ENVIRONMENTAL CHEMISTRY

When you are finished this unit, you should be able to …

- identify organic and inorganic substances essential for growth and reproduction
- describe the process by which chemicals are cycled (nitrogen, carbon, water) and returned to their original form
- explain the difference between active transport, osmosis, and diffusion in the uptake of nutrients
- describe the labelling on a bag of fertilizer and the significance of using fertilizer
- recognize water and air pollutants and describe monitoring techniques
- identify acids and bases and describe how they relate to neutralization
- interpret and calculate chemical dosages
- describe mechanisms for natural and human chemical cleanup
- describe the transportation of chemicals by air, water, and soil

PREREQUISITE SKILLS AND KNOWLEDGE

Prior to beginning this unit, you should be able to …

- recognize some elements and their symbols
- understand what is meant by a cycle and how cycles work
- recognize some common acids and bases
- know how to safely clean up chemical spills
- calculate mathematically using ratios
- perform research on items related to chemical pollution
- do an investigation on water and air quality
- analyze and discuss environmental issues
- take accurate measurements during experimental testing

Lesson 1 CHEMICALS OF LIFE

Look around at your environment. What do you see? Trees, flowers, animals, water, rocks, and air. These are physical features. In this section, you will learn about the environment from the chemical point of view. You will learn how living things use chemicals and how they are affected by their presence. Chemicals can be grouped into **inorganic** substances and **organic** substances.

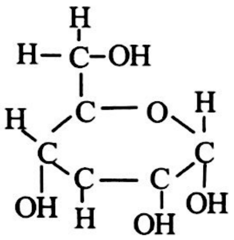
Inorganic substances generally do not contain the element carbon. Two exceptions are carbon dioxide and carbon monoxide. Examples of inorganic substances include water, potassium, salt, and oxygen gas.

Organic compounds **contain** the element **carbon** bonded together to make long chains of molecules. The carbon atom is always bonded to the hydrogen atom and in most cases to the oxygen atom, too. Examples of organic substances include glucose sugar, protein, and fat. There are many more organic chemicals than there are inorganic chemicals.

Inorganic chemicals: do not contain the element carbon

Organic chemicals: contain the element carbon

What does the glucose molecule look like?



All living things are made up of organic or inorganic substances and depend on them for survival. Organic compounds have three major elements—**carbon, oxygen, hydrogen**—in their molecular structure. Sometimes these elements are attached to minor elements such as nitrogen, magnesium, or sulfur. For example, nitrogen is bonded to hydrogen, carbon, and oxygen to produce amino acids (NH_2CH_2COOH).

Carbon, hydrogen, oxygen, and nitrogen (C,H,O, and N) are the building blocks of proteins.

Amino acids are the building blocks of protein and are required for growth and repair.

NUTRIENTS

Living things obtain many of the nutrients from their **substrate**; that is, from the material they live on. A mushroom on a fallen tree obtains its food from the rotting log. The nutrients obtained from the log are required by the mushroom for living, growing, and reproducing. Nutrients are grouped into two categories: **macronutrients and micronutrients.**

Macronutrients: elements required by living organisms in large amounts

Macronutrients are elements required in fairly **large amounts.** They include three common elements: *carbon, hydrogen, and oxygen* and several less common elements: nitrogen, phosphorous, potassium, magnesium, calcium, and sulfur. **Micronutrients** are elements such as selenium that are required by living things in **trace** or extremely small amounts.

Micronutrients: elements required by living things in trace amounts

Lesson 2 MAINTAINING A BALANCE

NOTES

Macronutrients and micronutrients are essential for plant and animal growth and survival. They are the building blocks of body structure and the source of energy. The table summarizes the importance of macronutrients in the survival of plants and animals.

Plants and animals require nutrients in **optimum amounts** to maintain a balance. That is, the most favourable amounts for the best health. An overdose is as harmful as not having enough.

Macronutrient	Importance to Plants	Importance to Animals
Carbon	Component of organic food	Component of organic food
Hydrogen	Component of organic food	Component of organic food
Oxygen	Component of organic food	Component of organic food
Nitrogen	Basis of chlorophyll	Component of protein
Phosphorus	Root and flower development	Component of bones and DNA
Potassium	Stimulates early growth	Muscle contraction
Magnesium	Component of chlorophyll	Component of bones
Calcium	Cell division	Component of bones
Sulfur	Production of fruit	Protein synthesis

Main organic compounds:
- carbohydrates
- lipids (fats)
- protein
- nucleic acids

There are four classes of organic compounds essential to healthy body makeup. They are:
- carbohydrates
- fats (lipids)
- proteins
- nucleic acids

Metabolism: all of the physical and chemical reactions in an organsim

Carbohydrates, obtained from foods such as rice, potatoes, and fruits, form simple and complex sugars and are required for body metabolism. Carbohydrates provide energy.

Lipids, found in foods such as walnuts and peanuts, form saturated and unsaturated fats and are needed for providing more energy.

Proteins, obtained from meats, fish, and eggs, are used for growth and repair. Proteins are made from amino acid units joined together.

Nucleic acids play an important role in heredity and cell division. There are two types of nucleic acid:

- deoxyribonucleic acid (DNA)
- ribonucleic acid (RNA)

DNA, RNA: play a role in heredity and cell division

DNA: deoxyribonucleic acid

RNA: ribonucleic acid

In terms of human consumption, all of the macronutrients that are necessary for maintaining health and preventing disease can be found in a balanced diet. Excesses or deficiencies of these nutrients have profound effects on mental and physical well-being.

Carbohydrates provide 50% of the metabolic energy for a human body, and play an important role in cell growth and development. A low carbohydrate intake leads to a condition known as ketosis, which creates an acidity of the blood and creates a number of negative health effects, including dizziness, confusion, nausea, and a loss of body water and minerals. On the other hand, excessive consumption of carbohydrates, particularly simple starches and sugars, can lead to obesity and high blood-glucose levels.

Fatty acids and lipids form an important part of body energy, and are closely linked with blood-clotting and the prevention of heart disease. Most fatty acids can be broken down into two groups - Omega-3 fatty acids and Omega-6 fatty acids. A deficiency in Omega-3 fatty acids is associated with depression and other psychological disorders, and a large imbalance between the two types of fatty acids can either lead to an increased risk of heart attack and stroke if there is not enough Omega-3, or hormonal and fluid imbalances in the case of a lack of Omega-6 fatty acids.

Proteins form essential building blocks of tissues and organs. However, while the body can store carbohydrates and fats, it cannot store the amino acids which constitute protein molecules, which means that a daily intake of protein is necessary for stable body metabolism. Of the 20 types of amino acids which the body requires, 9 are considered essential and a diet which does not provide a balanced intake of these amino acids leads to severe health conditions. Studies have shown that a low protein diet can lead to anemia as well as a number of enzyme and hormone disorders, while an excessive consumption of protein has been linked with poor bone composition, infections and immune system problems.

