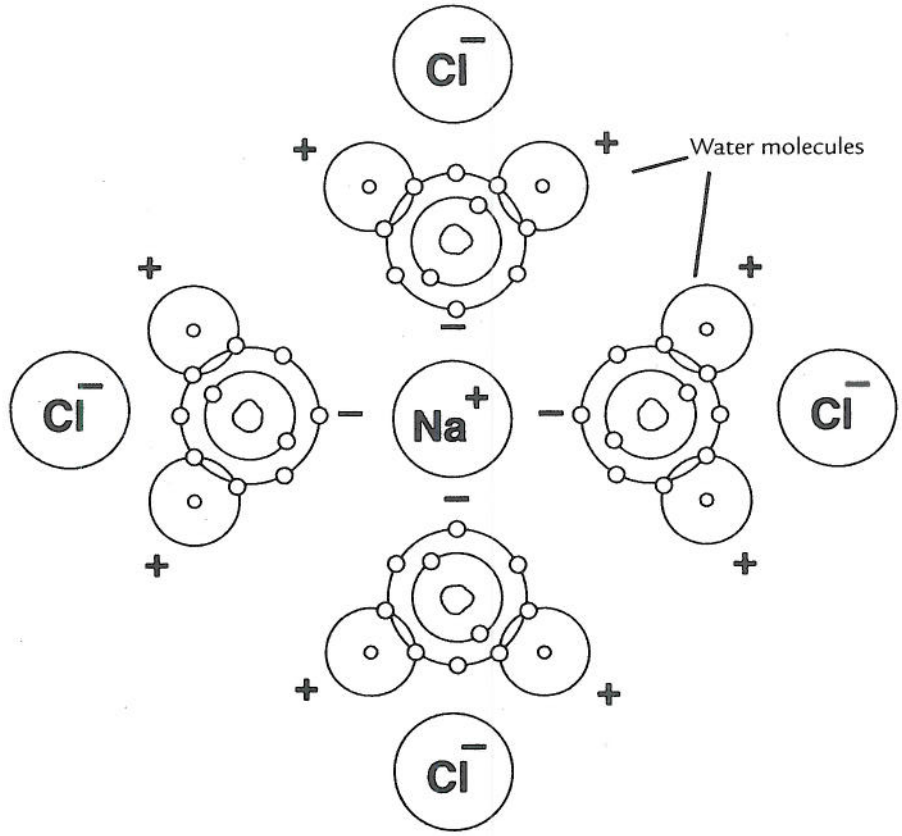
EXTENSIONS

1. If possible, have students collect additional samples from different ecosystems—estuarine and marine—and test them along with the fresh water environmental sample. A 0.1M $AgNO_3$ solution should be used for salt water, and can be made by adding 17 g $AgNO_3$ to 1 L distilled water.

2. Ask students to identify and summarize any trends that exist between the location of the sample, the amount of total salt, and the amount of chloride ion present in each sample.

Determination of Chloride in Water: Titration Model for Trace Level Analysis

Sea water is a complex mixture of many dissolved substances, the most abundant of which is sodium chloride (NaCl). A measurement of the chloride ion, therefore, can serve as a good indication of the total amount of salt in water. In this lab, we will use Fajens titration to compare the amount of chloride with the total amount of dissolved solids in an environmental sample. This titration process is one type of analysis that can be used to identify trace levels of released chemicals in solid and liquid samples.



PROBLEM

Describe the amount of chloride in an environmental sample as a percentage of the total dissolved solid.

MATERIALS

75 ml beaker
Oven, burner, or hot plate
Buret
Fluorescein indicator
$AgNO_3$ solution

PROCEDURE

1. Record the mass of a 75 ml beaker. Pour about 50.0 ml of the environmental sample into the beaker, and record the exact amount. Label the beaker.

2. Using either the oven, burner, or hot plate, evaporate the solution. Remove the label after the beaker has cooled down, and record its mass.

3. Place an amount of the sample, as determined by your teacher, in a small flask. Add 5 drops of fluorescein indicator.

4. Record the concentration of the $AgNO_3$ solution, and place it in the buret. Titrate the sample until a color change is evident. Do not over titrate. Record the volume of $AgNO_3$ you used.

5. Repeat steps three and four.

STUDENT DATA REPORT: Chlorides

	SAMPLE 1	SAMPLE 2	SAMPLE 3
Mass of Beaker			
Mass of beaker + salts			
Total mass of salts			
Amount evaporated (ml)			
Trial 1			
Amount of water			
Amount of $AgNO_3$			
Trial 2			
Amount of water			
Amount of $AgNO_3$			

CALCULATIONS

1. Calculate the concentration of the total salt content in grams per liter.

2. Calculate the concentration of the chloride ion in moles per liter.

3. Convert the molarity of the chloride ion into grams per liter.

4. Express the concentration of the chloride ion as a percentage of the total dissolved solids.

CONCLUSIONS

	ENVIRONMENTAL SAMPLE
Concentration of total solids in grams/liters	
Concentration of chloride in moles/liters	
Concentration of chloride in grams/liters	
Percentage of chloride in total solids	

QUESTIONS

1. Write a balanced equation describing the reaction between the chloride ion and the silver nitrate.

TRANSPORT

Scientists often refer to water as the universal solvent because so many chemicals are soluble in it. This solubility allows many chemicals to move in dissolved forms through ecosystems. A toxic chemical released into a stream by a manufacturing facility can be washed into a river, and eventually be detected in a bay many kilometers away. We can never be sure where the final resting place for chemicals released into the environment may be, or how long it may take for them to get there.

How fast a chemical moves through the environment is called its rate of transport. Chemicals with high rates of transport move extremely far in short amounts of time. Other chemicals move more slowly from their release sites. Because the rates of chemical movements vary, it is often difficult to predict how much of a a chemical may be found in its area of origin, or anywhere. A chemical's rate of dispersion, however, depends partly on the size of the area into which it has been released. The same chemical released into two different watersheds will have the same rate of transport and, therefore, will travel at the same rate through each watershed. However, the chemical will disperse more quickly through the smaller watershed because it has less distance to travel, and will "fill" the smaller area faster.

In this activity, students study the rate of the transportation of chemicals through the watershed they identified in Activity 1.1.

SECTION 4 GOALS

4.1

FOCUS

Pollution almost never stands still. Water carries many chemical passengers as it moves through its own cycle. These chemicals, both harmful and harmless, may end up miles from their sources. The major polluter of your neighborhood may not even be located in your state.

OBJECTIVES

To describe how chemicals move through the environment. To apply the concepts of a water cycle and solubility to an environmental problem.

4.2

FOCUS

What chemicals are moving through your local watershed, river or stream?

OBJECTIVE

To estimate the transport of chemicals using TRI data and chemical fact sheets.

4.3

FOCUS

Oxygen is critical to most life on Earth. In an aquatic ecosystem, the amount of oxygen present depends upon many factors, including the temperature of the water, the amount of oxygen produced by living organisms, and the amount of oxygen used by these organisms. The amount of dissolved oxygen is often used as a measure of the overall health of an ecosystem.

OBJECTIVE

To estimate the health of an aquatic organism by measuring the dissolved oxygen and the basic oxygen demand.

TRANSPORT

Modeling the Processes of Chemical Transport

ACTIVITY 4.1

An alternative procedure is presented in *Database Basics* Activity 4, which introduces indicators, detection, and detectability of various substances in a solution. You may also wish to conduct *Database Basics* Activity 6 to familiarize students with statistical descriptions. Activity 7 also provides students with techniques for plotting their data.

The air transport part of this activity requires the use of a fragrance, such as a perfume or fruit extract; several can be tested. For water transport, you will need food coloring.

The groundwater transport part of this activity requires some set-up time. The recommended soil types can be purchased at a hardware store or greenhouse. If you do not have stream tables, they can be made from aluminum gutter, available at local hardware stores, or from paint roller trays which have a minimum depth of 2.5cm. Place several long, thin slits at different heights along the lower side of the tray to allow water to exit. Ignore ladder clamps, if any.

ANSWERS

Air

1. Smaller, lighter chemicals move the fastest through the air. Because chemicals diffuse, the rate in any direction may be smaller than the actual movement of the chemical.

2. The larger the airshed, the longer it will take for a compound to completely disperse through the system.

Water

1. The rate of transport is affected by the solubility of the compound in water, and the rate of movement, or mixing, of the water.

2. It takes longer for a compound to disperse through larger watersheds.

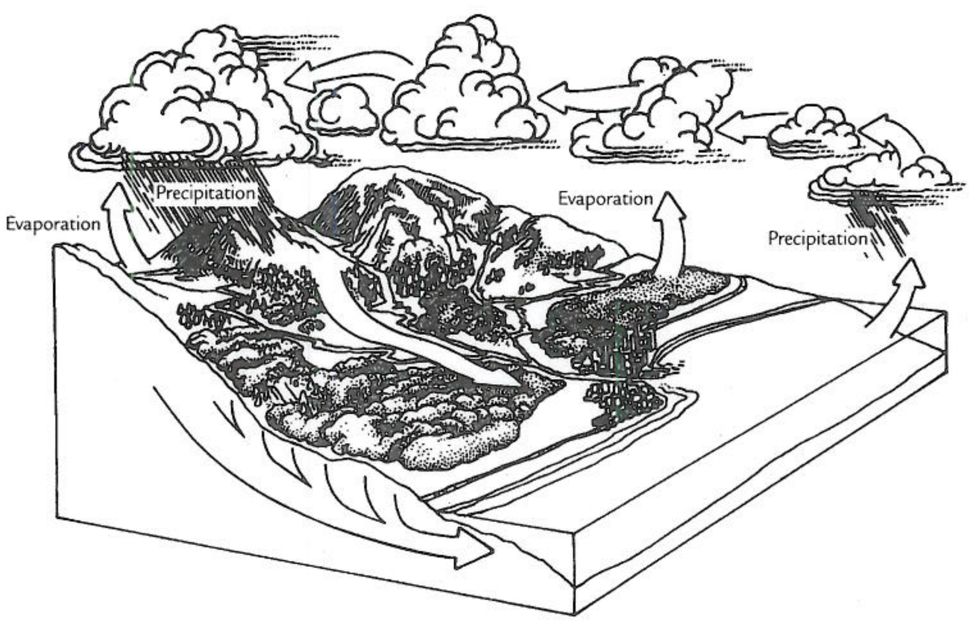
3. Location determines where and how fast the chemical will travel. A chemical released upstream of a populated area will have a drastically different impact than one released downstream.

