Hazardous Waste

It is defined as any waste which because of its quantity, concentration, physical, chemical or infectious characteristics may cause significant hazard to human health and environment when improperly treated, stored, transported or disposed off.

What Harmful Chemicals Are there in Your Home?

Cleaning

- Disinfectants
- Drain, toilet, and window cleaners
- Spot removers
- Septic tank cleaners

Paint Products

- Paints, stains, varnishes, and lacquers
- Paint thinners, solvents, and strippers
- Wood preservatives
- Artist paints and inks

General

- Dry-cell batteries (mercury and cadmium)
- Glues and cements

Gardening

- Pesticides
- Weed killers
- Ant and rodent killers
- Flea powders

Automotive

- Gasoline
- Used motor oil
- Antifreeze
- Battery acid
- Brake and transmission fluid

Characteristics of hazardous substances

- **Reactivity**: waste not stable at normal conditions and hence can cause explosive reactions or liberate toxic fumes, gases and vapours, reacts violently when mixed with water.
- Eg., Sodium and potassium metal, dry picric acid, cyanide plating operations etc.

Characteristics…..

Ignitability: Wastes which are easily ignited and burn vigorously at ≤ 60^{o}C. Eg., Volatile liquids such as solvents (acetone, toluene, methanol, ethers etc.), rubber, glue, paint thinners etc.

Corrosivity: Liquid wastes with pH less than 2 or greater than 12.5 and those that are capable of corroding metal containers. Eg., acids, lime, battery acid, drain cleaners etc.

Characteristics…..

- **Toxicity**: Toxic substances are harmful or fatal when inhaled, ingested or absorbed. Wastes which release toxic materials on leaching in excess of the permissible concentration pose a substantial hazard to human health and are termed toxic.
- Toxicity is of two types
  - Acute (one massive dose- may be fatal)
  - Chronic (long exposure to small dose-chronic disease)

Classes of hazardous waste

- Radioactive waste
- Biomedical wastes
- Chemical wastes

Radioactive waste

(i) Discharges from nuclear reactions contain a number of radio-nuclides. These nuclides emit radiations harmful to living organisms.

(ii) Use of radioactive materials in nuclear weapons

(iii) Mining and processing of ores to produce radio isotopes.

(iv) Radioactive fallout from nuclear bombs.

(v) Emissions from industrial use of nuclear energy

(vi) Leakage from underground nuclear detonations.