It is important to consider that while the human body needs many important nutrients in order to sustain healthy growth and maintenance, it is more effective to consider intake of these nutrients in terms of proportion to one another rather than simply in terms of quantity. Balance is the most important factor in terms of survival and development.

Lesson 3 UPTAKE OF MATERIALS AND NUTRIENTS

Both plants and animals absorb nutrients into their cells. To accomplish this, specialized processes are used. Plant roots are chemotropic (respond to chemical nutrients) and grow toward the nutrient source. Once the root is close to the source, water in the soil brings the nutrient in contact with the root cells. This is accomplished in three ways:

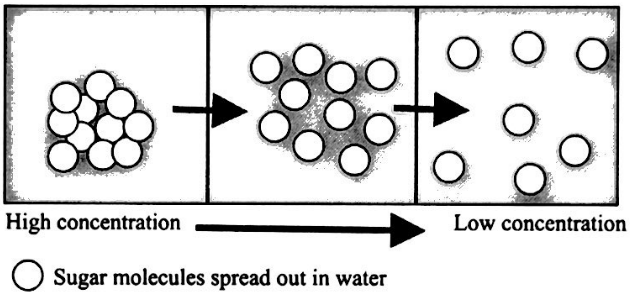
- diffusion
- osmosis
- active transport

Methods of water and nutrient transportation:

- diffusion
- osmosis
- active transport

In **diffusion,** the concentration of nutrients outside the cell is greater than inside. The molecules move from a solution of a higher concentration to one of a lower concentration until a balance is maintained.

Diffusion

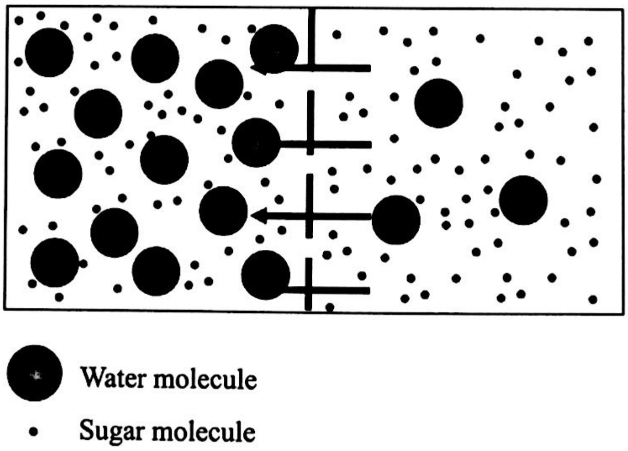


Glucose produced in chloroplasts dissolves in the watery cell and *diffuses* throughout the cell.

In **osmosis,** water is drawn into the cell because the concentration of the nutrient inside the cell is greater than it is outside the wall. Water moves through a *semipermeable membrane* from an area where there is more water molecules to an area where there are fewer water molecules.

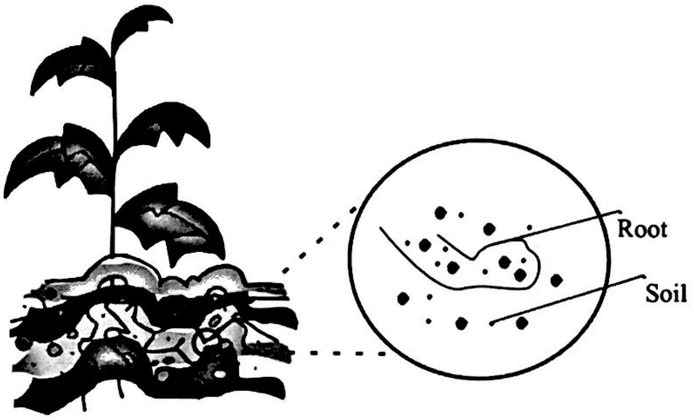
Semipermeable membrane: a membrane that allows certain small particles to pass through it, but that prevents larger particles from doing so

Osmosis



In **active transport**, plants use energy to move materials from a source of low concentration to high concentration. This is opposite to that of diffusion. Energy is used to move nutrients from the soil into the root cells.

Active transport



Plants use energy to move nutrients into root cells.

Animals get the substances necessary for survival by inhaling air and ingesting food. Oxygen gas is inhaled into the lungs when animals breathe, and food enters the digestive system when animals eat. Ingested food is broken down by the digestive process into smaller particles that enables them to pass through the cell wall. This process of breaking down complex molecules into simple molecules by using water is called **hydrolysis.**

Hydrolysis: reaction using water to break down complex organic molecules into simple ones

For example, complex starch molecules are broken down into smaller glucose molecules by hydrolysis. The word equation for this reaction is:

starch + water → maltose sugar

maltose + water → glucose sugar

Glucose molecules are small enough to pass through the membrane wall.

Lesson 4 CYCLES OF LIFE

To constantly replenish the energy in an ecosystem, chemicals must be cycled through living organisms and their environment. These chemicals enter producers, pass through consumers in food chains, and are returned to the nonliving environment by decomposers. Nitrogen, carbon, and water are the most important elements recycled through organisms and their environments.

3 natural cycles:

- carbon
- nitrogen
- water

NITROGEN CYCLE

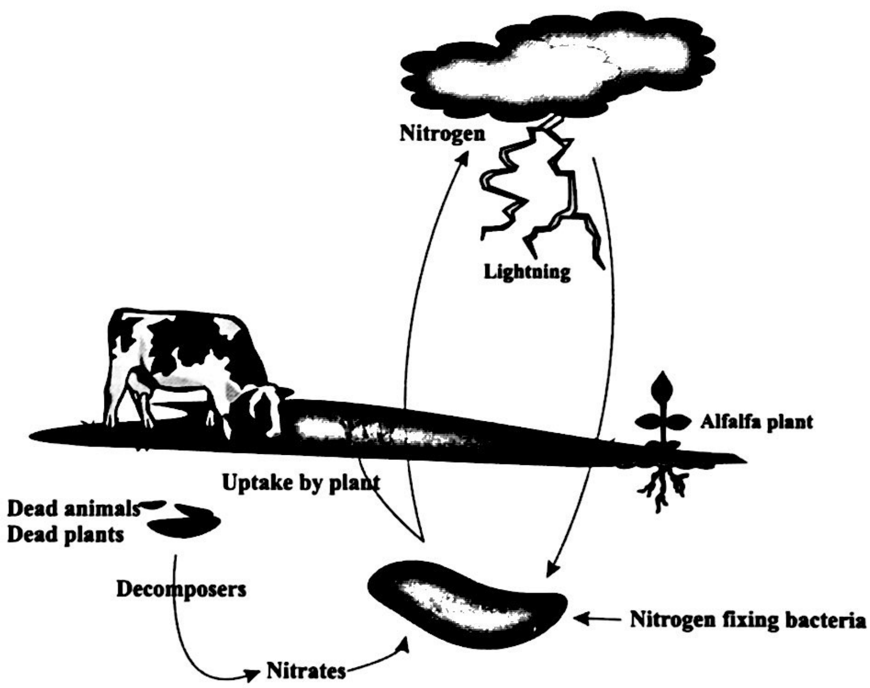
Green plants absorb nitrates from the soil through their root system. The nitrates are converted to amino acids and become the building blocks for proteins. Consumers rely on the plant protein for their energy source. Bacteria decomposers break down the protein in dead organisms, eventually converting it back to nitrates. The cycle is repeated.