Groundwater

1. The faster groundwater moves, the faster the chemicals are transported.

2. Chemicals are transported through the ground by water. Without water, they would move very slowly, if at all.

3. Location, topography, and geology determine the route the chemical will follow as it moves through the ground, and therefore what it will impact.



EXTENSIONS

Have students research the following topics:

1. Which agricultural methods may affect the movement of surface water?

2. What are the pros and cons of using pesticides and herbicides in agriculture?

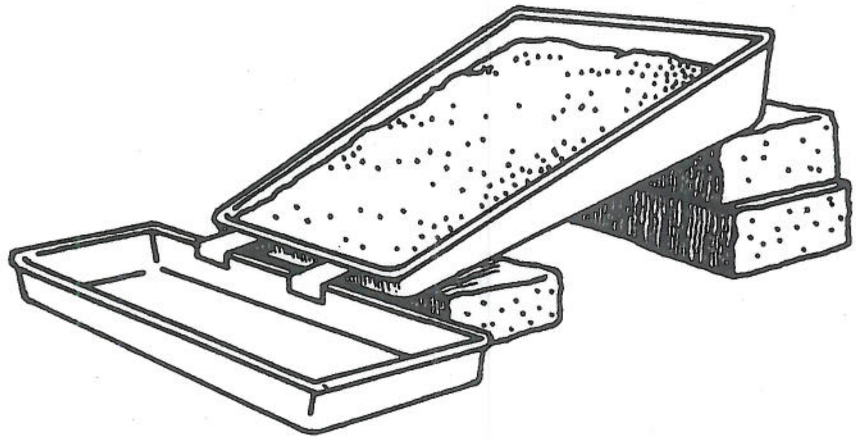
a. How are pesticides and herbicides applied to crops?

b. Do specific methods have a greater or lesser potential impact on runoff?

c. What regulations govern a farmer's ability to use pesticides and herbicides?

3. How do urban areas control surface water runoff?

Modeling the Processes of Chemical Transport



The purpose of this activity is to demonstrate the process by which chemicals move through air and water, and the relative rates at which they move.

PROBLEM

How fast can chemicals move through air and water?

MATERIALS

Fragrance or fruit extract
Measuring tape
Fan
50 ml buret
Food coloring
Stream tables
Three soil mixes: rocks and sand, loam, silt and clay

PROCEDURE: AIR TRANSPORT

1. To model the movement of a chemical through air, place a volatile chemical with a distinctive smell, such as a perfume or a fruit extract, on a table top at one end of the room.

2. Record the amount of time necessary for the chemical to diffuse throughout the room. Measure the distance from the starting point. Calculate the average rate of transport.

3. Use a fan to demonstrate the effect of winds. Point the fan in different directions and make comparisons.

PROCEDURE: WATER TRANSPORT

1. To model the transport of a chemical through a liquid medium, set up a 50 ml buret in a holder on a stand. Fill the buret with water and adjust the water to the zero mark. Measure 25 cm down from the top level of the water and place a mark on the buret with a grease pencil.

2. Add 3 drops of food coloring with a Pasteur pipet to the surface of the water. Begin timing when the first drop hits the water.

3. Record the amount of time before the color is visible at the 25 cm mark.

4. Repeat for three trials. Calculate the average rate of transport of the food coloring through the water.

PROCEDURE: GROUNDWATER TRANSPORT

1. To model the transport of a chemical through the ground by groundwater, fill three stream tables with soil mixes. One table should have a mixture of rocks and sand, one table should have a loam mix, and one table should have a silt and clay mix. Place the stream table so the end with the drain is several inches lower than the other end. Make a trench in the soil on the upper end.

2. Saturate the soil in each tray with clear water.

3. Fill a gallon jug with water and add enough food coloring so the water has a distinct color. Slowly pour the colored water into the trench. Begin timing when the colored water first touches the soil.

4. Continue adding colored water slowly, so the water is passing through the soil rather than running off on the surface.

5. Continue timing until the first of the colored water is seen at the drain. Repeat for each of the soils.

6. Calculate the average rate at which the color is transported through the soil.

STUDENT DATA SHEET: Modeling Transportation

AIR TRANSPORT

	TRIAL 1	TRIAL 2	TRAIL 3	AVERAGE
Time				
Distance				
Rate of Transport				

QUESTIONS

1. Make a general statement about the rate at which chemicals are transported through the air, and why this might be so.

2. How does the size of the airshed affect the dispersion time of an airborne chemical?

WATER TRANSPORT

	TRIAL 1	TRIAL 2	TRAIL 3	AVERAGE
Time				
Distance				
Rate of Transport				

QUESTIONS

1. Make a general statement about the rate at which chemicals are transported through the water, and the factors which affect it.

2. How does the size of the watershed affect the dispersion time of a waterborne chemical?

3. How does the location of a chemical released in water affect its impact?

GROUNDWATER TRANSPORT

	TRIAL 1	TRIAL 2	TRAIL 3	AVERAGE
Time				
Distance				
Rate of Transport				

QUESTIONS

1. Make a general statement about the rate at which chemicals are transported through the ground.

2. Why is groundwater important to the leeching of chemicals through soil?

3. How does the location of a groundwater chemical release affect its impact?

Rate of Transport

ACTIVITY 4.2

Before conducting this activity, you may wish to first use *Database Basics* Activity 3 to introduce surveying and extrapolation methods, or *Database Basics* Activity 7 to teach students to make predictions based on data.

This activity requires the use of TRI search instructions from Activity 2.1 (page 4).

ANSWERS

1. The most soluble chemical will be transported the fastest.

2. The least soluble chemical will be transported the slowest.

3. Chemicals which are not transported and do not degrade will most likely accumulate.

4. An increase or decrease in the amount of water will affect the concentration of chemicals in the water—more water means a lesser concentration, thus a smaller amount of chemical will be measured. A change in the rate of movement of the water will also change the amount of chemicals transported, and therefore the amount present.

Rate of Transport

In this activity, you will use TRI data to study how chemicals may flow through a local stream or river. If you identified a local watershed in Activity 1, then use the map you have developed. If not, use a map of a local river or stream.

PROCEDURE

1. Using the TRI database, do a search for the name of a waterway—stream, river, or lake—you have chosen to investigate.

2. If the set has more than 40 records, use the geographical search tools—state, county, etc.—to reduce the set to fewer than 40 entries. Select the chemicals that have the most releases over the four-year period. Select a total of 12 releases from a minimum of three locations.

3. Locate the position of each of the releases and mark it on the map. You may use addresses, or latitude and longitude coordinates. Develop a key that will allow you to identify the facility and chemical released.

4. Use the Chemical Substance Fact Sheets to determine if the chemical is soluble in water, or likely to precipitate into the sediments. Use this information to rank your chemicals by how quickly they will be transported.

5. Choose three locations downstream of the release sites and mark them on your map.

6. For each of the locations, predict which chemicals might be found there in measurable quantities.

STUDENT DATA SHEET: Chemical Transportation

Releases into (stream name) ______________________.

RELEASE NUMBER	CHEMICAL NAME	FACILITY NAME	LATITUDE	LONGITUDE
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

DOWNSTREAM LOCATIONS

CHEMICAL NAME	LOCATION 1	LOCATION 2	LOCATION 3

QUESTIONS

1. Which chemical do you think will be transported the fastest? Why?

2. Which chemical will be transported the slowest? Why?

3. Which chemical is most likely to accumulate in sediment from year to year?

4. How will events such as rainstorms or droughts affect the amounts or concentrations of the chemicals in a waterway?

Solubility of Oxygen

This activity requires the collection of several environmental samples. You can collect these samples yourself, or you can involve students in the collection process.

Collect water samples from at least three different sites, or three different points along the same waterway. Water can be collected in narrow-mouthed bottles, which should be completely filled and sealed to prevent the entrapment of atmospheric oxygen. The samples should be fixed to prevent further physical mixing or biological action. Biological action may be halted by fixing the sample with 1 ml of concentrated H_2SO_4 and 1 ml of 2% sodium azide (NaN_3) solution.

In addition to these three samples, collect enough stream or pond water for 500 ml samples for each student group.

Students should provide their own 500 ml, wide-mouth sealable glass jars.

ANSWERS

1. Heating provides energy for the gas to leave the solution.

2. Decomposers can grow and reproduce extremely rapidly, especially when there is a large supply of food. Decomposers will outcompete fish by outnumbering them, and using up available resources faster.

