# Science Nine

## Module Three:

## Environmental Chemistry

# Notes

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## Environmental Chemistry

## Notes

# Grade 9 - Unit 3 – **Environmental Chemistry** Concepts

* Medicines from the Environment *

**Nutrients**
- Optimum Amount -
Macronutrients
Micronutrients (trace)
**Organic** (contain carbon)
Carbs, fats, proteins, nucleic acids
**Inorganic**

**Harmful Human Activities**
Agricultural
Waste
Fuel Combustion
Industry
Manufacturing

**Water**
Chemical Testing (ppm)

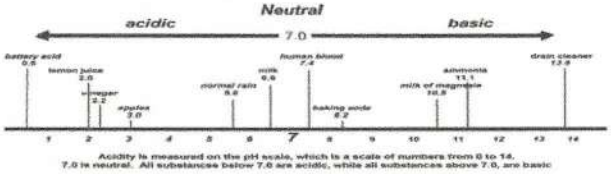
Bioindicator Species

**Air**
Sulfur Dioxide
Nitrogen Oxides
Carbon Monoxide
Ground--Level Ozone

Chloroflorocarbons (CFC's)

**Soil**

Pesticides
Heavy Metals
Toxins




**Atmosphere**
Greenhouse Effect
Enhanced Greenhouse Effect
Global Warming
Toxicity

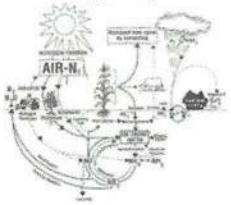
**Neutralization**
Acid + Base ⟶ Salt + Water

**LD50**

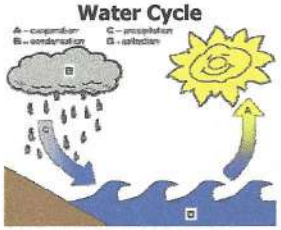
**Chemicals Support or Harm Living Things**

**Monitoring for Quality**

**Nitrogen Cycle**




**Water Cycle**



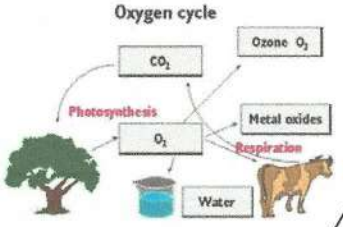
H
C
O
N

**Mo Mn Mg Na Se Fe Sn Ca**

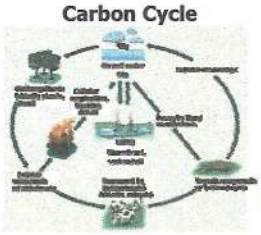
**Environmental Chemicals**

**Si V B I K Zn Cl Ni Cr Cu S**

**Oxygen cycle**




**Carbon Cycle**



F
P
O
H

**Chemical Transportation**

**Chemical Hazards**

**Plants**
Diffusion
Osmosis
Active Transport

**Animals**
Ingestion
Digestion
Absorption

**Environment**
Release
Dispersion
Deposition
Dissolving
Dilution
Leaching

**Substrate**

**Changing Chemical Concentrations**
Biodegradation Phytoremediation Photolysis

Biomagnification W.H.M.I.S. Labeling

Bioaccumulation MSDS Disposal Sites

Storage and Transportation of Dangerous / Hazardous Goods

Government Regulations

# Environmental Chemistry

## Unit C

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- A Balanced Approach
- The Root Source
- Commercial Fertilizers
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- Where To Now?

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- Waste Management – Back to the 4Rs
- Landfill Construction and Design
- Secure Landfills
- Bioremediation – Mother Nature to the Rescue

## Topic 1 - A Hair Raising Dilemma

*Medicine from The Environment* - ***Willow bark*** *contains* ***salicylic acid.*** ***Hippocrates*** *- now known as the 'Father of Medicine' - as early as 400B.C. - recommended willow bark be used to treat pain and fever. First Nations people used willow bark tea as a medicinal drink. A synthetic version of salicylic acid -* ***acetylsalicylic acid*** *- was developed by the Bayer company in 1898 and* ***Aspirin*** *was born. Other medicines derived from plants found in the environment include:*

- *Echinacea Purposa - extract from the purple cornflower stimulates the immune system.*
- *Check out other medicines developed from plants in the environment at:*

*Grade 7 'Science Focus' Notes - (Unit 2 - Topic 1)*

### Take Two Pebbles ...

The process of digestion breaks down the chemicals present in food. The molecules are small and soluble, which can then pass through membranes into your blood. These chemicals (nutrients) are then carried throughout your body to the cells which need them for energy, growth, body building and cell repair. Our body needs about 25 different chemicals for normal growth. The complex organization of these chemicals produces **organic compounds** which contain Carbon, as well as mostly Oxygen and Hydrogen. Substances that do not contain Carbon are called **inorganic compounds.** The organic nutrients, which come primarily from green plants, are classified into four major groups.

| Classes of Organic Compounds | Description and role in nutrition | Typical dietary sources |
|---|---|---|
| **Carbohydrates** | - are organic molecules made up of atoms of carbon, hydrogen, and oxygen<br>- energy source for metabolism | sugar, starch, cellulose, glucose<br>- rice, grains, potatoes, fruits |
| **Lipids** | - are compounds composed of many carbon, hydrogen, and oxygen atoms<br>- storage of unused chemical energy | fats, oils and waxes<br>- vegetable oils, nut oils, some dairy products |
| **Proteins and Amino Acids** | - proteins are organic compounds made up of amino acids (each protein has its own unique number, combination and arrangement of amino acids)<br>- functions include growth and repair, as well as a source of energy | enzymes<br>- meat, eggs, dairy products, legumes, nuts |
| **Nucleic Acids** | - large complicated molecules that play a major role in heredity and in controlling the cell's activities | DNA (deoxyribonucleic acid)<br>RNA (ribonucleic acid) |

Nutrients, made up of elements and compounds, help living organisms survive. Plants obtain carbon, oxygen and hydrogen from the air, and nitrogen, phosphorus, potassium, magnesium, calcium and sulfur from the soil. These nine elements are called macronutrients (because they are in needed in large quantities) are essential for plants to grow. There are other elements that are also needed, but not in large quantities. These elements are called trace elements.

The macronutrient elements are essential components in enzymes (which are special protein molecules that regulate chemical reactions in living organisms) and vitamins (large organic molecules which help enzymes function properly. The body cannot manufacture these macronutrients. It can only get them from food.

16 naturally occurring elements are present in all living organisms. Green plants require 18 elements for proper growth and functioning, while humans need 25 elements, which are used by for growth and function. The process of taking in the nutrients (elements and compounds) we need is called ingestion.

These compounds are broken down chemically in the digestive system by a process called hydrolysis. A substance that has been broken down by hydrolysis has been hydrolyzed.