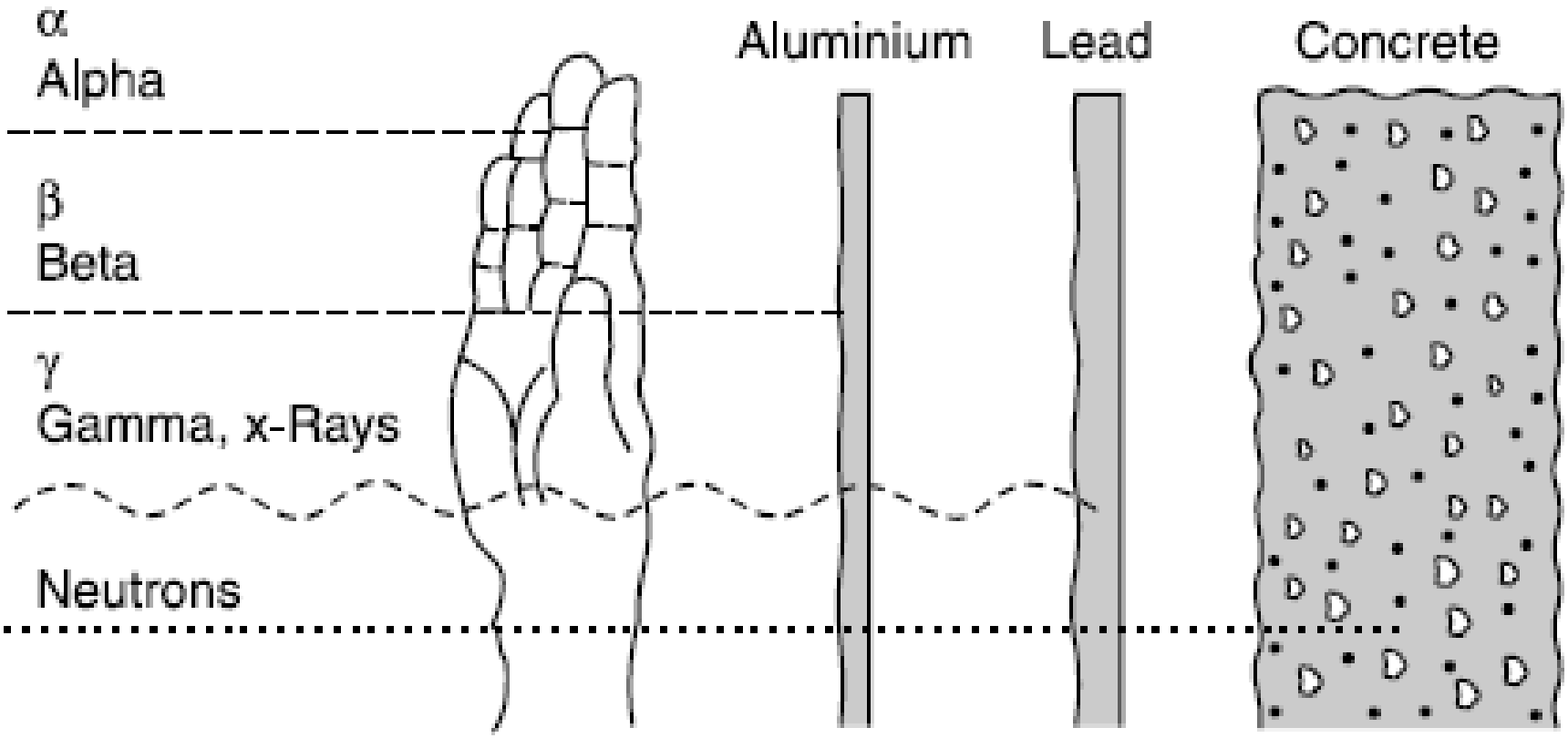
(v) Use of radio isotopes in medicine, industry, agriculture and research operations.

Radiations: alpha, beta and gamma

- Radiations require different forms of protection:
  - Alpha radiation cannot penetrate the skin and can be blocked out by a sheet of paper, but is dangerous in the lung.
  - Beta radiation can penetrate into the body but can be blocked out by a sheet of aluminium foil.
  - Gamma radiation can penetrate into the body, aluminium foil, but can be blocked by lead.

Note--Neutron radiation generally only occurs inside a nuclear reactor.

Radiations require different forms of protection



Effects-Somatic damage

- **Damage to the living organism itself, resulting in sickness and death.**
- The delayed or chronic somatic effects have a potential for the development of **cancer and cataract.**
- Acute somatic effects of radiation include **skin burns, vomiting, hair loss, temporary sterility in men** and blood changes.

Genetic damage

- **Damage which passes from one generation to another.**
- Appears in the future generations of the exposed person as a result of **radiation damage to the reproductive cells**
- **Risks from genetic effects** in humans are seen to be **considerably smaller than** the risks for somatic effects.