3. A polluted aquatic ecosystem will have lower levels of dissolved oxygen. Because catfish can tolerate lower levels of dissolved oxygen than trout or bass, they can be used as an indicator of pollution. More catfish indicate a less pure body of water; one that has many bass and trout is probably more pure.

4. Thermal pollution can have great impacts on the ecosystem. A major impact would be the dramatic decrease in the oxygen available in the area.

EXTENSION

1. Have your students research the area from where you collected the environmental samples in the TRI database. Can they connect the release of toxics in the area to the number of decomposers or different types of fish, and therefore to high or low levels of DO in the water?

ACTIVITY 4.3

You may wish to first conduct *Database Basics* Activity 4 to introduce the concepts of parts per million, detection, and indicators. Additionally, *Database Basics* Activities 5 and 6 can give students some basic mathematical tools for comparing and describing the measurements they take.

Solubility of Oxygen

The amount of oxygen dissolved in the water of an ecosystem is often an excellent indicator of the health of the ecosystem. Decomposers use dissolved oxygen to break down many pollutants, especially organic compounds present in sewage. A large amount of these pollutants may cause populations of decomposers to increase rapidly. However, high pollution levels may result in fewer complex organisms—such as fish—because the oxygen that they also need is used by decomposers. Oxygen solubility is also temperature dependent. As temperatures rise, the amount of oxygen that can be dissolved in the water decreases. A large influx of sewage during warm, summer months may cause a body of water to turn anoxic—lacking oxygen—and cause a fish kill.

The level of dissolved oxygen (DO) is an empirical indicator of water quality. Another indicator is the basic oxygen demand (BOD), which is measured in the same way as DO. The BOD is the amount of oxygen used by the microorganisms to break down pollutants. In a BOD measurement, the change in the amount of oxygen is measured over a set period of time. For a five-day test, a BOD of 1 ppm represents pure water, a BOD of 3 ppm fairly pure, and a BOD of 5 ppm is approaching impure. Untreated municipal sewage may have BOD values from 100 to 500 ppm.

METHOD OF MEASURING O_2

In the classroom, or in the field, there are two basic choices for measuring dissolved oxygen:

1. Dissolved Oxygen Meter or Probeware

2. Chemical Test Kits

A dissolved oxygen meter, or probeware, is the most flexible and portable tool to use, especially if multiple measurements are to be taken. It is, however, the most expensive method of measuring dissolved oxygen, unless it is used frequently. Several companies make either stand alone-meters or probes that are used with a variety of data collecting systems, including Vernier's Serial Box Interface, Texas Instruments CBL, Quantum Technology's LEAP system, and Logal's Explorer system.

Many companies sell chemical test kits that determine dissolved oxygen content. The kits have the advantage of being extremely easy to use and dispose of, and they cost about 50 cents per test. The best known water testing company, Lamotte, uses a modified Winkler Azide reaction in its test kit.

Solubility of Oxygen

PROBLEM

What is the effect of temperature on dissolved oxygen?

MATERIALS

Environmental sample
Thermometer
Hot plate with magnetic stirrer
Sealable glass jar
Compost
DO measurement equipment

PROCEDURE

1. Prepare your sample by slowly heating it up on a hot plate. Constantly stir with a magnetic stirrer. (Stirring will ensure the water is saturated for that temperature.) Place a thermometer in the sample.

2. Measure the amount of dissolved oxygen at 8–10°C, 15–18°C, 22–24°C, and 28–30°C.

3. Record the amounts of DO, in parts per million.

PROBLEM

What is the DO level in an environmental sample?

PROCEDURE

1. Record the temperature of each environmental sample.

2. Measure the DO level of each sample, and record your results.

PROBLEM

What is the BOD of an environmental sample?

PROCEDURE

1. Measure the amount of DO of the stream or pond water sample, and record your results.

2. Place a layer of compost at the bottom of a 500 ml, wide-mouth-bottle. Fill the bottle completely with the collected water and seal with the top.

3. Place the bottle on an inside window ledge and let stand for five days.

4. After five days, open the bottle slowly, so as not to disturb the surface, and quickly measure the DO. Record your results.

5. Calculate the BOD.

STUDENT DATA SHEET: Dissolved Oxygen

EFFECTS OF TEMPERATURE ON DISSOLVED OXYGEN

TEMPERATURE (°C)	8–10	15–18	22–24	28–30
Dissolved Oxygen (ppm)				

DISSOLVED OXYGEN IN ENVIRONMENTAL SAMPLES

SAMPLE NUMBER	1	2	3
Sample Temperature (°C)			
Dissolved Oxygen (ppm)			

BASIC OXYGEN DEMAND

Temperature of sample before ______________________________

Amount of DO before ______________________________

Temperature of sample after ______________________________

Amount of DO after ______________________________

BOD ______________________________

QUESTIONS

1. Most solids increase in solubility as temperature increases. Suggest a reason why oxygen and other gases decrease in solubility as temperature increases.

2. In the competition for oxygen, suggest a reason why fast growing decomposers may outcompete fish.

3. In a freshwater ecosystem, trout require the most dissolved oxygen, followed by bass. Catfish require the least dissolved oxygen. How can this be used to determine the purity of a body of water?

4. A factory uses water as a coolant. The water it returns to the stream is pure, but 30°C warmer. Explain why this is considered a form of pollution.

ACCUMULATION & BREAKDOWN

Each year the spring rains bring millions of liters of water into the Chesapeake Bay. With this water comes millions of metric tons of sediments, the soils and the chemicals that have washed off of the land in the Chesapeake's watershed. As fresh water pushes its way down the bay, it is met by salt water from the ocean. The mixing of these two types of water in an enclosed body is what makes the Chesapeake an estuary. This meeting point is a prime location for the accumulation of toxic chemicals.

The mixing of the salt water with the fresh water causes a change in the water's density. The denser water slows down, which causes it to drop the sediments it is carrying. This occurs at a location referred to as the turbidity maximum. It is the area where the light penetrates the water the least because of the suspended sediments. Just below the turbidity maximum is the zone where most of the sediments are deposited, and all of the chemicals tied up with those sediments are deposited in this zone. The pollution history of a region can be read by drawing a core sample (a long, narrow, cross-section of the sediment) in any major waterway, and analyzing the sediments for toxic chemicals. The chemical accumulation in the layer of sediments reflects the amount of the chemical in the environment when that layer of sediment was deposited.

In addition to naturally occurring accumulation, humans have caused the accumulation of chemicals in ecosystems by repeated releases at a point source. At these locations, the levels of these chemicals may far exceed the surrounding areas. Examples of this artificial accumulation include the burial of toxic wastes in landfills, storage lagoons for polluted waste, and the discharge of septic systems and industrial wastewater treatment plants.

SECTION 5 GOALS

5.1

FOCUS

Chemicals that enter the environment are not static. Some chemicals become concentrated over time, while other chemicals break down and "disappear" from the ecosystem. The amount of a chemical present in the environment at any time is a combination of these variables. How do scientists track the amounts of chemicals in the environment? How can they predict the changes that may occur?

OBJECTIVE

To estimate the amount of a toxic chemical in an ecosystem by using its persistence (half-life) and bioaccumulation data from the TRI Chemical Substance Facts Sheets, and the release data for a waterway.

5.2

FOCUS

Many people enjoy eating oysters. However, oysters are filter feeders, which may ingest and store large amounts of toxic chemicals that are released into waterways. How clean does a waterway have to be in order for humans to safely consume oysters?

OBJECTIVE

To demonstrate the accumulation of toxic compounds in a food chain.

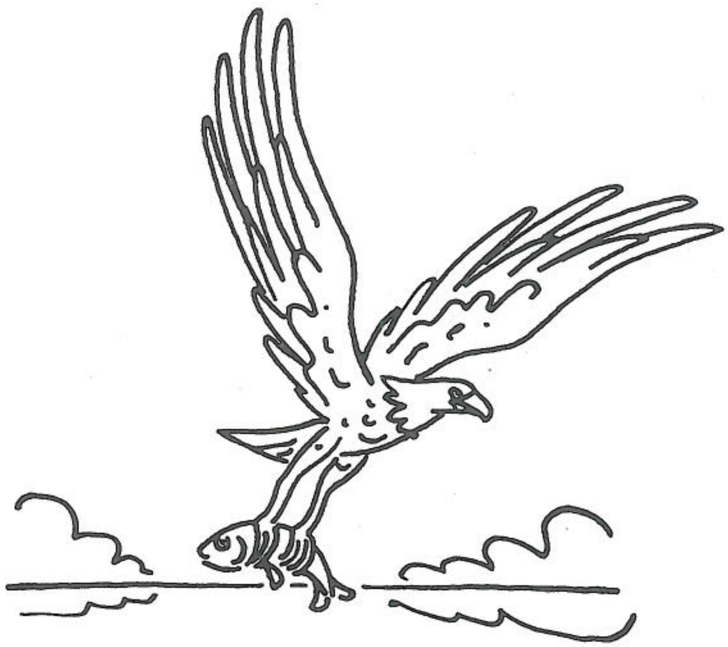
5.3

FOCUS

It is common to consider how chemicals affect living organisms. But how do living things affect the chemicals in their environment?

OBJECTIVE

To demonstrate and measure the chemical changes caused by a living organism.