(example) Maltose + Water ------ » Glucose

$C_{12}H_{22}O_{11} + H_2O$ ------ » $2C_6H_{12}O_6$

Nutrients such as glucose and amino acids are then absorbed through cell membranes and into the bloodstream, which carries them to where they will be used or stored.

| Nutrient | Importance in Plants | Importance in Humans |
|---|---|---|
| ***Nitrogen (N)*** | - proteins & chlorophyll<br>- leaf and stem growth | - composition of proteins & nucleic acids<br>- growth and repair of tissue |
| ***Phosphorus (P)*** | - root and flower growth<br>- cellular respiration & photosynthesis | - composition of bones, teeth & DNA<br>- metabolic reactions |
| ***Potassium (K)*** | - stimulates early growth<br>- starch and protein production<br>- disease resistance<br>- chlorophyll production & tuber formation | - muscle contraction & nerve impulses |
| ***Magnesium (Mg)*** | - chlorophyll structure<br>- photosynthesis | - composition of bones & teeth<br>- absorption of calcium & potassium |
| ***Calcium (Ca)*** | - cell wall structure<br>- cell division | - composition of bones & teeth<br>- blood clotting<br>- muscle & nerve function |
| ***Sulfur (S)*** | - production of fruits and grains | - protein synthesis<br>- enzyme activation<br>- detoxification |
| ***Sodium (Na)*** | | - helps regulate nerve impulses in nerves and muscles |

Important micronutrients (trace elements) include:

| | |
|---|---|
| ***Chlorine*** | - helps regulate water balance, plays a role in cell membrane function, part of the hydrochloric acid in stomach that helps digest foods |
| ***Iron*** | - crucial part of red blood cells, regulating oxygen transport |
| ***Zinc*** | - essential component in enzymes which regulate formation of proteins and carbohydrate metabolism |
| ***Iodine*** | - major component in thyroid hormones which regulate metabolism |
| ***Selenium*** | - component of antioxidant enzyme that helps decay of cell function |
| ***Copper*** | - promotes iron absorption and utilization<br>- component of many enzymes<br>- helps regulate nerve activity |
| ***Manganese*** | - component of some enzymes involved in bole formation and protein metabolism |
| ***Fluorine*** | - helps regulate calcium deposition |
| ***Chromium*** | - activates vitamin $B_3$ to control use of blood sugar in energy production |
| ***Molybdenum*** | - key component of 3 enzymes that regulate metabolism |
| ***Cobalt*** | - component of vitamin $B_{12}$, which helps regulate red blood cells |

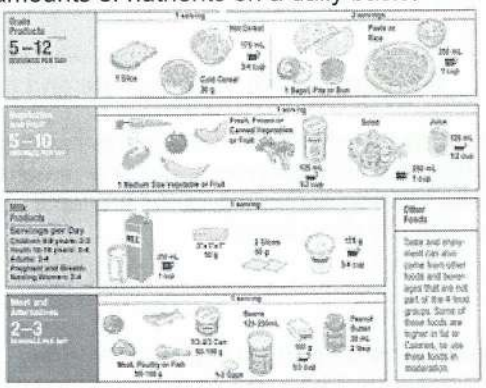
## A Balanced Approach

A micronutrient may be present in larger amounts than normal. If this occurs it can have harmful effects. Not enough of an element can also have harmful effects.

The optimum amount of a substance is the amount of that substance that provides an organism with the best health.

Taking medication can affect chemical reactions going on in your body and can also correct a chemical imbalance, relieving nagging or painful symptoms or discomforts as a result of not having the optimum amounts of the chemicals you need for good health.

**Canada's Food Guide** helps you to maintain proper health and take in the right amounts of nutrients on a daily basis.



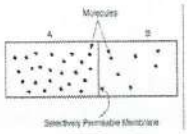
## The Root Source

All living organisms need a constant supply of raw materials and energy to produce new cells for growth, to repair damage and to maintain proper health. Plants take in inorganic compounds to make organic compounds. Consumers use the organic compounds made by plants for their energy, growth and repair. When organisms take in these compounds, other substances are also taken. These substances may be harmless or harmful. By knowing how plants use each element, agriculturalists can diagnose deficiencies and excesses, and act accordingly, to alleviate the problem.

*Problem:* yellow striping on lower leaves & soil test indicates high levels of potassium and low levels of magnesium
*Analysis:* potassium is interfering with the plant's ability to absorb magnesium
*Solution:* stop applying fertilizer containing potassium and apply more fertilizer with magnesium

(Nutrient comparison Chart Table 3.3 Science Focus p. 182)

Nutrients enter the roots by diffusion - the movement of molecules from an area of high concentration to an area of low concentration. This action continues until the areas are equal concentrations. (No energy is required for this to occur).



Water moves through plants by a special type of diffusion, called osmosis. In this process, water moves through the walls of the plant's roots from an area where there are more water molecules to an area where there are fewer water molecules. As the plant uses the water it draws more up from its roots.

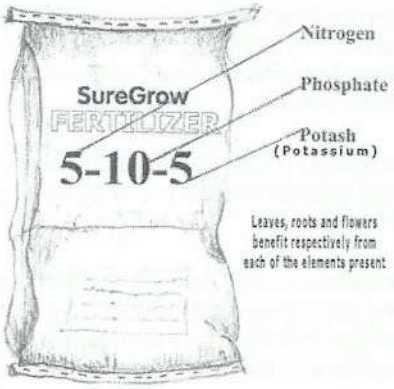
Plants need high concentrations of some nutrients in their roots. These nutrients may have higher concentrations in the roots than in the surrounding soil. To maintain these high concentrations, plants move more nutrients into their roots from areas of lower concentration (in the soil) by a process called active transfer. This process requires energy. Where organisms live affects how and when they can obtain the nutrients they need. Some organisms get the nutrients they need often by restricting other organisms from getting the same nutrients (reducing the competition). A substrate is a material on which an organism moves or lives. Some organisms attach themselves to the substrate, while others obtain their nutrients from their substrate.

**Red single-celled algae** survive on a substrate that is near freezing, low in nutrients and often acidic.

**Tubeworms** can survive on the floor of the ocean where lava is rising to the surface - "hot smokers' - and many harmful chemicals (like hydrogen sulfide) are being dissolved in the water nearby.

## Commercial Fertilizers

The three numbers on a bag of fertilizer refer to the percentage of nitrogen, phosphate and potassium that is available to plants from that bag of fertilizer.



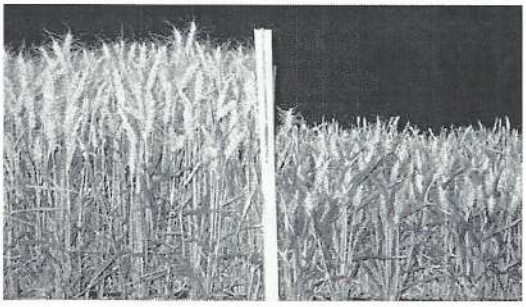

This product contains:
**5 % nitrogen, 10 % phosphate and 5 % potassium.**

The other 80 percent of what's in this bag typically will contain some micronutrients and filler material, which allows for even application of the nutrients across the area where the fertilizer is used.