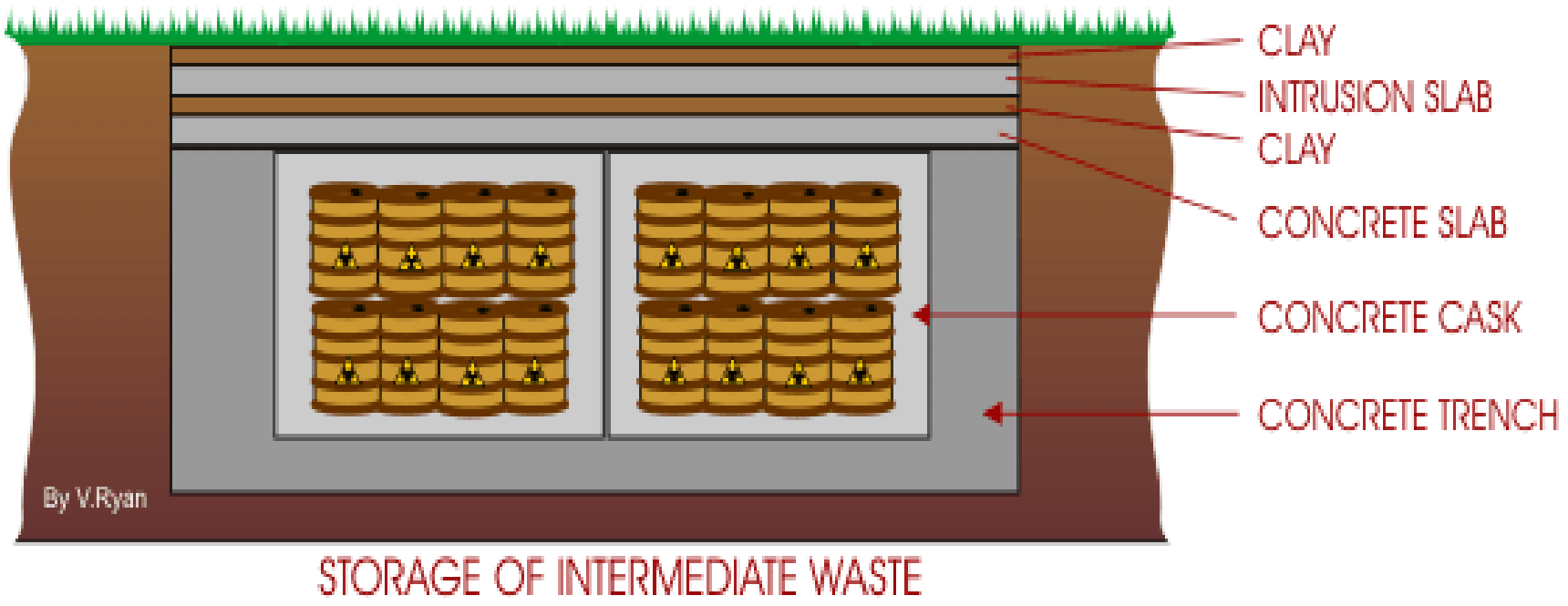
Disposal of Radioactive waste

1. Geological dumping

- Soil absorbs radioactive materials easily that is why disposal in ground is an easy method.
- Disposal is done in **tunnel, vaults or silos** in a particular geological formation at least a few hundred meters below ground level.
- Such a facility could be designed to accept high level radioactive waste (HLW), including spent fuels if it is to be treated as waste.
- The waste is kept buried for 13-15 yrs and finally disposed off in sea.
- Salt is a powerful absorber of radiations, hence the wastes are disposed off in salt heaps provided in mines.

DEEP GEOLOGICAL DEPOSITS

- Geological depository at depth of 250m to 1000m
- Implemented in USA for military waste.



STORAGE OF INTERMEDIATE WASTE

2. Ocean dumping

- OCEAN DUMPING is the dumping or placing of material in the ocean , often on the continental shelf.
- Hazardous and nuclear waste are also disposed but these are highly dangerous for aquatic life and human life also.
- Banned by most of the developed countries due to scientific proof of bad effects on ocean and marine life.

Biomedical Waste

(i) Human anatomical waste, that consists of tissues, organs or body parts, but does not include teeth, hair and nails.

(ii) Animal waste, that consists of tissues, organs, body parts, fluid blood and blood products, items saturated or dripping with blood, body fluids contaminated with blood, and body fluids removed for diagnosis or removed during surgery.

(iii) Microbiology laboratory waste, that consists of laboratory cultures, stocks for specimens of microorganisms, live or attenuated vaccines, human or animal cell cultures used in research

(iv) Waste sharps, that are clinical and laboratory materials consisting of needles, syringes, blades or laboratory glass capable of causing punctures or cuts.