Most organisms are unable to use nitrogen (N_2) unless it is joined to other elements.

Nitrogen-fixing bacteria found in the plant nodes or nodules of legumes such as peas, beans, clover and alfalfa, convert nitrogen from the air into nitrates. Lightning, too, converts nitrogen gas into nitrates.

Legumes: plants such as peas and alfalfa that have nitrogen-fixing nodules to convert nitrogen gas into nitrates

Nitrogen Cycle

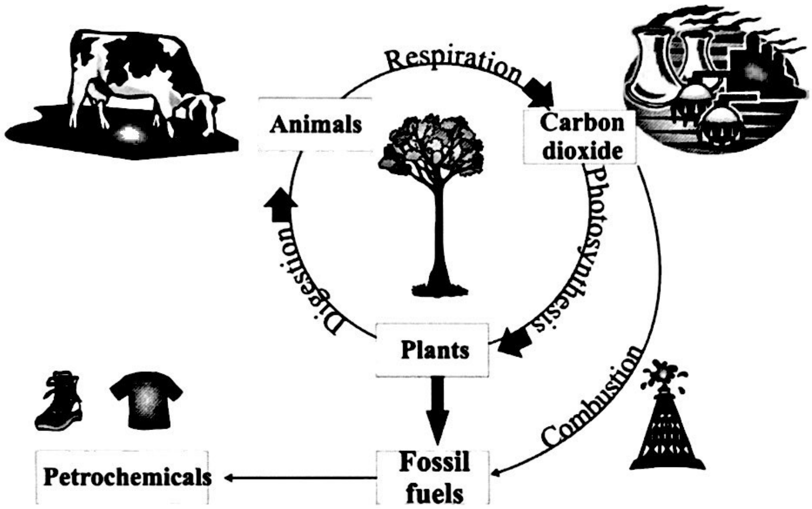


Nitrogen Fixation: reaction of N_2 with other compound so that it can be used by living organisms.

NOTES

CARBON CYCLE

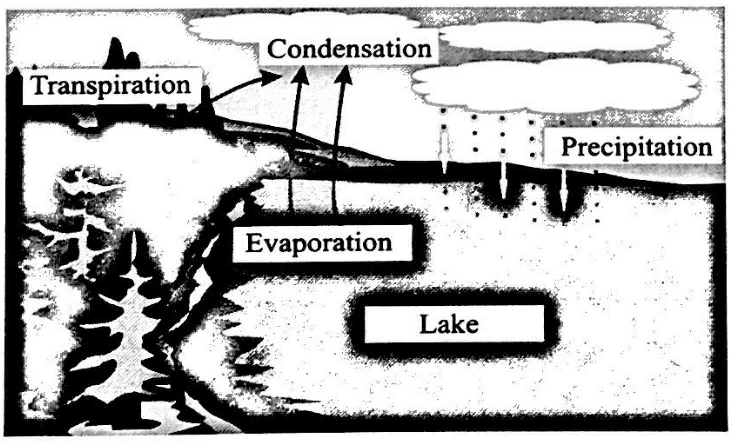
In the carbon cycle, carbon passes from the environment into living things and back to the environment. The carbon in carbon dioxide gas is used during photosynthesis to manufacture food in the form of glucose sugar. The food is eaten by consumers. The food is then broken down in the consumer by cellular respiration into carbon dioxide gas. The cycle is repeated.



WATER CYCLE

Water passes from the atmosphere to Earth and back to the atmosphere. The sun's heat changes the water in lakes and oceans into water vapour. The process is called **evaporation**. Water vapour is also released from the leaves of green plants through the process of **transpiration**. As the water vapour rises into the atmosphere, it cools and **condenses** into a liquid. This is evident in the formation of clouds. A liquid falls back to Earth in the form of **precipitation** (rain or snow). The cycle is again repeated.

Water Cycle



Transpiration: process through which plants lose moisture through their stems and leaves

Condensation: process through which a vapour becomes a liquid

Human activities release chemicals into the air, soil, and water on a daily basis. There are many issues and concerns about releasing chemicals into the environment and disrupting the natural cycles and balance of nature.

Farmers supplement soil with **fertilizers** to increase crop yields. Fertilizers contain the nutrient substances necessary for healthy plant growth.

Example

The three numbers on the label of a container of fertilizer indicate the nutrient elements present in the fertilizer.

Number	**Element**	**Percentage**
11	Nitrogen	11 %
52	Phosphorous	52 %
12	Potassium	12 %

DDT stands for dichloro-diphenyltrichloroethane

Classification of pesticides:

– Herbicides (control weeds)

– Insecticides (control insects)

– Fungicides (control fungi)

Effluent: treated clean water that is returned back to rivers and lakes

Fertilizer use should be carefully monitored. Overuse can result in chemicals leaching into the groundwater, affecting the quality of water. This is evident in areas where two crops of fruits and vegetables are grown in a single season.

Farmers and homeowners use herbicides to get rid of weeds, insecticides to kill insects, and fungicides to control mould and fungi. The practice of using pesticides can have a negative effect on the environment. The use of herbicides, insecticides, and fungicides affects the food chain in an ecosystem. An example of this was the use of DDT to control the mosquito insect population in the mid-1900s. It was found that the DDT concentration increased in the higher levels of the food chain and the animals at the top were most affected. This is referred to as biomagnification. DDT affected the reproductive ability of the peregrine falcon by causing the females to lay thin-shelled eggs.

NOTES

Wastewater, if left untreated, becomes a breeding ground for harmful bacteria. That is why wastewater coming from homes and industry is treated at a sewage treatment plant and released back into the river and lakes as clean water called **effluent**. The treatment process involves three stages: physical, biological, and chemical.

- Physical: much of the larger material is filtered out by screens
- Biological: organic sewage material is decomposed by the action of bacteria
- Chemical: chemicals are added to remove inorganic phosphates and nitrates

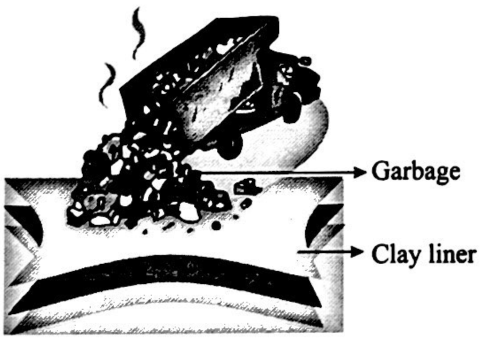
Wastewater in rural areas is usually collected in septic tank systems. Wastes are decomposed by bacteria in a septic tank, and the liquid is pumped out into a field.