## Issues Emerging From High Productivity

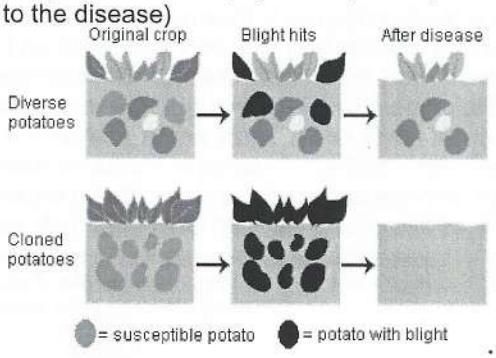
Until the early 1900s, plants received their nitrates exclusively from nature. The artificial production of fertilizers increased the nitrogen levels available to plants in the soil. This has increased the amount of nitrogen in the environment by as much as 140 million tons per year.

Nitrogen is used by plants for increased plant growth. Crop production has doubled worldwide due to the use of artificial fertilizers and high-yield varieties.



Food production has increased worldwide as a result in most countries. Great isn't it! – But wait: Consider the following –

- It takes a lot of water and fertilizer to produce a crop of high-yield varieties ( VERY EXPENSIVE ) for farmers.
- *Monoculture* – The planting of only one crop increases the chance of disease spreading through the entire crop. (a variety of crops allows for some of the crops to be resistant to the disease)



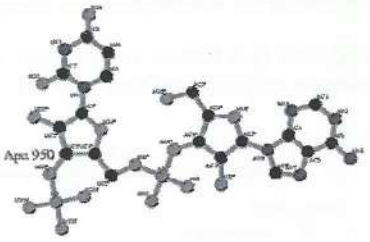

- Chemical agents used to protect the crop (pesticides and herbicides) reduce the amount of damage, but they are costly and have harmful effects on the environment.

## Topic 2 - A Growing Concern

Pesticide use is now common practice worldwide. Herbicides control weeds, insecticides control insects and fungicides control diseased crops. The use of chemicals, such as DDT, was originally thought to be directed only at the insects it was intended for. Unintentional harmful effects to other species resulted in a closer look.

### Issues Associated With the Use of DDT

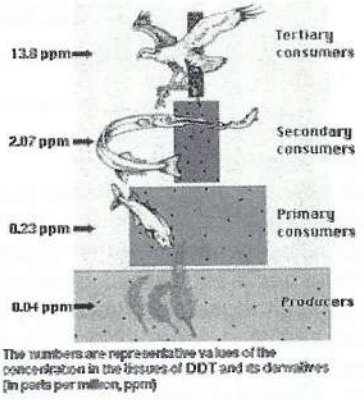
The invention of DDT by Swiss chemist Paul Müller was seen originally as a breakthrough in medicine.



Typhus -transmitted by lice- which wiped out Napoleon's army in the 1800s, was rampant during World War II among the Allied troops. DDT wiped it out. It proved to be so effective that Müller was awarded the Nobel Prize in Medicine for his discovery. During the 1950s it was used to try to control an outbreak of malaria.

### The DDT Story

When DDT gets into the food chain bioaccumulation can have devastating effects. As you move up the food chain the concentrations of DDT are higher.



The numbers are representative values of the concentration in the tissues of DDT and its derivatives (in parts per million, ppm)

Read more about its harmful effects here: http://www.marietta.edu/~biol/102/2bioma95.html It is the online version of the story on page 190 of the Science Focus textbook.

### What's Bugging You?

The use of DDT was recognized as having potentially harmful effects. Banning its use would also negate the positive effects it was having in controlling malaria (In Zanzibar alone – the incidence of malaria dropped from 70% to 5% over a 6 year span). When a restriction on the use of DDT was implemented in 1984, the incidence of malaria returned to the 50-60 % level. Nothing else proved to be as effective in controlling the insects that carried malaria. Should DDT be banned completely? http://www.panda.org/about_wwf/what_we_do/toxics/problems/ddt.cfm
Producing safe and effective insecticides, as alternatives to DDT is difficult due to cost, effectiveness and the problem of resistance. Check out other links on this website: http://www.panna.org/campaigns/docsPops/docsPops_030317.dv.html#A

### Where To Now?

No matter how it is developed, a pesticide (insecticide) is used to control pests. The potential these chemicals have to harm non-target species has caused concern and restraint on the widespread and uncontrolled use of pesticides in the environment. Research and development into newer and safer pesticides has resulted in these pesticides breaking down faster in the environment after they have been applied. It is now widely recognized that natural processes and cycles can minimize the effects of these pesticides, but it still remains a hotly debated issue. In the future researchers must determine what effects combinations of these pesticides will have on the environment and ultimately us.

## Topic 3 - How Do You Spell Relief

### Acids and Bases

**Properties and Examples**

***Acids*** *taste sour, are soluble in water and undergo similar chemical reactions, have a pH of less than 7*

phosphoric acid (fertilizers, detergents, pharmaceuticals, flavoring agent - tangy)

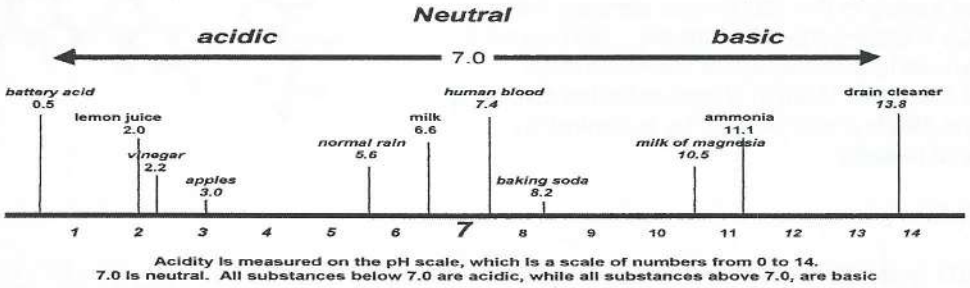
sulfuric acid (car battery, paints, dyes, oil and gas refining, synthetic textiles)

Substances that are neither acidic nor basic, such as water, are said to be ***neutral***.

***Bases*** *taste bitter, are soluble in water, feel slippery, and react with acids, have a pH of more than 7*

sodium hydroxide (household cleaners, bleaching agent, fixative in textiles, solvent in making electronic circuit boards, reagent in film processing)

aluminum hydroxide (antacid tablets)




**Acidity is measured on the pH scale, which is a scale of numbers from 0 to 14. 7.0 is neutral. All substances below 7.0 are acidic, while all substances above 7.0, are basic**

**pH** is a measure of the concentration of hydrogen ions in a solution.
It means the *"power of hydrogen"* and
refers to the formation of hydrogen atoms that have lost an electron (ions).

### pH: Powerful Scale

The strength or concentration of an acid or base determines the extent to which it reacts with water. The reaction changes the electrical conductivity of the water, which can be measured with a sensitive conductivity test meter. The pH scale is a way of comparing the relative acidity or alkalinity of a substance. To identify a substance as an acid, a base, or neutral, an **indicator** is used. It changes color according to the type of substance it is put into. Indicators can be solids, such as litmus paper, or universal indicator (which change color over a wide pH range can identify many different substances and is more precise), or they can be liquids, such as phenol red. *Common indicators* include: litmus paper / universal indicator paper / phenolphthalein / BTB (Bromothymol Blue) grape Juice / red cabbage Juice / tea

A **universal indicator** is used to measure **pH** over a wide range.