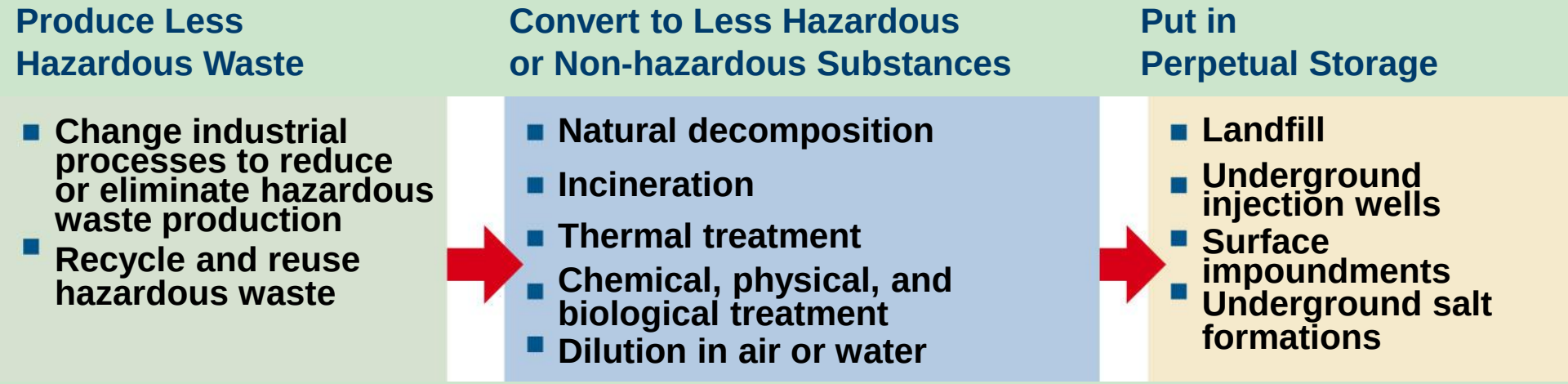
Effects: biomedical waste

- **Improper handling and disposal of biomedical waste can cause spread of deadly infections** like HIV, AIDS, Hepatitis A and B along with respiratory and gastrointestinal infections
- The infectious agents can **enter a healthy body through a puncture, abrasion or cut in the skin; through mucous membranes; by inhalation or by ingestion**.

Chemical wastes

- Acids and alkalis
- Non-degradable toxic heavy metals
  - Lead, mercury, and arsenic etc
- Organic compounds
  - Various solvents, VOCs (benzene toluene etc.), pesticides, PCBs, and dioxins etc

Integrated hazardous waste treatment



Hazardous Waste Treatment Technologies

- Physical processes
- Chemical processes
- Biological processes
- Incineration
- Land disposal

PHYSICAL PROCESSES
1. Sedimentation

- It separates solids from liquids. Involves gravity settling and natural floating.
- The floating solids are removed by skimming devices.
- Floatation is encouraged by introducing finely divided bubbles into the waste stream.
- The bubbles alongwith particles are then skimmed out

2. Adsorption

- Dissolved substances which donot settle out can be removed.
- Most common adsorbent is Granular activated carbon (GAC), which has large surface area of about 1000m^2/g. A single handful of GAC has an internal surface area of about one acre.
- Used GAC is regenerated either by burning the contaminants or washing it with solvent.

3. Aeration

- Contaminated wastes are sprayed downward through a packing material in a tower, through which air is blown upward carrying away the chemicals that are relatively volatile.
- This process can remove 95% Volatile organic compounds (VOCs) such as trichloro ethylene, tetrachloro ethylene, benzene, toluene etc.
- Sometimes adsorption is combined with aeration and many Volatile and non-volatile compounds are removed. This extends the life of carbon because no clogging with VOCs take place.