In cities, street water enters the storm sewers. It carries with it salt from snow-clearing operations, oil from leaking car engines, and pesticides from lawn care into the river system. This water is untreated, and the pollutants become part of the river water.

Solid wastes and garbage contain chemicals that can affect the environment. Many of the solid wastes are disposed in a sanitary landfill site. A landfill is a carefully selected site that is lined with a thick clay layer or plastic to prevent seepage. Occasionally, seepage does occur and the leachate enters the groundwater supply.

The burning of fossil fuels has a considerable impact on air and water quality. The release of carbon dioxide and sulfur dioxide gases into the air adds to the problem of global warming and acid rain contamination.

Sanitary landfill



Lesson 5 ACIDS AND BASES

NOTES

Indicator: substance that identifies an acid or a base by a colour change

Your grocery purchase includes lemons, milk, tomatoes, and soap. Have you purchased an item that is acidic, neutral, or basic? An **indicator** will help determine which category various items fit into.

ACIDS

Acids are compounds that release **hydrogen ions (H+)** when placed in water. The more hydrogen ions that are released, the greater the acidity of the compound.

Strong Acids	**Weak Acids**
Hydrochloric acid	vinegar
Sulfuric acid	acetylsalicylic

Acids tend to **be sour in taste and are readily soluble in water**.

It is important for gardeners to know the chemical nature of the soil. They buy fertilizers that supplement soil deficiencies. Acidic soil requires fertilizer containing potash to make it less acidic. Manufacturers of car batteries use sulfuric acid to provide the reaction required for producing an electrical current. Stomach acid helps breakdown food protein into forms that can be absorbed into the blood stream.

BASES

Bases are compounds that release **hydroxyl ions** $\mathbf{(OH)^-}$ into water. Bases are **slippery to the touch, bitter in taste, and soluble in water**. Bases, too, are important in our lives. Baking soda makes cakes and bread rise. Soaps and shampoos are used for cleaning.

INDICATORS

Universal Indicator: pH is the most commonly used acid–base indicator

An indicator is a chemical substance, usually obtained from plant material that changes colour in the presence of an acid or base. The most common indicator is called the **universal indicator**. It comes as a special bottled solution or paper dipped in this solution (pH paper). Several other types of acid–base indicators include litmus and red cabbage juice.

The universal indicator changes to different colours in different substances. The colour is compared to a pH scale and the pH number of the substance is determined.

pH Scale:

0 to 6 acidic

7 neutral

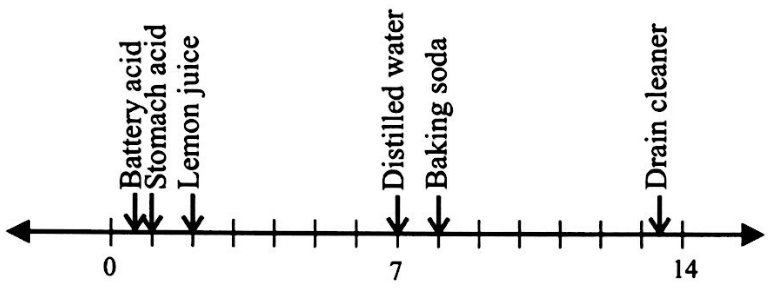
8 to 14 basic

The pH scale is designed to indicate the concentration of hydrogen ions in a solution. A pH scale ranges from 0 to 14. Acids fall in a range from 0 to 6, neutral substances are 7, and bases range from 8 to 14. A pH test paper is dipped into a solution and the colour produced is compared with a commercial colour scale. A reddish colour indicates a pH of 1, green indicates pH of 7, and blue indicates pH of 14.

The following lists the pH of common acids and bases.

- Battery acid pH 0.7
- Stomach acid pH 1.0
- Lemon juice pH 2.0
- Distilled water pH 7.0
- Baking soda pH 8.0
- Drain cleaner pH 13.5

PH Scale



A substance with pH 1 is a strong acid whereas a substance with pH 5 is a weak acid. A substance with pH 8 is a weak base whereas a substance with a pH of 14 is a strong base.

As the pH of a substance increases or decreases, the acid concentration increases or decreases. Every number on the pH scale represents a difference in concentration by a factor of 10. A pH reading of 4 is 100 times more acidic than a pH of 6. Similarly, a pH of 11 is 1 000 times more basic than a pH of 8.

Litmus paper indicates whether a substance is an acid or a base.

Indicator	Acid	Base	Neutral
Red Litmus	No change	Blue	No change
Blue Litmus	Red	No change	No change

Using a universal indicator has the **advantage** of determining how strong or how weak the acid or base is. Cabbage juice is a universal indicator that changes to many different colours just like universal indicator.

Neutralization reaction:

Acid + base
→ salt + water

NEUTRALIZATION

Strong acids and strong bases are corrosive and can be dangerous if not handled properly. Should the need arise, a strong acid can be neutralized with a strong base. The process of **neutralization** involves mixing an acid with a base to produce **salt** and **water**.

The word equation for a neutralization reaction is expressed as:
Acid + Base → Salt + Water

Example 1

Limestone (calcium hydroxide) is added to an acidic lake to neutralize the water.

Solution

calcium hydroxide + sulfuric acid → calcium sulfate + water

$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + H_2O$

base acid salt water

Example 2

sodium hydroxide + hydrochloric acid → sodium chloride + water

Solution

$NaOH + HCl \rightarrow NaCl + H_2O$

base acid salt water

Lesson 6 WATER QUALITY

Water is a crucial resource for Earth. It is used for drinking, recreation, irrigation and as a habitat for living organisms. The Government of Alberta has set high standards for acceptable levels of chemical pollutants and micro-organisms in our water supplies. It is important that the quality of the water supply be monitored using both biological and chemical indicators.

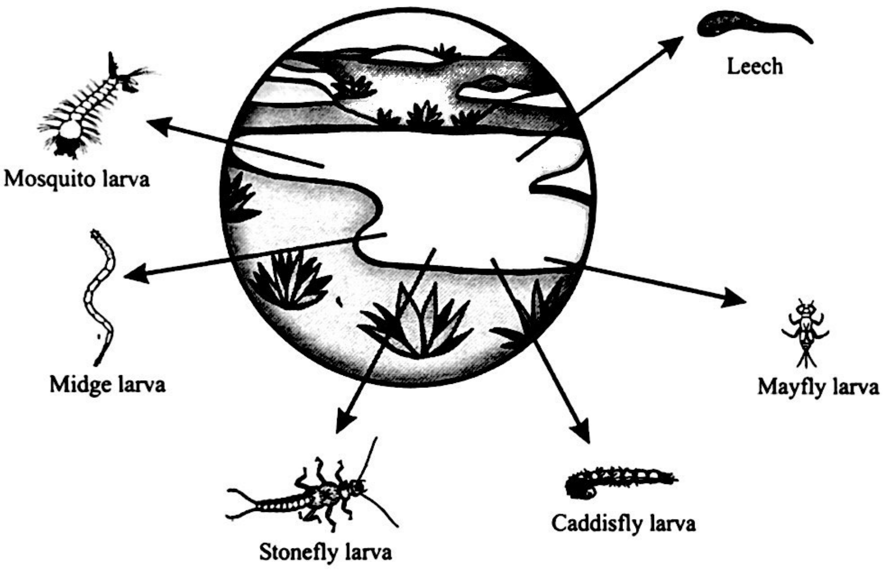
BIOLOGICAL INDICATORS

Invertebrate aquatic organisms are an excellent indicator of water quality.