**Red litmus** paper will turn **blue** in the presence of a **base**.

**Blue litmus** paper will **turn red** in the presence of an **acid**,

*Neutralization*

Acids and bases react together when they are mixed. This type of reaction is called neutralization. Both the acid and the base are used up in this type of reaction. A salt and water are produced.

**Hydrochloric Acid + Sodium Hydroxide ------ » Sodium Chloride + Water**
***HCL*** **+** ***NaOH*** ***------ »*** ***NaCl*** **+** ***$H_2O$***

Acid in your stomach has a normal pH of 2. This acid helps in the digestion of food and kills off bacteria. If you eat too quickly, or are under stress, your stomach produces an excess amount of gastric acid (giving you heartburn). To neutralize the excess acid, an antacid tablet is swallowed. This antacid is a mild base. (eg. Tums, Rolaids, Milk of Magnesia, Pepto Bismal)

## Acid Precipitation – A Global Concern

Sulfur, nitrogen and carbon oxides emitted from industries (such as smelters) combine with water vapor in the air to produce sulfuric, nitric and carbonic acid.

$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)} \quad [\text{ sulfurous acid }]$$

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)} \quad [\text{ sulfuric acid }]$$

$$2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{2(aq)} + HNO_{3(aq)} \quad [\text{ nitrous and nitric acid }]$$

$$CO_{2(g)} + H_2O_{(l)} \rightarrow H_2CO_{3(aq)} \quad [\text{ carbonic acid }]$$

These pollutants then fall to the ground as **acid precipitation** (with a pH lower than normal rain - which is about 5.6)

... chemical change reduces soil fertility
... kills organisms in lakes & streams
... leaches toxic chemicals from the soil
...damages or destroys aquatic ecosystems
... retards tree growth
... corrodes exposed metal surfaces
... breaks down stone and limestone

Acidity is measured on the pH scale with anything below 7 being acidic. A decrease of one unit indicates the acidity has been multiplied by a factor of 10. Periods of extreme acidity (like in the spring when the acid snow melts and the acidic water enters the waterways) are called **acid shock**. Concentrations of chemical indicators are usually measured in ...

**parts per million** (ppm) $\quad ppm = \frac{\text{grams of solute}}{\text{grams of solution}} \times 10^6$

or **milligrams per Litre** (mg/L) $\quad ppm = \frac{\text{mg of solute}}{\text{L solution}}$

One part per million means that one unit of an element or chemical can be found in one million units of solution. Investigating Parts per million

**International Agreements**

In 1996 an agreement between Canada and the US targeted a 10% reduction in industrial exhaust emissions by the year 2000. Vehicle emissions for cars built before 1998 was also targeted to be reduced by 60%. As a result total emissions are on the decline.

Acid precipitation dissolves minerals in the soil and allows them to be washed or leached away, leaving fewer nutrients for plants to grow healthy. Heavy metals have also be released into streams and water supply systems where they are consumed as toxic substances by plants and animals.

## Using Chemistry to Control Acid Effects

To neutralize acid rain precipitation, lime (calcium hydroxide - which is a base) is added to lakes.

**Calcium Hydroxide + Sulfuric Acid ------ » Calcium Sulfate + Water**

$$Ca(OH)_2 + H_2SO_4 \text{ ------ » } CaSO_4 + H_2O$$

*This is not necessary in Alberta because the mountains contain rich deposits of limestone, making the water naturally basic. When the acid rain falls, it is neutralized almost immediately.*

Alkaline minerals – such as calcium carbonate or calcite - left after glaciers melted, following the Ice Age provide a basic aquatic environment, so that the acid precipitation gets neutralized almost immediately after it enters lakes and water systems.

## Using Chemistry to Control Harmful Emissions

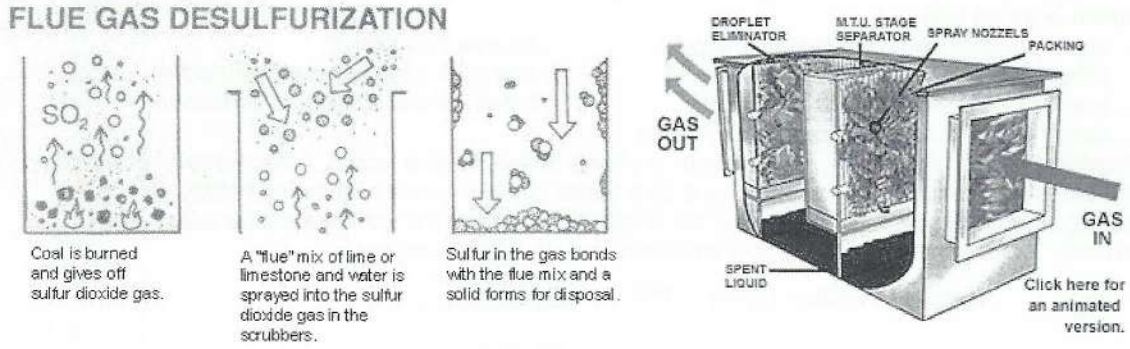
The concentration of chemicals in the environment can be changed using different techniques. Dispersion is the scattering of a substance away from its source. Dilution reduces the concentration of a pollutant by mixing it with large quantities of air or water. A fast flowing river or air mass can disperse and dilute a chemical very quickly. Regulations set by governments require that acceptable levels of pollutants be achieved. To do this biodegradation may also be an effective alternative.

Reducing emissions at the source is more economical and more effect. Catalytic converters contain a ceramic or wire honeycomb-like structure that is coated with a thin layer of metallic catalysts, which speed up chemical reactions, without being used up. A converter helps the formation of $CO_2$ and $H_2O$, reducing CO and $NO_2$. The purpose of the converter is to encourage complete oxidation.

### Scrub Those Cares Away

The oxide emissions from industries and thermal-electric power plants that burn coal can be a major source of oxides, depending on the concentration of sulfur in the coal. The addition of 'scrubbers' is a technological solution to reduce oxide emissions.

A scrubber is a device that uses a sorbent that absorbs or captures the sulfur oxides.




The key to scrubbing exhaust gases is the addition of calcium oxide ( **CaO** ), which reacts with the sulfur dioxide gas ( $\mathbf{SO_{2(g)}}$ ) to form calcium sulfite ( $\mathbf{CaSO_3}$ ) – the sorbent, which is soluble in water.

Newer scrubber technologies utilize metal oxide sorbents. The **COBRA** system uses a sorbent of small aluminum oxide (impregnated with copper) beads. As a result of this process, sulfur, sulfuric acid and ammonium sulfate fertilizer can be recovered as by-products, which then provide added revenue to the industry.

An added bonus in the COBRA scrubber, the addition of ammonia to the heated gases triggers a catalytic reaction that breaks down nitrogen oxides into nitrogen, oxygen gas and water vapour.