ACCUMULATION

Regardless of how chemicals enter the ecosystem, they may be there for a long time. In the 1960s, scientists noticed that some birds of prey, such as ospreys and eagles near the Long Island Sound, were dying in alarming numbers. Females were laying eggs with extremely weak shells, which led to a high chick mortality rate and a drop in the species' population. Analyses revealed extremely high concentrations of dichloro-diphenyl-trichloro-ethane (DDT), a pesticide used during the 1950s to clear the beaches of mosquitoes, in the birds' bodies and eggs. Analyses of the environment, especially the water of the estuary, however, revealed low concentrations of DDT. Scientists posed the question: How were the birds absorbing enough DDT to harm themselves when the levels all around them were so low?

The answer lies in the concept of bioaccumulation. DDT is far more soluble in lipids (fats) than it is in water. The DDT that was being applied on the beaches was running off the land into the estuary, and being absorbed in the fatty membranes of aquatic microorganisms, such as algae and bacteria. Small fish ate the algae, and DDT accumulated in the fatty tissue of their bodies. The small fish were eaten by larger fish, who also accumulated the DDT. They, in turn, were eaten by the ospreys and eagles, resulting in the further concentration of DDT in their tissues. When the bioaccumulated concentrations reached toxic levels, the bird population was drastically impacted.

Not all chemicals are accumulated in the same form in which they are released into the environment. Once chemicals are introduced into the environment, the breakdown process begins. Chemicals may be broken down into simpler compounds by many processes. Ultraviolet light, heat, and microorganisms all break down toxic chemicals into smaller, less harmful substances. Chemicals with very different lifetimes have been designed for use in industry. Polychlorinated biphenyls (PCB), for example, were used extensively during World War II to manufacture electric equipment such as transformers. PCBs were effective for industry use because they do not readily break down. However, PCB use was banned when it was discovered that they persist and accumulate in the environment. Many of the toxic chemicals that are persistent—resist breakdown—may be bioaccumulated.

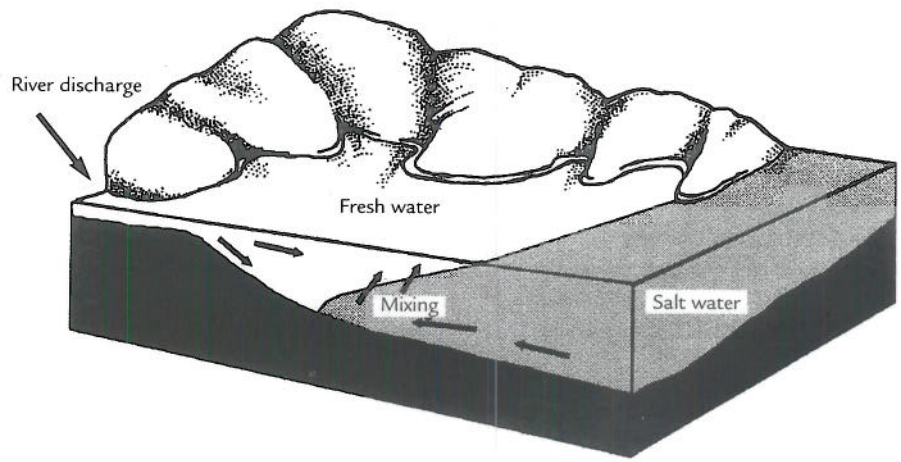
Today, many chemicals are designed to have very short lifetimes—to do their job then break down. Dimilin, for example, is a pesticide used to combat gypsy moths. It controls the reproduction of the moths by inhibiting their ability to produce chitin, which forms their exoskeleton. However, many other aquatic organisms, such as crabs and shrimp, also rely on chitin exoskeletons. If the Dimilin were to be transported from the moths' ecosystem to the crabs' ecosystem, the result could be disastrous. In order to prevent this, Dimilin is made to be thermally unstable. Extended exposure to moderate heat causes it to break down into two less harmful substances.

BREAKDOWN

In 1989, a major environmental disaster occurred when the Exxon *Valdez* spilled thousands of gallons of oil into Alaska's Prince William Sound, an estuary that covers about 8,800 km^2 and provides habitat for huge numbers of birds and marine species. The spill impacted all the organisms that lived in that ecosystem. Many ideas were presented on how to clean up the spill but bioremediation was decided upon in the end. Bioremediation is the process of using living organisms, such as bacteria, to clean environments that have become chemically polluted. It is made possible by the existence of living organisms that can make changes in their chemical environment. Some bacteria use a wide variety of chemicals as part of their natural energy pathways. Therefore, if a bacteria will use pollutants as energy sources, they can be used to break these pollutants down to less harmful compounds.

When this process occurs naturally, it is called biodegradation. When man purposely introduces an organism to an environment for the purpose of removing pollutants, it is called bioremediation. An important decision is always involved when scientists decide to introduce new organisms to an environment. However, many of the bacteria used for bioremediation have a special attribute that makes this particular kind of decision a little easier: these organisms are highly selective. When the pollutant is completely removed from the environment, the bacteria lose their source of food and die, thereby posing no threat to the whole ecosystem.

A Typical Salt-Wedge Estuary



Half-life and Bioaccumulation

ACTIVITY 5.1

You may want to introduce students to basic search concepts before beginning this activity. One way to do this might be to distribute copies of Introduction to Data and Databases on pages iv to vi of *Database Basics*. You might also discuss concepts such as toxicity during or before this activity; *Database Basics* Activity 4 presents a procedure for teaching about toxicity. And because students will be working with very big and very small numbers in this exercise, you might wish to first conduct *Database Basics* Activities 4 or 5.

You may want to print out the Chemical Substance Fact Sheets for the chemicals prior to class, in order to have more time for discussing accumulation and half-life.

ANSWERS:

Barium Nitrate	P
Arsenic Pentoxide	P
Styrene Monomer	N
Mercuric Nitrate	P
1,4 Dichlorobenzene	N
Beryllium Oxide	P
Ethylene Dibromide	S
Manganese Dioxide	P
Molybdenum Trioxide	P
Ethylene Glycol	S
Vinyl Acetate	S
Maleic Anhydride	N
Diocofol	S
4-Nitrophenol	S
Antimony Trichloride	P
Zinc Potassium Chromate	P
2,4 Dimethylphenol	S
Chromic Sulfate	P
1,2-Butylene Oxide	S
Lead Dioxide	P
1,3-Butadiene	N
Zinc Oxide	P
Asbestos	P
Chromium Nitrate	P
Toluene	N
Anthracene	S
Hydrazine Sulfate	S,P
Ethyl Benzene	N
Benzyl Chloride	S
Chromic Acetate	P
Manganese Nitrate	P
Chromium (III) Oxide	P
Mercuric Subsulfate	P
Allyl Chloride	N
Lead Sulfide	P
Aluminum Oxide	P
Mercurous Oxide	P
Propoxur	S
p-Cresidine	S

SAMPLE ANSWERS

1. Zinc Potassium Chromate
2. a. Discharge from galvanizing plants.
   b. Death in animals, death and low growth rates in plants.
   c. High chronic toxicity to aquatic life, shortened life spans, lower fertility.
   d. Yes. The level of zinc in fish may be considerably higher than concentrations in the water.
   e. 11103-56-9

Half-life and Bioaccumulation

The purpose of this activity is to estimate the amount of a toxic chemical in an ecosystem by determining its persistence, half-life, and bioaccumulation using TRI's Chemical Substance Fact Sheets and the release data for a waterway.

PROCEDURE

1. Locate the TRI Chemical Substance Fact Sheets for each of the chemicals. Mark each as either persistent (half life greater than 200 days), moderately persistent (half-life 20 to 200 days), slightly persistent (half-life 2 to 20 days), or non-persistant (half-life less than two days).

2. Return to the TRI releases database. From the **Select** menu, choose **CASRN** and enter the CAS number of the persistent chemical you selected. From the **Options** menu set the **Search Set** to **Last Set Created**. From the **Select** menu choose **Sum Water Releases** and enter the low value of 100 and the upper value of 1000. Display the results by the facility name. Choose a facility that has a release for three consecutive years. Enter the information on the Student Data Report sheet.

HALF-LIFE

Highly persistent chemicals have a half-life of greater than 200 days. This means it takes at least 200 days to reduce the chemical to one half of its original amount. For the purpose of this book, use a half-life to exactly 200 days to estimate the maximum amount of the chemical remaining if the chemical was released on the first day of each year. The chemical released during the first year will degrade through 5.5 half-lives (365 days x 3 years/ 200 days) before the end of the third year. The chemical released during the second year will degrade through 3.7 half-lives (365 days x 2 years/ 200 days). The chemical released the final year will only have 1.8 half-lives (365 days/ 200 days) to degrade. The total amount remaining after three years can be found by calculating the sum:

Total Remaining = **(Amount Released Year 1)$(1/2)^{5.5}$**
(Amount Released Year 2)$(1/2)^{3.7}$
(Amount Released Year 3)$(1/2)^{1.8}$

FOR EXAMPLE:

Calculating the accumulation and breakdown of asbestos released by Vermont Asbestos Group Inc., from 1991 to 1993:

Year of Release	**1991**	**1992**	**1993**
Amount of Release	**250 lbs**	**250 lbs**	**250 lbs**

Total remaining at the end of 1993 = (250 lbs)$(1/2)^{5.5}$
(250 lbs)$(1/2)^{3.7}$
(250 lbs)$(1/2)^{1.8}$
= 5.5 lbs +
19.2 lbs +
71.8 lbs
= 96.5 lbs of asbestos

STUDENT DATA REPORT: Accumulation and Breakdown

Barium Nitrate
Arsenic Pentoxide
Styrene Monomer
Mercuric Nitrate
1,4 Dichlorobenzene
Beryllium Oxide
Ethylene Dibromide
Manganese Dioxide
Molybdenum Trioxide
Ethylene Glycol
Vinyl Acetate
Maleic Anhydride
Diocofol