Biological indicator: aquatic invertebrates used to monitor water quality

Invertebrate: animal without a backbone

Pond Organisms



Factors such as temperature, pH, and dissolved oxygen affect the kind of organisms found in water habitats. Organisms living in a stagnant pond are different from the ones living in a stream or large lake.

Biological Indicators of Dissolved Oxygen in Water		
Poor Quality (0–4 parts/million of oxygen)	**Moderate Quality** (5–8 parts/million of oxygen)	**Good Quality** (9–10 parts/million of oxygen)
Midge larvae Leech Mosquito wriggler	Freshwater clam Dragonfly nymph Fairy shrimp	Caddisfly larvae Stonefly larvae Mayfly larvae

Dissolved oxygen: oxygen mixed with air

ppm: parts per million

If the water supply has many midge larvae, some leeches, and no caddisfly larvae, it has little dissolved oxygen and is of a poor quality. If the water has caddisfly and mayfly larvae, it is rich in dissolved oxygen and is of good quality.

NOTES

Chemical indicator: a substance used to determine a specific characteristic of water, such as mercury in a thermometer or phenol phthaline to measure pH.

Government regulations enforce testing of water for organic and inorganic chemical compounds. Dissolved oxygen, acidity, heavy metals, plant nutrients, and pesticides all affect the quality of water and their concentration is frequently monitored.

The concentration of chemicals is measured in **part per million** (ppm) or **milligrams per litre** (mg/L).

A concentration of 4 ppm of chlorine in water means there is 4 parts chlorine in 1 million parts of chlorine/water solution.

A concentration of 8 mg/L of dissolved oxygen in the water is equal to 8 ppm. This is mathematically determined by using ratios.

Concentration of chemicals is measured in:

– ppm (parts per million)

– mg/L (milligrams per litre)

8 mg / L = 0.008 g/1 000 g

Set up a ratio:

$$0.008 \,/\, 1\,000 = y \,/\, 1\,000\,000$$
$$1\,000 \times y = 0.008 \times 1\,000\,000$$
$$1\,000\,y = 8\,000$$
$$y = 8 \quad \text{or 8 ppm}$$

Solute: chemical in a solution

Extremely low concentrations are occasionally encountered and must be measured in part per billion (ppb) or in parts per trillion (ppt).

Conversion:

0.2 mL of chemical in 1 000 L of H_2O

$$\frac{0.2}{1000} = \frac{\times}{1\,000\,000}$$

= 200 ppm

MICRO-ORGANISMS

E. coli and other disease-producing organisms are found our water supply. Constant monitoring determines what needs to be done to control their numbers. Proper monitoring could have prevented the catastrophe that occurred in Walkerton, Ontario, in May 2000. Eleven people died from *E. coli* bacteria poisoning by drinking contaminated water.

***E. coli*:** a harmful bacteria

DISSOLVED OXYGEN

An acceptable level of dissolved oxygen for aquatic life is between 5 and 8 ppm. The amount of dissolved oxygen in water is dependent on:

- temperature
- turbulence
- decay

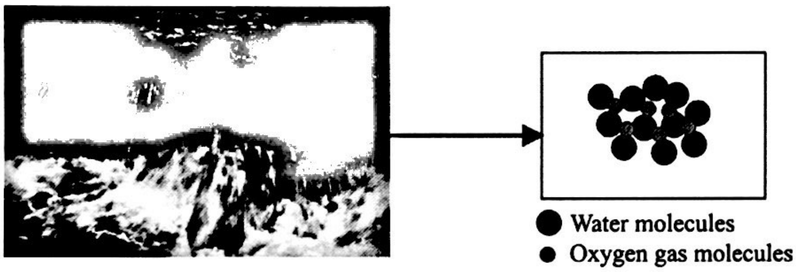
TEMPERATURE

Cold pop contains more carbon dioxide and fizzes more than warm pop. Similarly, cold water contains more dissolved oxygen than does warm water. Because living things depend on the amount of available oxygen, cold water streams have a greater diversity of living species.

TURBULENCE

Oxygen from the air has a better chance to mix and dissolve in turbulent water. Oxygen gas molecules squeeze in between the water molecules more readily in fast-moving streams.

Turbulence: state of being disturbed



DECAY

Fertilizers used by farmers and homeowners are beneficial in one sense but harmful in another. The phosphorous and nitrogen fertilizers often leach into the soil or are carried into nearby lakes. Once dissolved in lake water, the nutrients promote rapid plant growth. Plants grow out of control until the nutrients become depleted. When there is no longer a food supply available, the plants die and start to decay. Aerobic bacteria use oxygen during the decay process, leaving little for the aquatic organisms. This process of decay that causes oxygen depletion is called **eutrophication.**

ACIDITY CONTENT

The pH of rain water is slightly acidic, about 5.6. Most organisms can survive at this level. If the pH drops below 4.5, fish and other aquatic organisms soon die. As mentioned previously, the burning of fossil fuels contributes to high sulfur dioxide and nitrogen oxide concentrations in the atmosphere. When sulfur dioxide and nitrogen oxide combine with water vapour, rain containing sulfuric acid and nitrous acid falls. This acidic rain —known as acid rain—enters the soil and water supply. Organisms exposed to acidic water go into **acid shock.** This affects their reproductive ability.

Eutrophication: process of decay that depletes the oxygen supply

Rain water has a slightly acidic pH (5.6)

Acid shock: conditions that organisms undergo in acidic water

NOTES

PESTICIDES

Some pesticides have long-term effects and remain in the environment for many years. DDT is a good example of such a pesticide. DDT was used as an insecticide to control mosquitoes and other insects in the mid-1900s. Its use is now banned in Canada. It was found that DDT was cumulative in the food chain. The peregrine falcon and other birds of prey were particularly affected by DDT. The high DDT concentration in the body of these birds affected their reproductive process, causing the female to lay very thin-shelled eggs. The eggs cracked before hatching.

It was also noticed that many insects developed a tolerance to the chemical pesticide and were no longer effectively control by it.