## Topic 4 - How Much Is Too Much?

### How Much Is That?

Water is a vital source of life for all living organisms. When this is affected by pollution, all living things connected in the web of life are affected. A pollutant is any material, or form of energy that can cause harm to living organisms. Pollution is any alteration to the environment that produces a condition which threatens living organisms. To determine if something is a pollutant or pollution we must determine how much of it is present.

'Percent' of weight, or volume, means how much there is in a weight or volume sample of 100. Concentrations of chemicals are usually measured in …

**parts per million** (ppm) $\text{ppm} = \frac{\text{grams of solute}}{\text{grams of solution}} \times 10^6$

or **milligrams per Litre** (mg/L) $\text{ppm} = \frac{\text{mg of solute}}{\text{L solution}}$

One part per million means that one unit of an element or chemical can be found in one million units of solution. Investigating Parts per million Some substances are measured in ppb (parts per billion) or even ppt (parts per trillion). To visualize ppt - one part per trillion would be equal to: 1 meter in 1,013,543 kilometers, 1 second in 32,000 years, or 1 cent in $10 billion.

### The Danger Is In the Dose

When chemicals that can do harm to living organisms remain in the environment, a toxin is created. Several toxins mixed together can have a cumulative effect and become very toxic. A toxic substance is poisonous. Toxicity is the ability of a chemical to cause harm to an organism. Acute toxicity occurs when serious symptoms occur after expose to the toxic substance. Chronic toxicity occurs when the toxic substance accumulated as a result of many exposures over time. Some insects have become pesticide-resistant and so, new pesticides have to be developed. Heavy metals are toxic agents and have a density of 5g/cm$^3$ or more. Examples include: mercury, copper, lead, zinc, cadmium and nickel. These metals occur naturally and are also processed into a wide variety of products. Heavy metals can be toxic to a wide range of organisms, so concentrations are constantly monitored. Heavy metals can enter the water supply by the action of acid rain and improper solid waste disposal (which can leach heavy metals into the groundwater). Heavy metals are especially toxic to children causing abnormal development, brain damage, or even death.

### Lethal Dose 50

Scientists measure toxins in LD50 amounts.

**LD stands for 'Lethal Dose"**
**50 represents 50% of the subject group that will die,**
**if they are given the specified dose, all at once.**

| Substance | $LD_{50}$ (g/kg) | Substance | $LD_{50}$ (g/kg) |
|---|---|---|---|
| Strychnine | 0.005 | Iron(II) sulfate | 1.5 |
| Arsenic trioxide | 0.015 | Chloroform | 3.2 |
| DDT | 0.115 | Ethyl alcohol | 10.6 |
| Aspirin | 1.1 | Sodium cyclamate | 17 |

Table - http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/L/LD50.html

The classic LD50 test is controversial and many countries have restricted, regulated, or outlawed it. http://iacuc.cwru.edu/policy/nihpolicies/iracld50.htm Experiments to determine LD50 are rarely performed anymore because they provide very little toxicological information compared to the data that can be gained from more modern techniques. However, LD50 values are available for most chemicals from past studies. Some organizations tell it like it is, so that people can see how cruel a practice it really is to the animals involved in the test.
http://www.animalliberation.org.au/toxtest.html What do you think would happen if we didn't know the LD50 of certain chemicals (Table 3.4, p. 218) that we consume? The most lethal poison known comes from a bacterium, *Clostridium botulinum*, which is commonly found in foods we consume. It can be destroyed by high temperatures and acidity.

## An Acceptable Risk?

Government agencies and legislators are often pressured to fast track drugs or substances which could potentially help many people, by relieving discomfort or pain. Testing programs follow strict guidelines to prevent fatal doses being consumed, of a medication, or substance, that is intended to be helpful. Most of our fatal-dose information for humans comes from accidental-exposure case studies (Why would anyone want to volunteer to be a test subject in a lethal dose test?).

## Thalidomide Issue

Thalidomide was originally developed as a sleeping pill.
Its use in the 1950s and 1960s by pregnant women, to treat morning sickness, http://cerhr.niehs.nih.gov/genpub/topics/thalidomide2-ccae.html resulted in thousands of birth defects. http://www.thalidomide.ca/en/

A close inspection of these effects resulted in finding out that rats could take a dose of 4000 ppm, whereas pregnant women would have her fetus affected with a dose as small as 0.5 ppm if taken at the wrong time during development of the fetus.

## The Evaluation of Risk

Rachel Carson's *Silent Spring* woke up a nation to the effects chemicals were having on living organisms in our environment. With all the publicity on the human use and abuse of toxic chemicals, we often overlook that these chemicals are for the most part, naturally occurring, and not made by humans. There are other toxins that plants and animals have that are helpful to their survival.

*For every molecule of human-made pesticide, there are 10,000 molecules of naturally formed pesticides.*

What risks do we take, and of those, which are acceptable, or not?
Contemplate, for a minute, the following – to put it in perspective:

- To receive an LD50 dose of a particular substance that was tested for mice – a human would have to drink 70 cups of that substance – all at one – in one sitting
- LD50 can vary from animal to animal even differing between rats and mice.
- In addition, LD50 value depends on the type of exposure: ingestion (eating or drinking), inhalation (breathing) or skin contact.

Every chemical has the potential to be harmful, even the ones we take to help us. It is the dose, our susceptibility and how it reacts with other chemicals that determine it toxicity. Tough decisions need to be made to determine if it is more beneficial than harmful. Evaluation of the risks and benefits of any chemical, form the basis of how chemical use is regulated.

## Topic 5 - Getting Away From It All

Exploitation of the environment happens all the time. As the world population grows waste production also grows and the proper handling of this waste is a concern.

### Environmental Monitoring

All wastes entering the environment are potentially harmful and must be broken down into non-polluting compounds, or be treated to reduce the harmful effects these wastes can have. Non-persistent wastes care naturally degraded. Persistent pollutants accumulate and take a long time to degrade. It is the concentration of these wastes that can affect living organisms. To determine the concentration scientists test wastes, persistent and non-persistent to determine how to handle them and deal with their effects in the environment. Monitoring keeps track of something for a specific purpose. Clarity may be one indicator, but clear water does not indicate what chemicals are present. Water Quality is determined using *chemical* and *biological indicators* according to what the water is going to be used for. Chemical tests (Testing for Phosphates and Nitrates and Testing Water Quality by determining the amounts of Dissolved oxygen and Carbon Dioxide) were done in Inquiry Investigation 3-H, p. 225-229.