4-Nitrophenol
Antimony Trichloride
Zinc Potassium Chromate
2,4 Dimethylphenol
Chromic Sulfate
1,2-Butylene Oxide
Lead Dioxide
1,3-Butadiene
Zinc Oxide
Asbestos
Chromium Nitrate
Toluene
Anthracene

Hydrazine Sulfate
Ethyl Benzene
Benzyl Chloride
Chromic Acetate
Manganese Nitrate
Chromium (III) Oxide
Mercuric Subsulfate
Allyl Chloride
Lead Sulfide
Aluminum Oxide
Mercurous Oxide
Propoxur
p-Cresidine

1. Select one of the highly persistent chemicals listed.
2. Locate its Chemical Substance Fact Sheet. Answer the following questions:
   a. How does this chemical enter the environment?
   b. What are its acute, or short term, ecological effects?
   c. What are its chronic, or long term, ecological effects?
   d. Is this chemical subject to bioaccumulation?
   e. What is the CAS number of this chemical?
3. Calculating the accumulation and breakdown of

______________________ released by ______________________ during ______________________.
(chemical name) (facility name) (reporting years)

Year of Release			
Amount of Release			

The Bioaccumulation Game

The purpose of this activity is to demonstrate the accumulation of toxic compounds in a food chain. This activity is best explained verbally, and has no Student Section. Provide the reading on bioaccumulation (page 42) prior to class, and ensure that students understand the concept before you begin.

MATERIALS

300 colored beads or jelly beans
100 Paper cups

PROCEDURE

1. Prepare markers, such as colored beads or jelly beans, to represent food units—choose one specific color to represent toxics in the food chain. Students should not know which color represents the toxics. Distribute one score sheet (at right) to each student which designates them as a first-level consumer or a top-level consumer. There should be one top-level consumer for every five first-level consumers.

2. Place three beads or beans each in 100 paper cups before class. Not all cups need to have a toxics bead or bean, but no cup should have more than one.

3. Have each first-level consumer take one cup and tally each color they have. The first-level consumers should continue "eating" and tallying colors until all of the cups are used up. After the cups are gone, have each top-level consumer select five first-level consumers, and "consume" them by summing their tally sheets.

4. When the top-level consumers are done tallying their colors, announce the toxics color. All first-level consumers who have five beads/beans of that color would have died by toxic poisoning, had they not been eaten. Top-level consumers who have accumulated 10 markers through their consumption of first-level consumers have been killed by bioaccumulation of toxics.

5. Repeat steps two through four until all top consumers are dead. First-level consumers begin each round in perfect health. Top-level consumers must carry over their number of toxics from the previous round. You may change the color of the toxics bead or bean after each round, but continue to place no more than one of that color in each cup.

EXTENSION

1. Have students research species that have been endangered by the accumulation of toxic compounds.
a. What was the source of the toxic chemical?
b. How did it enter the species' ecosystem?
c. How did it get into the species?
d. How did it affect the species?
e. How was the issue addressed, and what has happened to the species?

ACTIVITY 5.2

Prior to beginning this activity, you might wish to teach students about toxicity using *Database Basics* Activity 4. Additionally, *Database Basics* Activity 5 might be used to review the concepts of mass, weight, and size.

SCORE SHEET FOR FIRST-LEVEL CONSUMERS

ROUND NUMBER	NUMBER OF COLOR 1	NUMBER OF COLOR 2	NUMBER OF COLOR 3
1			
2			
3			
4			

SCORE SHEET FOR TOP-LEVEL CONSUMERS

ROUND NUMBER	NUMBER OF COLOR 1	NUMBER OF COLOR 2	NUMBER OF COLOR 3
1			
2			
3			
4			

Chemical Changes by Living Organisms

ACTIVITY 5.3

You might wish to conduct *Database Basics* Activities 7 and 9 to prepare students to graph data and display their findings.

Bacillus subtilis, a bacteria, can easily be grown at slightly above room temperature, and cultured in a liquid medium. *Bacillus subtilis* is a fermenter that produces acetic acid from dextrose. The amount of acid provides the information about the rate of sugar degradation in the medium.

Unlike most microbiological procedures, this activity does not require extensive materials, special equipment, or aseptic techniques. *Bacillus subtilis* is legal for classroom use. It is not an animal or plant pathogen, and is available from Carolina Biological in a slant tube or on a plate.

The medium used to grow the *Bacillus subtilis* is a phenol red broth with dextrose. This medium is available from Carolina Biological as Phenol Red Broth Base and Dextrose or premixed as Phenol Red Dextrose Broth. The premixed medium is not preferred for this activity because the initial amount of dextrose can not be investigated as a variable.

The pH can be monitored with universal pH indicator strips, a pH meter with a pH probe (calomel electrode), or with a recording pH system such as Vernier's Serial Box Interface and Data Logger Program.

Assign each group an amount of dextrose to add to their mediums, so that they may compare their data. An appropriate range for the amount of dextrose is 0.5 g/L to 5.0 g/L.

You will also need Benedict's solution for this activity.

ANSWERS

1. A control can be made with no organism to show the dextrose does not break down spontaneously.

2. The faster the pH changes, the faster the organisms are growing and using the glucose.

3. The rate of growth changes.

4. Yes, a compound is changed by a living organism.

5. By making a direct comparison.

EXTENSION

1. Have students give an example of a living organism used for bioremediation, and describe one event in which it was used.

Chemical Changes by Living Organisms

In this activity, you will measure the amount of a nutrient in a medium, monitor an organism as a population grows to the limits of its food supply, and measure the amount of a waste product.

MATERIALS

Phenol Red Broth
Distilled water
2 L beaker
Dextrose solution
Benedict's solution
Hot plate
Magnetic stirrer

PROCEDURE

1. Create a medium by adding 5 g of the Phenol Red Broth Base to 1.0 L of distilled water in a beaker. Heat and stir on a hot plate until the solution is homogeneous. The solution should be a clear red color.

2. Continue to heat for several minutes, until the solution is just about to boil.

3. You will be assigned an amount of dextrose to add to the medium.

4. Demonstrate the presence of the dextrose in the medium by adding Benedict's solution to a small amount of the medium in a separate test tube. These samples of the medium with a known concentration of dextrose can be retained for comparison with the results of the Benedict's test after the organism has grown.

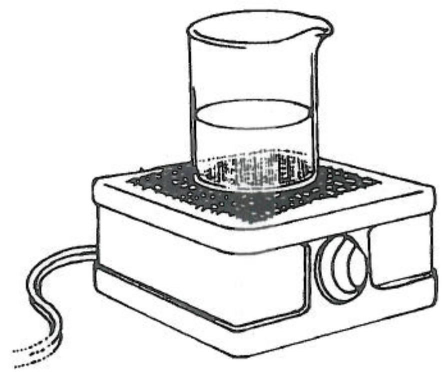
5. Transfer a small amount of the organism into the prepared medium by using a spatula or pipet.

6. Mix the medium with a magnetic stirrer. Heat to a temperature of 25-30°C, then allow to stand at room temperature. The culture may take 24 to 72 hours to completely use all of the available nutrients.

7. Sample and record the pH on a regular basis for the duration of the experiment. (The Phenol Red in the medium will turn yellow as the amount of acid increases.)

8. After the culture has crashed—mostly died—another sample can be drawn and tested with the Benedict's solution for the presence of dextrose.

9. Graph your data.



STUDENT DATA REPORT: Chemical Changes by Organisms

Initial concentration of dextrose ______________________

TIME vs. pH

TIME	pH	TIME	pH

Final concentration of dextrose ______________________

QUESTIONS

1. How can we determine the organism is responsible for the change to the dextrose?

2. How does the pH show the rate of growth of the organisms?

3. What does graphing pH versus time reveal about the process?

4. Is this a good model of biodegradation?

5. How can a series of known concentration solutions be used with the Benedict's solution to quantify the amount of dextrose in an unknown solution?

TOXICITY

SECTION 6 GOALS

6.1

FOCUS

We are repeatedly warned that certain chemicals can harm our health, but it is nearly impossible to completely avoid harmful chemicals. How do we know how much we can tolerate without risking our health?

OBJECTIVE

To describe and measure the toxic effects of chemicals on humans and other organisms.

6.2

FOCUS

We breathe constantly because we need oxygen. However, the air we take into our bodies is a complex mixture. How do we know if we are at risk from chemical pollution of the air?

OBJECTIVE

To use information found on Chemical Substance Fact Sheets to make a risk assessment.

6.3

FOCUS

A local waterway has experienced a fish kill. Hundreds of fish of all sizes are dead. How can you determine what has caused it?

OBJECTIVE

To determine the toxic levels of chemicals in an aquatic environment.

A chemical is considered toxic if it affects adversely the health and growth of an organism. Defining chemicals as toxic is a slippery business, because each organism reacts differently to each chemical, or combination of chemicals, in its environment. Different amounts of the same chemical may cause different reactions in the same organism. The result of exposure to a toxic chemical may be varied, and may include reactions such as avoidance, irritation, sterility, or death.

The Union Carbide factory in Bhopal, India produced pesticides, which were intended to increase the amount of food harvested in India by limiting insect damage. In 1984, an industrial accident caused the release of methyl isocyanate, a deadly gas. This release killed thousands of people.