Toxicity: measure of how poisonous a substance is

LD50: measure of toxicity

TOXICITY

The use of pesticides and combinations of pesticides can produce a poisoning effect. This is referred to as the chemical's **toxicity**. Toxicity describes **how poisonous a substance is.**

Toxicity is measured by a scale called the Lethal Dose 50, or LD50. "LD" stands for lethal dose and "50" refers to 50%. LD50 is the amount of chemical that causes 50% of the population to die if given the specified dosage at once.

EXAMPLE

The LD50 dosage for DDT on rats is 87 mg/kg. Half of the rats in a population would die if given a dosage of 87 mg/kg of DDT.

Heavy metals have a density greater than 5 g/cm^3.

HEAVY METALS

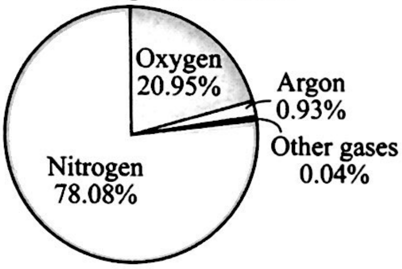
Many of the fish caught in Alberta lakes are unfit for human consumption because of high mercury content. Mercury, along with copper, lead, zinc, cadmium, and nickel are classified as **heavy metals. Their density is greater than 5 g/cm3**. This means that, for an equal volume, the metal contaminant is more than five times heavier than water. Some of the heavy metals are found naturally in rock formations and are mined for use in the manufacture of batteries, gasoline, paint, and thermometers. Improper disposal of heavy metals can lead to soil and water contamination.

Lesson 7 AIR QUALITY

NOTES

Air is a blend of several gases. It is just as important as water for sustaining life.

Composition of Air



The quality of air should be carefully monitored and good air quality maintained. Collecting data about chemicals in the air provides information about immediate and long-term trends. There is presently concern about emissions of sulfur dioxide, nitrogen oxide, carbon dioxide, and chlorofluorocarbons into the atmosphere and the effect of these emissions on the environment.

Fossil fuel pollutants:

- carbon dioxide (CO_2)
- sulfur dioxide (SO_2)
- nitrogen dioxide (NO_2)

SULFUR DIOXIDE

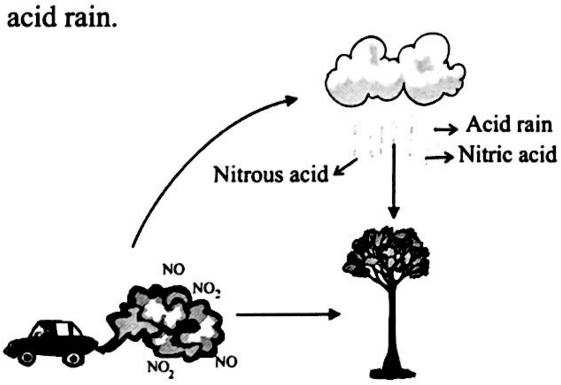
Industrial burning of fossil fuels has contributed to an increase in sulfur dioxide emissions. The burning of coal in the production of electrical power is one of the leading causes of sulfur dioxide pollution.

Sulfur dioxide combines with moisture in the air to produce acid rain. Sulfur dioxide in precipitation lowers the pH of soil and lakes, making them more acidic in nature. Most living organisms cannot survive in conditions with a pH less than 4.5

SO_2, NO_2, CO_2 + rainwater → acid rain

NITROGEN OXIDES

Nitrogen and oxygen combine to form compounds of nitrogen oxide (NO) and nitrogen dioxide (NO_2). Both of these are a common byproduct of vehicle exhaust. Nitrogen oxide and nitrogen dioxide combine with the water in the air to produce a nitrous and nitric acid, another form of acid rain.



The Great Lakes of eastern Canada have become acidic in nature. This is mainly a result of the emissions from the vast numbers of industry and vehicles in the area. The changing acidic nature of the soil and water has caused large areas of trees and many aquatic organisms to die. This indirectly affects food chains and the balance within the ecosystem.

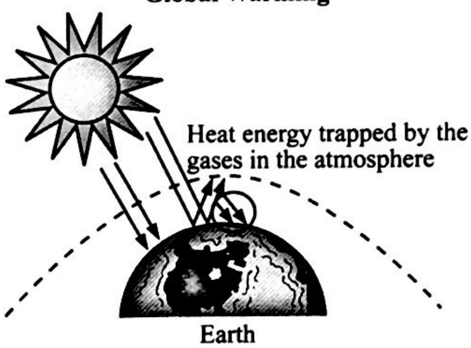
CARBON DIOXIDE

Carbon dioxide gas is part of the natural carbon cycle. It is required for photosynthesis by plants and is produced during respiration by animals. With emissions of carbon dioxide gas by industry and vehicles, the amount of CO_2 accumulating in the atmosphere has increased.

Carbon dioxide, along with nitrogen oxide and methane gas, contributes to the **greenhouse effect**. These gases in the atmosphere act like glass in a greenhouse. They trap heat from the sun and prevent it from being reflected back into space.

Greenhouse effect: trapped atmospheric gases prevent reflected sunlight from losing heat in space

Global Warming



As a result of trapped gases, the average global mean temperature has gone up by 0.5°C over the past 150 years, producing a phenomenon called **global warming**. Scientists believe that global warming has an affect on climate and may be one of the causes that produce the severe weather patterns we are experiencing throughout the world.

Global warming: increase in average mean global temperature

Scientists believe that human activities such as clearing and burning large areas of rainforest are contributing factors in increased atmospheric carbon dioxide levels. Combustion (burning) produces carbon dioxide that accumulates in the atmosphere. Cleared land reduces the number of trees available to use up carbon dioxide during photosynthesis. The result is more CO_2 in the atmosphere. This situation is referred to as **enhanced greenhouse effect**.

NOTES

THINK ABOUT THIS!

What is going to happen in the future if the rate of global warming continues? Perhaps:

- ecological boundaries will shift farther northward
- permafrost in Canada's north will continue to melt
- water levels in the lakes will drop
- polar ice caps will continue to melt
- weather patterns will change

CHLOROFLUOROCARBONS (CFCS)

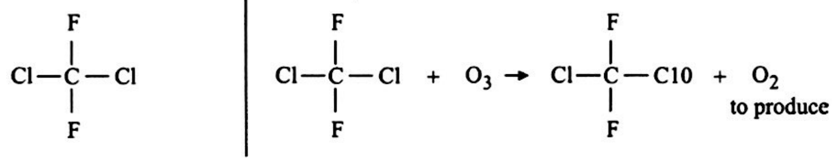
At one time, chlorofluorocarbons (CCl_2F_2) were commonly used in aerosol spray cans, air conditioners, and refrigerators. Then, it was discovered that CFCs released into the atmosphere combine with the ozone molecule (O_3) in the air to produce oxygen gas (O_2) molecules. Each chlorine atom removes up to 100 000 ozone molecules. This reaction reduces the thickness of the ozone layer and the protection it provides from harmful ultraviolet rays.