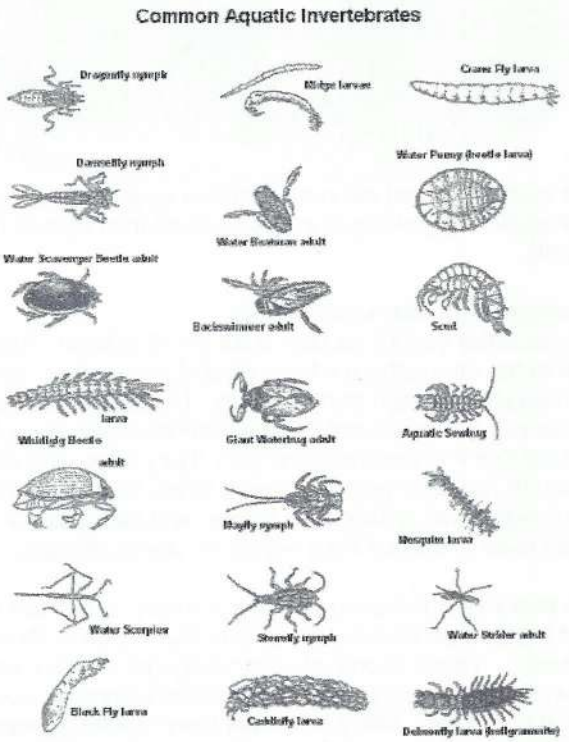
### Biological Indicators of Water Quality

Most types of pollution adversely affect water quality and directly affect living organisms. Microscopic organisms (bacteria) can cause serious health problems if they are present in sufficient numbers. Samples are taken to identify their presence to avoid contamination of the water supply.

Aquatic Invertebrate Identification: (see also SF p. 233)

Aquatic Environments are places where macroinvertebrates – visible to the human eye , without a backbone - live depending on the pH level and the amount of dissolved oxygen present.
… there will likely be no fish, shrimp, mayfly or stonefly invertebrates in water that has a pH below 5.0
... worms, leeches and midge larva thrive in polluted water, as they require only small amounts of dissolved oxygen for survival

Chemical indicators of water quality include: dissolved oxygen, acidity, heavy metals, nitrogen, phosphorus, pesticides, salts – such as sodium chloride and magnesium sulfate.




### Point Versus Non-point Sources

Pollutants entering the environment from specific locations are point source pollutants. These are easy to monitor and control. Non-point source pollutants are those that enter the environment from locations that cannot be easily monitored or controlled. They occur as a result of run-off or leaching and they get dispersed quickly. Agencies set regulations and monitoring protocols to determine amounts affecting the environment. The 4Rs – Reduce, Reuse, Recycle and Recover - have provided a basic framework to reduce the amount of waste pollutants that are produced.

## Topic 6 - N.I.M.B.Y. There Is No Away In Throwing

The acronym N.I.M.B.Y stands for NOT IN MY BACKYARD. With humans producing more and more waste, the disposal of these wastes in our backyards is becoming a concern. How do they get there?

### Blowing In The Wind

The source of a pollutant may be in one place, but it can show up in many other places around the world. There are three stages of transport of substances in the environment:.

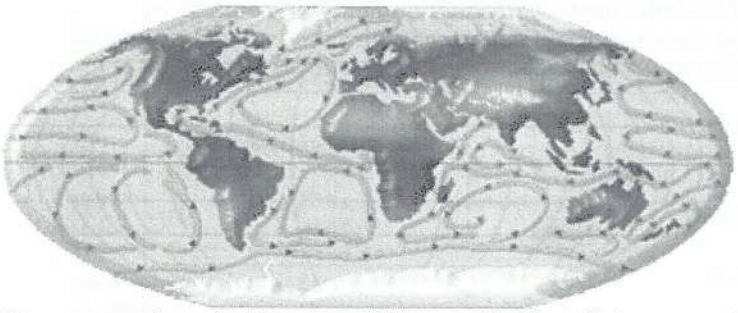
- Release of chemicals at the source
- Dispersion of the chemical into the atmosphere
- Deposition of the chemical in soil or water

The direction and distance that airborne chemicals travel are determined by various factors, including:

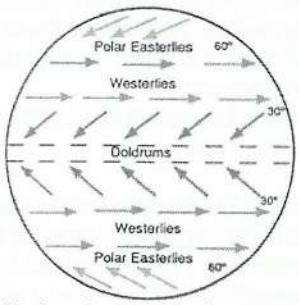
- The properties of the chemical pollutant
- The wind speed
- The direction of the prevailing winds

The distribution of particles may also be limited by lack of wind or precipitation.

Ocean Currents



Surface Winds




The source of most airborne particles now is primarily human activities (industries, agriculture and manufacturing), whereas in the past natural sources (forest fires and volcanoes) were the main culprits.

### Stratospheric Ozone and CFCs

Ozone at the Earth's surface is an irritating toxin. Atmospheric ozone is the chemical that occurs high in the atmosphere where it maintains a shield around the Earth protecting everyone from harmful UV radiation from the Sun. The ozone layer is a natural formation 15 to 50 kilometers above us. Since the late 1970's Scientists who have been monitoring this protective layer, have noticed that it is becoming thinner. They have also discovered 'holes' in the layer. This results in more UV radiation getting through to the surface of the Earth and increasing the likelihood of more organisms getting skin cancer and cataracts. It is also affecting the plankton population – which is an important food supply for many animals.

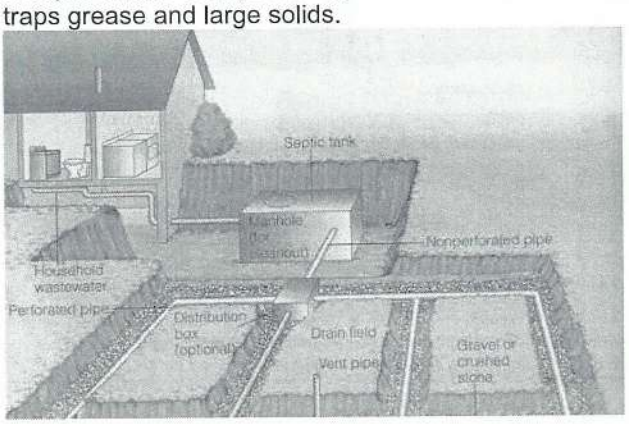
The thinning of the atmosphere is caused by our use of chlorofluorocarbons ( CFC's ). In the past these chemicals were used in: Styrofoam™, aerosol spray cans and coolants in refrigeration systems. These chemicals eventually get into the upper atmosphere where they are broken down into elements like chlorine – which destroys ozone. (1 chlorine atom can destroy 100, 000 ozone molecules. Many countries have signed agreements to reduce their use of these chemicals, which are stable and will persist in the atmosphere for many years to come.

### Controlling Water Pollution in Surface Waters http://www3.gov.ab.ca/env/water/SWQ/index.cfm

Hazardous chemicals can enter surface water from the air, the groundwater, runoff from agricultural fields and industrial sites and outflow from storm sewers and sewage treatment plants. A substance that dissolves in water easily may be carried by water a fair distance and dispersed over a wide area. Substances that do not dissolve easily may sink to the bottom and be concentrated close to the source, affecting organisms in the immediate area. Because humans use water for drinking and agricultural use, its quality is monitored regularly.

Most surface water pollution is a result of washing clothes or watering lawns. Nitrates and phosphates enter the water system through storm sewers, runoff or untreated wastewater. Treatment of wastewater and sewage is necessary to reduce its harmful effects when it reenters the water system from which it was taken. Sewage includes: dissolved and undissolved materials from your kitchen, bathroom and laundry. Treatment can occur in rural areas with septic systems and urban areas with waste treatment plants.