Similar events happen every day, when organisms find themselves poisoned in the only environment in which they can live. Toxicologists tabulate the effects of chemicals by measuring LD_{50} values—the concentration, or lethal dose, of a chemical that causes death in half of the organisms tested. A species may have several LD_{50} values for the same chemical, because larval and juvenile forms may have different tolerances than adults.

Permissible exposures for humans are established by government agencies such as the Occupational Safety and Health Administration (OSHA). For example, the permissible exposure limit (PEL) for methyl isocyanate has been set at 0.02 ppm over an eight hour period. No person should be exposed to a greater level of this chemical without follow-up medical care. The acute (short-term) health affects occur shortly after exposure, including severe irritation of the lungs and possible pulmonary edema, a build-up of fluid in the lungs. The chronic (long-term) effects of repeated exposure may include permanent lung damage.

Toxic Effects on Organisms

The toxicity of various chemicals to algae and aquatic invertebrates, can easily be tested using a simple setup built from aquarium supplies. Each setup will allow for the testing of one replicate consisting of a control and four test trials. Replicates should be duplicated by different groups within a class to provide a sufficient amount of data. To be statistically significant, each control and test trial should consist of a minimum of 30 organisms. A setup consists of five 600 ml beakers, an aquarium pump, an aquarium gang valve, tubing, and five airstones or bubblers.

This activity requires the collection of pond water from just below the surface; avoid floating debris or mats of algae. You can collect these samples yourself, or you can involve students in the collection process.

You will also need to obtain a commercial liquid herbicide; weed killer will suffice. If students have trouble starting the naturally occurring algae, a commercially obtained freshwater culture may be added in equal amounts to each of the beakers.

Answers will vary.

EXTENSIONS

1. Ask students how easy or difficult they think it is to be exposed to toxic chemicals in their own environments, like their home or school. Have students make a list of all the toxic chemical substances they can find in their homes—not including foods or food-related products. In the following class, have students discuss their lists. Did they identify similar products? Do they agree with the identification of each chemical? Distribute copies of the Chemicals in the Household list (Appendix A, page 69), and ask students to compare their lists to it. Did they identify many of the chemicals on the list? Why do they think they overlooked the ones they did not identify?

2. Ask students to choose one chemical on the Chemicals in the Household list, and locate its Chemical Substance Fact Sheet. Have them write a brief report about that chemical. For example: what are the health effects related to the chemical; what household product(s) is it found in; what is it used for; where was it located in their house; how should it be disposed of; how long does it persist in the environment?

ACTIVITY 6.1

Prior to beginning this activity, you might wish to teach students about toxicity and concentration using *Database Basics* Activity 4. You might also wish to have students conduct *Database Basics* Activities 7 and 9 to prepare them to graph and display their findings.

Toxic Effects on Organisms

In this activity, you will test the toxicity of herbicides to algae found in pond water.

PROBLEM

What is the toxic level of a herbicide to naturally occurring algae in pond water?

MATERIALS

Pond water
Aquarium pump and air stone
Five 1 L beakers
Herbicide

PROCEDURE

1. Set up five beakers in natural sunlight, or under a grow light. Place an airstone connected to an aquarium pump, via the valve, in each of the five beakers.

3. Label each of the beakers as Control, Test Trial 1, Test Trial 2, Test Trial 3, and Test Trial 4.

4. Measure 500 ml of unfiltered pond water into each of the beakers. Adjust the airpump valves to produce a slow bubbling.

5. Using a micropipet, add 200 µl of the herbicide to Test Trial 1, 600 µl of the herbicide to Test Trial 2, 1200 µl of the herbicide to Test Trial 3, and 1500 µl of the herbicide to Test Trial 4.

6. Allow the algae to grow in the light. Each day record the growth as very strong, strong, weak, or no growth. Monitor the growth until the controls have reached the maximum growth sustainable.

STUDENT DATA SHEET: Aquatic Toxicity

ALGAE AND HERBICIDES

	DAY 1	DAY 2	DAY 3	DAY 4
Control				
Test Trial 1				
Test Trial 2				
Test Trial 3				
Test Trial 4				

SUMMARY OF CLASS DATA

REPLICATE NUMBER		1	2	3	4
Maximum Amount of Herbicide Allowing Growth					

QUESTIONS

1. During which day was the density of the algae in control the greatest?

2. In which of the test trials was the growth inhibited by the presence of the herbicide?

3. Interpolate the maximum amount of herbicide tolerable for growth from your four trials.

4. Determine the class average for the maximum amount of herbicide tolerable for growth.

Risk Analysis of Air Releases

The purpose of this activity is to allow the student to use the TRI Chemical Substance Fact Sheets to determine the toxicity of common chemicals and to do a risk analysis for humans and other organisms.

EXTENSION

1. As a class, contact the facility responsible for the release. Have students find out about the safety precautions used by the facility. What would the facility do in the event of an accidental release?

Risk Analysis of Air Releases

In this activity, you will use the TRI database to identify a chemical that is released into the air from a facility near your home, and determine what risks might be posed by this chemical.

PROCEDURE

1. Use the TRI database to locate the facility nearest to your home that has a significant air release of a chemical. Locate the TRI Chemical Substance Fact Sheet for that chemical and answer the questions on the Student Data Report.

STUDENT DATA REPORT: Toxic Air Releases

1. What is the name of the chemical released?

2. How much was released?

3. What is the name of the facility that released the chemical?

4. Estimate the distance, by air, from the facility to your home or school.

5. Summarize the hazards of exposure to the chemical.

6. What is the PEL for the chemical?

7. Estimate the amount of chemical which would need to be released at the facility in order to exceed the PEL at your home or school. (Hint: Use a map to estimate the volume of the hemisphere that has the facility at the center and your house on the edge.)

8. Are you at risk if an air release of this chemical occurs? How much release can occur before you are at risk?

9. How soluble is the chemical in water?

10. How is the chemical distributed in the environment?

11. What other organisms may be at risk from a release of this chemical? Why?

Chemical Toxicity in an Aquatic Environment

This activity requires the collection of pond water from just below the surface; avoid floating debris or mats of algae. You can collect these samples yourself, or you can involve students in the collection process.

Be sure to dispose of lead nitrate properly.

ANSWERS

1. Answers will depend on individual data.

2. Answers will vary. (About 0.05 mg/m^3).

3. In solutions or compounds that humans ingest or inhale.

4. Leaded gasoline and lead-based paints.

EXTENSIONS

1. Have students research the "Sick Building" syndrome. Have modern building techniques addressed this problem?

Chemical Toxicity in an Aquatic Environment

MATERIALS

5 L of pond water
Aquarium pump and air stone
Five 1 L beakers
Pipet
Daphnia magna

PROBLEM

What is the LD_{50} for Lead (II) ion on *Daphnia magna*, a freshwater, column-dwelling invertebrate?

PROCEDURE

1. Set up five 1 L beakers. Place an air-stone connected to an aquarium pump via the valve in each of the 5 beakers.

2. Label the beakers as Control, Test Trial 1, Test Trial 2, Test Trial 3, and Test Trial 4.

3. Measure 500 ml of unfiltered pond water into each of the beakers. Adjust the valves to produce a slow bubbling.

4. Use a pipet to place 10 *Daphnia* in each of the beakers.

5. Make a stock solution that is 0.1 g/L of Lead (II) by dissolving 0.16 g of $Pb(NO_3)_2$ in 1 L of distilled water.

6. Add 5 ml of the stock solution to Test Trial 1 to make an exposure concentration of 1,000 ppm.

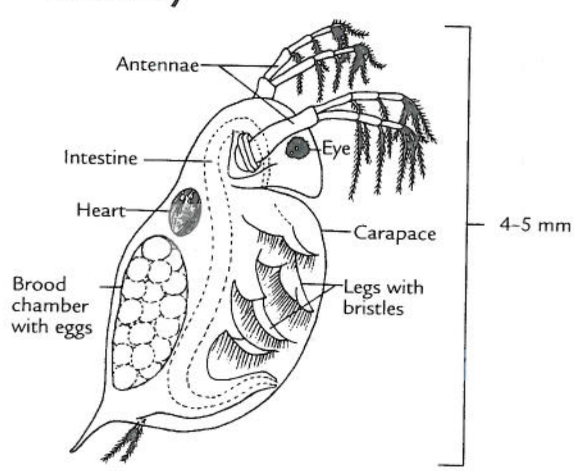
7. Add 2.5 ml of the stock solution to Test Trial 2 to make an exposure concentration of 500 ppm.

8. Add 500 µl of the stock solution to Test Trial 3 to make an exposure concentration of 100 ppm.

9. Add 50 µl of the stock solution to Test Trial 3 to make an exposure concentration of 10 ppm.

10. Allow the *Daphnia* to grow for three days. Each day, count the number of survivors in each of the beakers and record the number in your data table.

Simplified *Daphnia* Anatomy



STUDENT DATA SHEET: Lead(II) and *Daphnia*

	DAY 1	DAY 2	DAY 3
Control			
Test Trial 1			
Test Trial 2			
Test Trial 3			
Test Trial 4			

Calculate the average number of survivors at each concentration

	DAY 1	DAY 2	DAY 3
Control			
Test Trial 1 1000 ppm			
Test Trial 2 500 ppm			
Test Trial 3 100 ppm			
Test Trial 4 10 ppm			

QUESTIONS

1. Estimate the LD_{50} for the *Daphnia* exposed to Lead(II).

2. Lead poisoning is common in humans. How does the toxicity of lead to *Daphnia* relate to the toxicity of lead to humans? Use the TRI Chemical Substance Fact Sheets to determine the exposure level for humans.