CFC: chlorofluorocarbon

Ozone: O_3

Oxygen gas: O_2

Structure of the CFC Molecule | Ozone Depletion



By changing the ozone molecule to oxygen, CFCs deplete the ozone supply and cause a thinning of the ozone layer. Satellite images have shown that holes in the ozone layer exists, particularly at the poles.

CFC formula: Cl_2F_2C

changes ozone to oxygen gas; this depletes Earth's protective ozone layer

Hole in ozone layer in Antarctica | Hole in ozone layer in Antarctica

1998 | 2001

The sun's ultraviolet light is partially absorbed by the ozone gas. When the layer becomes thin, more UV rays pass through and strike Earth. An increase in skin cancer is directly related to an increase in ultraviolet light.

OZONE

Atmospheric ozone is beneficial. It prevents excess ultraviolet rays from reaching Earth. **Ground-level ozone** is harmful. Ground-level ozone forms when oxygen reacts with volatile organic compounds (VOCs) found in gasoline and solvents. Large quantities of ground-level ozone are harmful to people with lung disease and often cause respiratory problems.

VOC: volatile organic compounds

– found in paints, varnishes, and waxes

– react with O_2 to increase ground-level ozone

Lesson 8 DISPERSAL OF CHEMICALS IN THE ENVIRONMENT

Chemicals do not remain isolated in one area. They are transported to other areas by wind, water, and soil. **Dioxin** is a highly toxic chemical found in pesticides. Traces of dioxins were detected in the Arctic, an area where pesticide spraying does not occur. How did they get there?

NOTES

Dioxin: toxic chemical found in pesticides

Prevailing winds: direction from which winds blow most frequently; Alberta's prevailing winds are from the northwest

Ground water: water trapped in porous rock below Earth's surface

Water table: top level of the ground water level

Disperse: to spread out

Impermeable: nothing can pass through

Semi-permeable: only certain materials pass through

DISPERSAL BY AIR

Scientists found that the source of the dioxins in Nunavut was incinerators and metal process factories in United States. The dioxins were carried by prevailing winds that blow over eastern Canada from the southeast. Alberta's prevailing winds are from the northwest. Many of Alberta's airborne pollutants originate in Asia.

Prevailing Wind Pattern

The transport of chemical pollutants by air is a three stage process.

Release of the chemical from a specific area → Dispersal of the chemical in the atmosphere by wind currents → Deposition of the chemical in soil or water in a different place

DISPERSAL BY WATER

Precipitation in the form of rain and snow filters through the pores in the soil and collects above an impermeable rock layer. This water is referred to as ground water, and the top level of the ground water zone is called the water table. It is estimated that about 25% of the Canadian population relies on ground water for domestic consumption.

Many chemical pollutants leach into the ground water. Some of the more common pollutants are:

- natural elements such as iron, calcium, and selenium
- organic pollutants, such as pesticides and solvents, produced by humans
- heavy metals such as lead, mercury, cadmium, inorganic fertilizers, and household chemicals detergents, produced by industry

These ground water pollutants accumulate and become concentrated in specific areas of soil and rock. Because water moves through soil and rock very slowly, it is unable to dilute or carry away the polluting chemicals. It is almost impossible to clean up contaminated ground water. The best solution is prevention—avoid contamination in the first place.

Chemical pollutants are also transported by surface water. Fast-moving river water dissolves the chemical solute and carries it downstream. It is therefore important for communities along rivers to monitor the quality of their water at all times.

DISPERSAL IN SOIL

Leachate is the liquid solution formed when a chemical dissolves in water as it passes through the soil. The composition of the soil affects the rate at which the leachate moves. Porous, sandy soil contains spaces between particles and allows a more rapid movement than does fine clay soil.

BIOMAGNIFICATION

Chemicals that enter the environment often end up in the food chain of living organisms. Mercury emissions from coal-fired power plants end up in lakes and are absorbed into the body of producers such as algae. An insect that lives in the water may have some mercury in its system and then accumulates more when it eats the algae. A fish that eats the insect accumulates the mercury from both the algae and insect. The animals at the end of a food chain are most affected. This increase in concentration of a chemical as it moves up the food chain is called **biomagnification**.

The fish in many Alberta lakes are not recommended for eating because of their high mercury content.

Solute: solid part of a solution of salt in a salt-water solution

Leachate: liquid mixture formed as water passes through chemicals in the soil

Biomagnification: "bio" means life; "magnification" means to make larger; therefore, biomagnification is an increase in concentration of chemicals in a food chain

Food chain: pathway of energy flow from one organism to another

Lesson 9 CHEMICAL CLEANUP AND SAFETY

NOTES

A gas station has a leaking underground tank: the soil around it becomes contaminated. A chemical spill occurs on a major highway from an overturned transport truck: a nearby stream becomes polluted.

Harmful chemicals must be cleaned up quickly. This can be done by **diluting** or **dispersing** the chemicals.

DISPERSION AND DILUTION

A farmer accidentally spills too much fertilizer on a small section of pasture grass that is being fertilized for a better crop yield. If left in a pile, the high concentration of chemical will kill the grass. To prevent this, the farmer can do one of two things:

- disperse the fertilizer and spread it out eventually over a large area
- dilute the chemical fertilizer with plenty of water

Nature has a way of breaking down chemicals and cleaning up contaminated areas.

BIODEGRADATION

"Bio" refers to living things and "degrade" means breaking apart. Leaves that fall from the trees in the autumn are broken apart or decomposed by micro-organisms. Bacteria and fungus act on the leaves changing them to nutrients in the soil. This process is called **biodegradation**.
Bacteria can be of two types:

- **Aerobic**—bacteria that require oxygen
  - Aerobic bacteria use oxygen to decompose a fallen tree.
- **Anaerobic**—bacteria that live "without oxygen"
  - Anaerobic bacteria break down polychlorinated compounds deep within landfill sites. They do so in the absence of air and oxygen.

Biodegradation includes:

– phytoremediation (cleanup by plants)

– photolysis (cleanup by light)

The rate of biodegradation is dependent on **temperature, moisture, and oxygen supply**. Bacteria are better decomposers under the favourable conditions of high temperatures, moist conditions, and adequate supply of oxygen.

PHYTOREMEDIATION

"Phyto" refers to "plants" and "remediation" means "to clean up." Phytoremediation means using green plants to reduce the concentration of harmful chemicals. For example, sunflower plants have been used at the Chernobyl nuclear site to remove radioactive material from the soil and groundwater. Cattail plants have specialized root systems that absorb pollutants in stagnant water and break them down into safe usable forms.

PHOTOLYSIS

"Photo" means "light" and "lysis" refers to breaking something down. Photolysis is the breakdown of chemical substances by sunlight. Certain plastics are made of chemicals that when exposed to light, react and break down into safe forms.