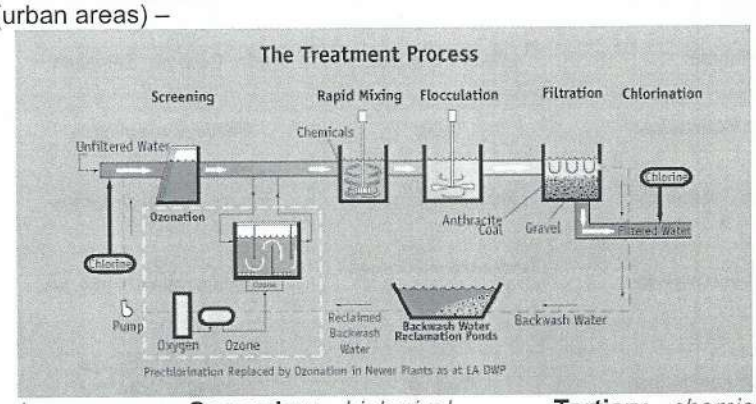
Septic tank (rural areas) –
A septic tank is a large underground container that traps grease and large solids.




The remaining liquid waste is distributed through pipes with holes (perforated); the pipes lead into a drainage area containing gravel. Bacteria and other micro-organisms in the gravel and soil break down the organic waste and use it as a source of food energy. This system mimics the way in which decomposers normally recycle biodegradable wastes. The septic tank is periodically pumped out to prevent overflow.

Sewage Treatment Plant (urban areas) –

A waste facility treats sewage in three levels or steps.




**Primary** - *physical*
- filtering. sieving and settling
- waste water can be further treated with chlorine and returned to the environment as effluent. Waste material, called sludge, can be recycled as fertilizer or landfill.

**Secondary** - *biological*
- bacteria and micro-organisms decompose most of the remaining biodegradable waste.

**Tertiary** - *chemical*
- removes dissolved nitrates, phosphates and undissolved solids from the effluent

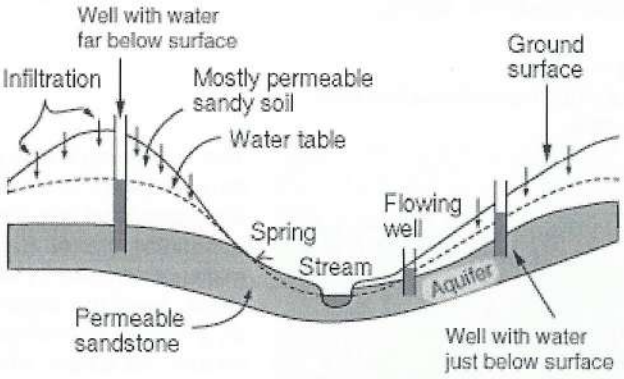
**Controlling Water Pollution in Ground Water**

Water that soaks into the soil is collected in a zone called the groundwater zone. The top of the groundwater zone in the soil is called the water table. Groundwater moves sideways, up or down and can move very slowly (1 meter per year) or very quickly (1 meter per day).

Water in Alberta - http://www3.gov.ab.ca/env/water/index.cfm http://www.groundwater.org/kc/kc.html

Certain contaminants ( http://www.cee.vt.edu/program_areas/environmental/teach/gwprimer/gw-types.html ) can remain collected in the groundwater for long periods of time (because they are heavy metals), posing problems if the groundwater is used for drinking, agricultural purposes or industrial use. A factor that affects the movement of contaminants in groundwater is the number and connection of pores (tiny spaces between soil grains) in the soil. When the pores are packed together very tightly and are not connected, the soil is considered impermeable. If the pores are connected the soil is permeable and water can move through easily.

Permeable ground can create aquifers, which collect naturally filtered amounts of water that providing a good source of drinking water, accessible when a well is drilled. Unfortunately they can also contain concentrated soluble substances as well. They are difficult to clean up and the solution is prevention.




Pollutants, which occur naturally or through human activities, can move more quickly through permeable soil.

**Some Substances That Contaminate Groundwater**

| Substance | Source | Examples | Occurrence |
|---|---|---|---|
| Minerals | Rocks and Soil | Iron, Calcium, Selenium | Natural |
| Organic Substances | Soil | Pesticides, solvents | Natural & Human Activities |
| Leached Substances | Landfill sites, mines | Heavy metals, organics | Human Activities |
| Leaked substances | Underground storage tanks, pipelines | Gasoline, Natural gas, oil | Human Activities |
| Inorganic substances | Run-off | De-icing roadways, sewage, industrial processes | Human Activities |
| Micro-organisms | Septic tanks, sewage treatment ponds, runoff | Bacteria, viruses, Protozoans | Human Activities |
| Chemicals | Household | Nitrates, phosphates, detergents, cleaners | Human Activities |

### Biodegradability and the Environment

Biodegradation occurs in the environment because living things (earthworms, bacteria and fungi) are actively breaking down organic substances, including many pollutants. Micro-organisms are especially important in the biodegradation of pollutants. The existing organic molecules provide carbon atoms, which are used to build biological compounds, such as carbohydrates and proteins. This is a multi-step process in which the large organic molecules are broken down (hydrolyzed) either inside or outside bacteria.

Some bacteria grow and reproduce only when oxygen is present. They use the oxygen for the process of aerobic biodegradation. When oxygen is not present – in an anaerobic environment (like deep in landfill sites) - some bacteria remove chlorine from harmful chlorine-containing compounds, such as PCB's (polychlorinated biphenyls - human made oils used in electrical equipment), by replacing them with hydrogen atoms – which can then be used as food for the bacteria. During the winter, biodegradation is slow, because *temperature* is one factor that affects the rate of biodegradation. Other factors include *soil moisture, pH, oxygen supply and nutrient availability*.

## Hazardous Wastes

A hazardous waste is any discarded material that contains substances that can be poisonous, toxic, corrosive, flammable, or explosive. Chemicals used in the home and garden can be classified as hazardous wastes.

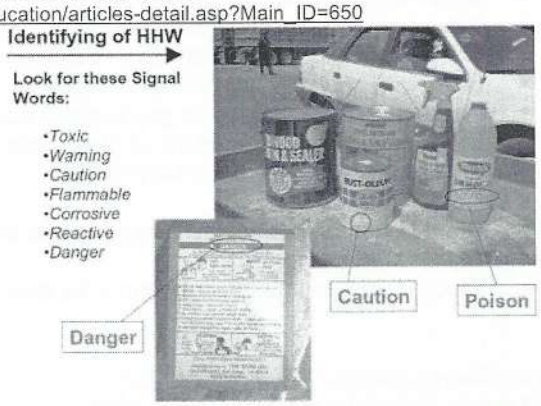
HOUSEHOLD PRODUCTS DATABASE - http://householdproducts.nlm.nih.gov/products.htm

A Sample List of Products Used in the Home
http://www.checnet.org/healthehouse/education/articles-detail.asp?Main_ID=650

Common Household Hazardous Waste
http://www3.gov.ab.ca/env/waste/aow/hhw/common.html

Improper storage, transport and disposal of these products can contribute to burns, heart problems, kidney failure, lung (respiratory) ailments, cancer and even death.