3. The *Daphnia* were exposed to lead ions dissolved in solution. How are humans usually exposed to lead?

4. Name two sources of lead contamination.

RECYCLING

SECTION 7 GOALS

7.1

FOCUS

You may use a newspaper as kindling to light a fire in your fireplace. The paper, like all materials, has energy stored in it. What other materials would be good as fire starters?

OBJECTIVE

To allow students to access the pollution prevention data contained in the TRI database. To examine industry methods of source reduction and energy recycling using the TRI data.

7.2

FOCUS

Paper or plastic? Reduce, reuse, recycle. The language of recycling is commonplace in today's society. What items are commonly recycled? What are their characteristics?

OBJECTIVE

To distinguish between the different types of commonly used plastics. To identify household plastics in terms of type and whether they can be recycled.

Every high school student should be familiar with the saying, "Reduce, Reuse, Recycle." In today's world, many shoppers prefer buying items in bulk to minimize packaging; students may carry reusable lunch bags instead of paper; and it has become a common household practice to separate items into different solid wastestreams: recyclable plastics, cans, newspapers and glass. Some consumers, however, do not think beyond the waste they generate. Many people are unaware that large industries look for creative ways to recycle the waste produced in their manufacturing processes.

The Pollution Prevention Act (PPA) of 1990 established a national policy of pollution prevention as the first choice of waste management practices. This strategy involves reducing the amount of waste at the source, and recycling wastes on-site. Starting in 1991, the TRI database contains additional data from facilities, including the amounts of chemicals recovered from manufacturing processes and recycled; chemicals used for energy recovery (burning the chemical to degrade it, and provide heat for manufacturing processes); and waste treated on-site.

Recycling Methods

Depending on time and the number of computers you have available, you may want to perform the TRI search prior to class, and provide students with records.

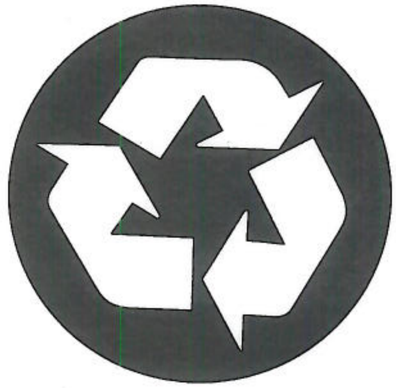
ANSWERS

1. Answers will vary according to site.

2. Environmental clean-up costs are reduced. The materials may provide additional sources of materials and energy.

EXTENSION

1. Discuss the issues related to recycling with your class, such as: source reduction; cost reduction; reducing on-site pollution; analyzing the costs and benefits of recycling a particular material; and deciding whether it is more practical, or even possible, to recycle on-site, versus paying for removal. Have some students role-play being owners and directors of manufacturing companies faced with these decisions. Have other students role-play being members of the town council who must decide which of those manufacturers they would allow to move to their town. (See *Database Basics* Activity 10 for more background about this type of activity.)



ACTIVITY 7.1

You may want to introduce students to basic database search concepts before beginning this activity. One way to do this might be to distribute copies of Introduction to Data and Databases on pages iv to vi of *Database Basics*. This activity also presents an opportunity for developing students' decision-making abilities; *Database Basics* Activity 10 explores a decision-making format you might adapt to this activity.

Recycling Methods

This activity is designed to show you how to access the pollution prevention data contained in the TRI database.

PROCEDURE

1. Open the 1990-1994 TRI database. From the **F3=Select** menu choose **Reporting Year** and highlight 1994.

2. From the **F2=Options** menu set **Search Set: to Last Set Created**. From the F3=Select menu choose **Facility State** and enter your state. From F3=Select choose **Source Reduction Activities**.

3. Display the entries. Choose three records and complete the following chart.

Student Data Report: Recycling Methods

Facility Name: ____________________

Chemical Name: ____________________

Maximum amount on-site: ____________________

On-site Energy Recovery, Current Year: ____________________

Off-site Energy Recover, Current Year: ____________________

On-site Recycling, Current Year: ____________________

Off-site Recycling, Current Year: ____________________

On-site Treatment, Current Year: ____________________

Off-site Treatment, Current Year: ____________________

Source Reduction Activities: ____________________

Source Reduction Methods: ____________________

QUESTIONS

1. For each of the facilities, express the amount recycled as energy as a percent of the total amount recycled.

2. Describe two reasons why you think it is economical to reuse or recycle waste on-site rather than throwing chemicals away.

Identifying Plastics

For this activity, you will need to provide samples of each type of plastic for your class. Make your samples large enough so students can cut small pieces for their tests, and try to choose unknown samples that do not look like types of plastics your students might recognize. You may also want to divide your class into groups of two to three students for this activity.

The homework assignment is a good way for students to learn about the characteristics of plastics they use in their daily lives. You should have an open class discussion of the various types of plastics they found in their homes. Write down the plastic codes and characteristics on the blackboard, and then fill in any of the types the students didn't find. Discuss the various types of plastics and their characteristics.

TYPES OF PLASTIC

CODE 1 Polyethylene terephthalate (PET): Commonly used for soft-drink bottles. Transparent, flexible, and rigid. Will crack but not shatter. Recycled into fiber fillings, carpeting, and epoxies such as surfboards and boat hulls.

CODE 2 High Density Polyethylene (HDPE): Commonly used for milk jugs, bleach bottles, and water bottles. Opaque with a rough surface. Stiff but will bend. Recycled into drain pipes, lumber substitutes, toys, and flower pots.

CODE 3 Polyvinyl Chloride (PVC): Commonly used for plastic wrap, drain pipes, shower curtains, and vinyl car parts. Glossy, difficult to burn, and may be either rigid or flexible. Recycled as floorings and truck bed liners and tool boxes.

CODE 4 Low density polyethylene (LDPE): Commonly used for condiment bottles, plastic bags, and coffee can lids. Opaque and very flexible. Recycled as insulation and used in making mixed plastics.

CODE 5 Polypropylene (PP): Commonly used for bottle caps, the bottoms of soda bottles, and candy wrappers. Translucent to opaque with smooth surfaces which may reflect light (have luster). Commonly recycled as park benches and fencing.

ACTIVITY 7.2

You may wish to have students create flow charts of more commonly-known topics prior to conducting this activity; *Database Basics* Activity 1 has a procedure for developing a flow chart for a library. This activity also presents an opportunity for developing students' decision-making abilities; *Database Basics* Activity 10 explores a decision-making format you can adapt to this activity.

RECYCLING

CODE 6 Polystyrene (PS): Commonly used for drinking cups, eating utensils, deli and fast food containers. Transparent or opaque, and it may be semi-rigid, brittle, or a foam. Polystyrene is not recycled.

CODE 7 Mixed Plastics: are made by combining the other classes of plastics. Characteristics vary widely. Mixed plastics are not recycled.

TEST RESULTS

1. Densities of Common Plastic Types

CODE	SAMPLE TYPE	DENSITY G/ML
	Water	1
1	PET	1.38-1.39
2	HDPE	0.95-0.97
3	PVC	1.16-1.35
4	LDPE	0.92-0.94
5	PP	0.90-0.91
6	PS (rigid)	1.05-1.07

2. A green color indicates the presence of a halogen.

3. Styrene will swell in the acetone.

4. PET will soften.

6. LDPE burns slowly and blue, PP burns quickly and yellow.

ANSWERS

1. Efficiency in collection and processing, and a demand for the process and/or the recycled products.

2. Answers will vary.

3. Different types of plastic have specific properties that define what it could, or could not, be used for.

EXTENSIONS

1. Arrange for a tour of a local recycling facility if one exists in your area. Students will be able to see how plastics are sorted and processed for reuse.

2. Many municipal and county governments have a recycling coordinator who oversees the local recycling program. Invite this person to visit the class to discuss the community's efforts and answer questions from students.

3. Assign students to write reports in which they investigate questions they may have about recycling. For example, what are the environmental benefits and costs of recycling? Is recycling less or more expensive than throwing waste in a landfill or burning it in an incinerator? What would be needed to recycle more types of plastics?

4. What products are recycled in your community?

a. Pick one product, and trace it from manufacturing to the waste stream. Is the path circular, product is recycled, or linear, product ends up in a landfill.

5. Bring several packaged items to class. (The packaging can be of any type, and the items should not be visible during the activity.) Ask students to determine why the manufacturer chose the particular packaging for each product. Can they identify potentially less-wasteful types of packaging for any of the products. This extension can be done in class or as a take-home assignment.

Plastics Recycling

IDENTIFYING PLASTICS

Plastics are very much part of our everyday lives. They hold the beverages we drink,keep our food fresh, carry water to our homes, and perform a number of other functions that we probably take for granted. Plastics come in a wide variety of shapes, sizes, and types.

As recycling has become more widespread, manufacturers have begun placing identification codes on the bottoms of most plastic containers. The codes include a letter designation and a number inside of a recycling symbol. Because not all plastics are recyclable, the codes identify the specific type of plastic and its recyclability.

PLASTICS IN THE HOME

For homework, identify the different types of plastics that your family uses on a regular basis. There are seven types of commonly used plastics; try to identify as many as you can. Prepare a list that identifies the product's code, how it is used, and the main characteristics of the plastic. Is it clear or opaque? Is it rigid or does it bend easily?

You should be prepared to discuss your list in class. After the discussion, you will conduct experiments on different samples of plastics to better determine their physical and chemical properties. You will test known samples as controls, and then test unknown samples against your results.