Bacteria can be:

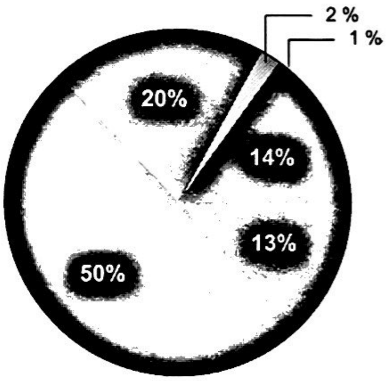
– aerobic (use oxygen)

– anaerobic (need no oxygen)

CASE STUDY: EXXON VALDEZ OIL SPILL

In 1989, the Exxon Valdez ran aground in Prince William Sound off the coast of Alaska spilling over 200 million litres of oil into the water. Most of the oil remained in the water; some, however, washed onto the shoreline. The results were devastating. Algae and aquatic invertebrates died. Fish eggs did not hatch. Seabirds and mammals became covered with oil.

The chart below shows the cleanup techniques used. Some methods were a result of human activity, others were natural.



Recovery	(14%)
Dispersal by water	(1%)
Bleached with non-toxic chemicals	(2%)
Degraded by light (photolysis)	(20%)
Biodegraded by bacteria	(50%)
Other methods	(13%)

SAFE HANDLING OF HAZARDOUS PRODUCTS

Strict government regulations insist on the safe handling of all chemicals. Students in school must become familiar with the WHMIS symbols, hazardous product symbols, and the MSDS charts.
All chemical products must be correctly labelled and stored.

Safety Tips

- Leave all chemicals in their original containers.
- Store in well ventilated areas.
- Flammables should be stored in specially labelled cabinets.
- Safely discard chemical products by bringing them to collection stations.
- Paint, oil, batteries, solvents, fluorescent light bulbs, pesticides, and other household chemicals should be taken to an EcoStation.

IN CONCLUSION

Chemicals play an important role in the makeup and survival of living organisms. Chemicals, too, can play a negative role. Pollutants and emissions affect natural life cycles and the balance of nature. Humans must become more conscious about their environment and must take steps to ensure that a balance between nature and human progress is sustained.

LET'S PRACTICE THE 4 RS AND MAKE THE WORLD A BETTER PLACE TO LIVE IN

Recycle ***Reuse*** ***Reduce*** ***Recover***

4 Rs
- reduce
- recycle
- reuse
- recover

REVIEW SUMMARY

NOTES

- The environment is made up of biotic and abiotic factors that rely on chemicals to sustain life. Living things require both organic and inorganic compounds for survival. Living organisms are composed mainly of organic compounds made from the elements carbon, hydrogen, and oxygen. They require nutrients that contain traces of inorganic elements, magnesium, phosphorous, and calcium.
- Many of the nutrient materials come from the soil and are recycled back to the soil. Nitrogen gas is converted by lightning and nitrogen-fixing bacteria into usable nitrogen compounds. Nitrogen compounds are eventually converted back into free nitrogen by decomposers. Carbon and carbon compounds are also cycled.
- The release of industrial chemical compounds into the air and the leaching of agricultural products into the soil may interfere with natural carbon and nitrogen cycles. The combustion of fossil fuels is the leading cause of acid rain. Sulfur dioxide and nitrogen oxides combine with water vapour in the air to produce rain that is acidic in nature. Excessive use of fertilizers and pesticide by farmers also has an effect on the normal balance of living things. Fertilizers may cause an overgrowth of plants while pesticides end up destroying helpful plants and animals.
- Chemical substances are classified as *acids*, *bases,* or *neutral substances.* Acids have a high hydrogen ion (H^+) concentration while bases have a high hydroxyl (OH^-) concentration. On a pH scale, acids fall in range from 0 to 6, while bases are in range 8 to 14. A substance with pH of 7 is neutral.
- Acids are neutralized when mixed with a base. The neutralization process produces a *salt* and *water.* The neutralization reaction can be represented as a word equation.
  Acid + Base → Salt + Water
  For example, an antacid can be taken for a hyperacidic stomach to relieve the discomfort. The antacid is a base that neutralizes the acid in the stomach.
- All living things require nutrients for growth and reproduction. Elements such as nitrogen, phosphorous, magnesium, and calcium are required in large quantities and referred to as macronutrients. Micronutrients, such as selenium, are needed in small or trace amounts.
- Nutrients are absorbed by plants passively or actively. During diffusion, nutrient particles move into the plant's cells from an area of high concentration to an area of low concentration. During osmosis, particles pass from an area of high concentration to an area of low concentration through a semi-permeable membrane. No energy is required for diffusion and osmosis. In active transport, plants use energy to move nutrient molecules from an area of lower concentration to an area of higher concentration.
- Animals require organic compounds. Animals require carbohydrates for energy, lipids for energy, proteins for repairing, and nucleic acids for controlling heredity and cell activities.

- Monitoring the chemical dispersion in water and air is important. Water is monitored for dissolved oxygen, acidity, heavy metals, pesticides, salts, and excessive plant nutrients. The chemical concentration must fall within government guidelines in *part per million*. A concentration of 4 ppm means 4 parts of chemical in 1 000 000 parts of chemical water solution.
- Toxins or poisons are measured with a scale called LD50. LD stands for "lethal dose" and 50 stands for 50%. LD50 refers to the amount of substance that will cause 50% of a test sample of organisms to die if given a specified dose. The LD 50 for common table salt is 3 000 mg/kg.
- Air is monitored for sulfur dioxide, nitrogen oxide, carbon dioxide, and ground -level ozone emissions. Sulfur dioxide and nitrogen oxides, released mainly from vehicles, are the leading causes of acid rain. Carbon dioxide is a greenhouse gas; it is the leading cause of global warming. The use of chlorofluorocarbons (CFC) is depleting the upper atmosphere ozone layer.
- Air and water quality monitoring is carried out using chemical analysis and biological indicators. Chemical analysis includes the use of chemical reagents to test for pH, iron, chlorine, phosphorous, and heavy metal. Biological testing uses invertebrate organisms. Organisms such as caddisfly larva require high oxygen concentrations. Leeches need very little oxygen. The higher the oxygen concentration, the greater the biodiversity of organisms.
- Potentially harmful chemicals are dispersed in the air by wind and air currents. Chemicals are leached into soil by water and transported with the ground water. Certain bacteria remove chlorine from certain chemicals. Certain plants use their root systems to breakdown chemical pollutants into usable forms. This method is called phytoremediation. When sunlight decomposes plastic material the process is called photolysis.
- If chemicals are left to build up, their accumulation leads to *biomagnification*. Mercury, for example, builds up in a food chain to a point where the animal at the top of the chain accumulates the highest concentration.
- It is important to store, dispose, and transport chemical wastes properly. Proper transportation and collection of hazardous chemical must be closely monitored. It is the responsibility of every individual to properly handle, store, and dispose of chemicals.