Regulations are designed to protect consumers and reduce the risk of hazardous chemicals. The regulations reflect current scientific research done on the products and how they might interact with other products.




Learn about Chemicals in your home http://www.epa.gov/kidshometour/index.htm

**WHMIS**

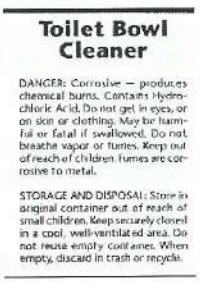
**W**orkplace **H**azardous **M**aterials **I**nformation **S**ystem

***MSDS***

***M**aterial **S**afety **D**ata **S**heets*

MSDS information sheets give a detailed description of the product – its composition, physical appearance, and chemical characteristics. It also describes the precautions that should be taken when handling, transporting and disposing of the product, as well as health effects, first aid treatment and what to do in case of a spill.

Different labels are used for different purposes:

| Transporting | Supplying | Used in the Workplace | Disposal |
|---|---|---|---|
|   Figure 2 POISON Placard <br> Transporting Hazardous Materials Test |   | If a controlled product is transferred at the workplace to other containers, the employer may need to apply a workplace label to the new container. Workplace labels provide the following information: product identification; information for safe handling and a statement indicating that the MSDS is available. |   |

**Eco-Label -** Established in 1988, Canada's "Environmental Choice" Eco-Logo program helps consumers identify products and services that are less harmful to the environment.

http://www.environmentalchoice.com/index_main.cfm

**New Product Regulations**
When new products are produced, the supplier must apply for approval to make it available to the consumer. The information about the product must include:

- Intended use, physical and chemical properties, active ingredient(s)
- Instructions for use, safety precautions
- Health effects, environmental effects, toxicity to humans, and first aid instructions in case of poisoning

**Storage of Hazardous Chemicals in the Home**

- Leave original label on the product
- Keep out of reach of children (locked up)
- Containers should be in good condition and secure
- Store in a cool, dry, well-ventilated place
- Never store flammables or gas in glass containers
- Store different classifications of chemicals on separate shelves in separate locations
- Keep oxidizers away from flammables
- Keep upright
- Store chemical in proper place when not in use
- Discard old products
- Place rusted or leaking containers inside a second container – dispose of both

**Waste Management – Back to the 4Rs**
Solid waste includes the garbage collected from households, industries, commercial retailers, institutions and construction or demolition sites.

Some of this waste can be reduced, recycled, recovered or reused, but most of it is placed in landfill sites. The most preferred option is to **reduce** – in other words don't make as much waste and the problem of disposal will take care of itself.

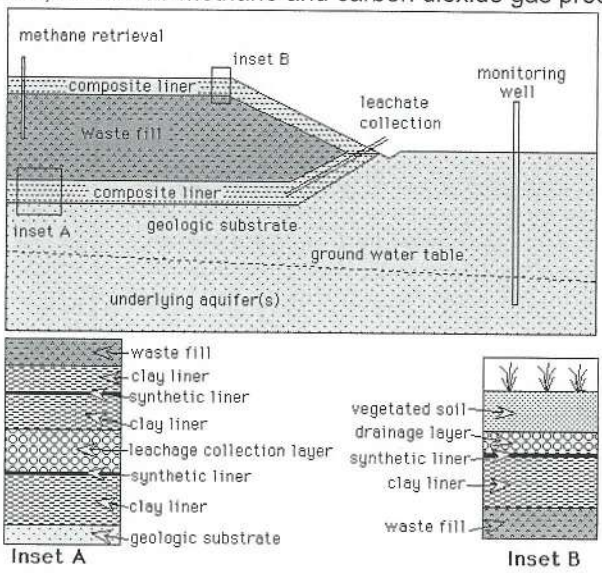
Follow the *4Rs* to avoid waste products being placed in a sanitary landfill and eventually coming back to haunt us.


Hazardous Waste Collection Sites http://www.landcentre.ca/foundation/hazardous/legab.cfm
A small amount of waste is incinerated (burned). Materials that cannot be recycled are packaged into larger containers and are then transported to **incinerators** like the one in Swan Hills.

Swan Hills Special Hazardous Waste Treatment Facility http://www.townofswanhills.com/aswt.html
Some of the hazards that can occur when solid waste, containing chemicals harmful to the environment, are not properly disposed of include:
- air pollution (controlled emissions - scrubbers)
- leaching (prevented by plastic liners and compacted clay foundation at the landfill site)

## Landfill Construction and Design

Activities around a sanitary landfill often evoke a N.I.M.B.Y. response. There are so many negative impacts of landfills that the activities to make sure they are safe must be monitored daily. The problems that can be encountered include: wind dispersal, scavengers and disease, leaching into groundwater, as well as methane and carbon dioxide gas production.




## Secure Landfills

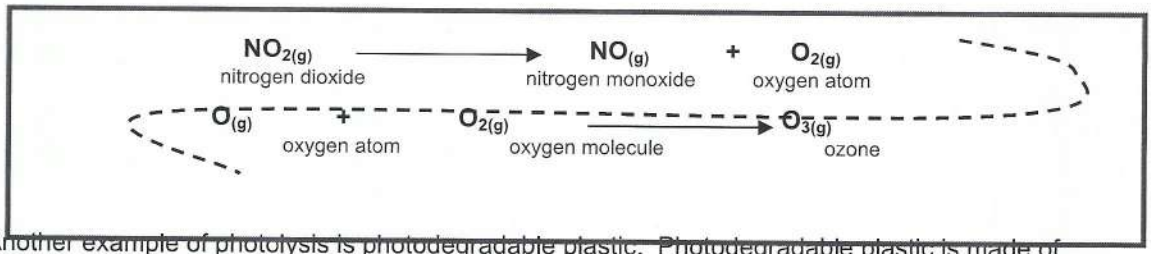
To reduce these problems, a sanitary landfill is designed to ensure that possible negative impacts are addressed and the landfill site is a secure and safe operation.

## Bioremediation – Mother Nature to the Rescue

Bioreactors are a new technology that speeds up the rate of biodegradation by adding water to organic waste in a sanitary landfill site. *Planting vegetation* also encourages faster biodegradation because the populations of bacteria and fungi are larger around plant roots and this higher level means more microbial activity.

Phytoremediation is a technique that can be used to reduce the concentration of harmful chemicals in the soil or groundwater. Plants have been used to clean up metals, hydrocarbons, solvents, pesticides, radioactive materials, explosives, and landfill leachates. The plants are able to absorb and accumulate large amounts of these chemicals. When the plants have matured, they are harvested, burned or composted. In some cases, the metal can be recycled. When most of the harmful chemicals are removed by phytoremediation from the soil, then other plants can be planted there.

Photolysis is the breakdown of compounds by sunlight. The formation of ozone is an example of this process (outlined below)




Another example of photolysis is photodegradable plastic. Photodegradable plastic is made of chemicals that react when exposed to sunlight. In three months, the plastic becomes a fine powder that is easier to dispose of. (This type of plastic will only degrade if it is exposed to sunlight – if it is buried, it will last in its original shape for hundreds of years.)