MATERIALS

Samples of the seven plastic types
Three unknown plastic samples

PROCEDURE

1. Obtain one sample of each type of plastic and label them accordingly. Carry out each of the tests on a separate small piece of each known sample, and record your results. Use your findings to create a flow chart.

2. Obtain each of the three unknown plastics. Test them to determine their properties, and compare your findings to your flow chart. What are they?

TESTS TO DETERMINE TYPE

1. Specific Gravity: Submerge the sample in water. Make sure no air bubbles are adhering to the surface of the plastic. Record whether the density is greater or less than water.

2. Copper Wire Flame Test: Using tongs, hold a copper wire in the flame of a Bunsen burner until it is red hot. Push the hot wire through the plastic sample. Place the wire back in the Bunsen burner flame, observe and record the color that comes from the wire.

3. Acetone test: Cover the sample in acetone in a small beaker. Observe any change in the surface of the plastic. Record a "+" if any reaction occurs and a "-" for no change.

4. Heat test: Using tongs place the sample in boiling water for 3 minutes. Record as "+" for softened and a "-" for no change.

5. Isopropyl alcohol test: Cover the sample in isopropyl alcohol in a small beaker. Record whether the sample floats or not.

6. Combustion Test: Cut a small corner off of the sample. Use tongs to hold it in the flame of the Bunsen burner until it ignites. Remove the sample from the flame and observe and record its color.

STUDENT DATA REPORT: Identifying Plastics

PLASTIC SAMPLE	SPECIFIC GRAVITY	CU WIRE	ACETONE	HEAT	ISOPROPYL ALCOHOL	COMBUSTION
PET						
HDPE						
PVC						
LDPE						
PP						
PS (rigid)						
Unknown #1						
Unknown #2						
Unknown #3						

Unknown #1 is ____________________

Unknown #2 is ____________________

Unknown #3 is ____________________

QUESTIONS

1. What factors must be present to make plastic recycling economically feasible?

2. Name three plastic items that you used today that may have been made from recycled plastic. What type of plastic do you think was used?

3. Why is one type of plastic used for one product and not another?

Chemicals in the Household

CHEMICAL PRODUCTS	HAZARDOUS INGREDIENTS	POTENTIAL HEALTH AND ENVIRONMENTAL EFFECTS	POSSIBLE ALTERNATIVES AND HINTS*
Toilet Cleaners	Muriatic (hydrochloric) acid Oxalic acid Paradichlorobenzene Calcium hypochlorite	COR, MECO K, COR, MECO L, N, K, MECO K, MECO	Toilet brush and baking soda; Mild detergent; Vinegar soak for tub and sink finishes. Avoid direct skin contact and breathing of fumes.
Drain Cleaners	Sodium or potassium hydroxide Sodium hypochlorite Hydrochloric acid Petroleum distillates	COR, IR, MECO COR, MECO COR, MECO CAN, D, MECO	Plunger; Flush drain with 1/4 cup baking soda and vinegar. Avoid direct skin contact and breathing of fumes.
Oven Cleaners	Potassium or sodium hydroxide Ammonia	COR, IR, MECO HECO, COR, IR	Baking soda and water; Avoid direct skin contact and breathing of fumes.
Bleach Cleaners	Sodium or potassium hydroxide Hydrogen peroxide Sodium or calcium hypochlorite	COR, IR, MECO MECO COR, MECO	1/2 cup of white vinegar or baking soda for laundry. Avoid direct skin contact and breathing of fumes.
Dishwashing Detergent	Chlorine Surfactants	LU, CAR, IR LU, CAR, IR, MECO	1 part borax to 1 part baking soda. Handle all cleaning solutions with care.
Ammonia-based Cleaners (All-purpose cleaners)	Ammonia Ethanol	COR, IR, HECO D, L	Vinegar and salt-water mix for surfaces; baking soda and water.
Glass Cleaners	Ammonia Naphthalene	D, L, MECO CAN, IR	Wash windows with 1/4 to 1/2 cup white vinegar to 1 quart warm water. Rub dry with newspaper.
Fabric Softener	Ammonia Cationic Surfactants	COR, IR, MECO HECO	1 cup white vinegar or 1/4 cup baking soda in final rinse water.
Air Fresheners	Cresol Phenol Formaldehyde	IR, SEN, L, K, LU, MECO IR, SEN, L, K, LU, MECO IR, SEN, L, K, LU	Open box of baking soda or dish of vanilla; simmer cloves. Open windows or use exhaust fans.
Laundry Detergent	Surfactants	IR, LU, MECO	Avoid breathing powder.
Mothballs	Naphthalene Paradichlorobenzene	CAN, IR, MECO L, K, N, CAN, MECO	Cedar chips; newspapers, lavender, flowers, or other aromatic herbs and spices
Rug and Upholstery Cleaners	Naphthalene Perchloroethylene Oxalic acid Diethylene glycol	CAN, IR, MECO K, D, R, N, CAN K, COR, MECO D	Baking soda on rug. Then vacuum.
Floor and Furniture Polish	Diethylene glycol Petroleum distillates Nitrobenzene Mineral spirits	D CAN, D R, CAR, L, MECO CAN, D	1 part lemon oil, 2 part olive/veg oil. Vegetable oil soap.

continued on page 70

APPENDICES

Chemicals in the Household, *continued*

CHEMICAL PRODUCTS	HAZARDOUS INGREDIENTS	POTENTIAL HEALTH AND ENVIRONMENTAL EFFECTS	POSSIBLE ALTERNATIVES AND HINTS*
Furniture Strippers	Acetone	FLAM, D, R, N	Equal portions of boiled linseed oil, turpentine, and vinegar with steel wool. Sandpaper or heatgun. Use in well-ventilated areas or outdoors. Handle all solvents with care.
	Methyl ethyl	D, R, N	
	Ketone	D	
	Alcohols	D	
	Xylene	N, K, L	
	Toluene	N, K, L, D	
	Methylene chloride	CAN, L	
Stains/Finishes	Mineral Spirits	CAN, D	Natural earth pigment finishes. Use in well-ventilated areas or outdoors. Handle all dyes and paints with care.
	Glycol ethers	D, R, BL	
	Ketone	D, R, N	
	Halogenated hydrocarbons	CAN, D, R, N, L, HECO	
	Naphtha	CAN, D	
	Xylene	N, K, L	
	Toluene	N, K, L, D	
Enamel or Oil-based Paints	Pigments	CAN, D, SEN, MECO	Water-based paints if appropriate; Always use in well-ventilated areas.
	Aliphatic Hydrocarbons	CAN, L, K	
Latex Paint	Mercury	N, D, R	Handle all paints with care.
Antifreeze	Ethylene glycol	N, K, D	Clean up all spills.
Automobile batteries	Sulfuric acid	COR, MECO	Bring old batteries to recycling center. Avoid direct skin contact. Wash spills with plenty of water.
	Lead	BL, N, D, CAN, HECO	
Automobile Lubricants (transmission and brake fluids, used oils)	Hydrocarbons (benzene)	N, CAN	Seal used oil in plastic container and bring to recycling service station.
	Mineral oils	D, CAN	
	Glycol ethers	D, R, BL	
	Heavy Metals	N, AC, K, L, CAN, MECO	

NOTES:

* The above listed alternatives are offered as options and are not presented as recommended courses of action.
* Several listed alternatives are also potentially hazardous and can cause harm if handled improperly.
* Various commercial products which fall into the product categories listed here may not contain all of the listed chemical constituents.

KEY TABLE:

AC	Acute toxicity
BL	Blood effects
CAN	Cancer
CAR	Cardiopulminary injury
COR	Corrosive
D	Developmental toxicity (birth defects, fetal toxicity)
FLAM	Flammable
HECO	High ecotoxicity
IR	Irritant
K	Kidney toxicity
LU	Lung effects
MECO	Moderate ecotoxicity
N	Neurotoxicity (nerve toxicity/poison)
R	Reproductive toxicity (sterility, decreased fertility)
SEN	Sensitization (immunological toxicity, allergic response)

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Spooner, Barbara and Jay Barracato. *Teach With Databases: Database Basics.* Arlington, VA: National Science Teachers Association, 1998.

Stapp, William B., Mare M. Cromwell, David C. Schmidt, and Andy W. Alm. *Investigating Streams and Rivers.* Dubuque, IA: Kendall/Hunt Publishing Company, 1996.

United States Environmental Protection Agency. *Toxics Release Inventory, 1987–1993 CD-ROM User's Manual.* Washington, DC: United States Government Printing Office, 1995.

INTERNET RESOURCES:

U.S. Environmental Protection Agency: http://www.epa.gov

Surf Your Watershed: http://www.epa.gov/surf

U.S. Geological Survey: http://www.usgs.gov

Environmental Mapping and Assessment: http://earth1.epa.gov/emap/

Recycler's World, Plastics Recycling Section:
http://www.recycle.net/recycle/Plastic/index.html

Lower Chesapeake Bay

HUC 02080101

These data are offered here as a general representation only.

LEGEND

- EPCRA TRI Site (Toxics Release Inventory)
- PCS Facility Site
- Basin Boundary USGS Catalog Unit
- County Boundary

1990 POPULATION DENSITY PER SQ MI

- Under 10
- 10-100
- 100-1000
- 1000-3000
- 3000-6000

0 1 2 3 4 5 6 7 8 9 10

MILES

Scale 1:250,000 Albers Projection

EPA

U.S. Environmental Protection Agency

Produced February 19, 1996

By BASINSINFO (Req b40174)