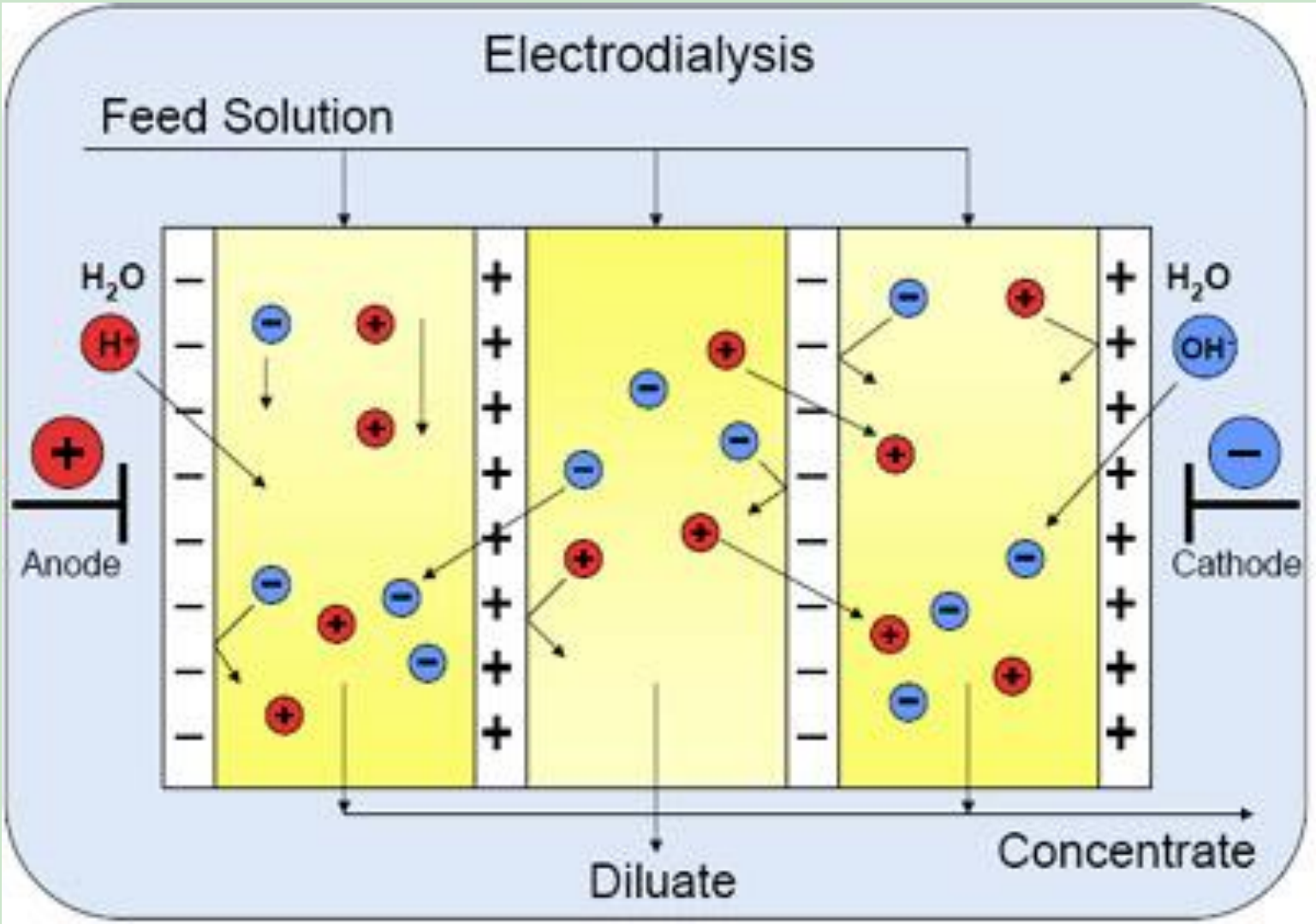
4. Reverse osmosis and 5. Ion-exchange process

- In Reverse Osmosis, the contaminated water is forced against a semi-permeable membrane, which acts as a filter. The water passes through the pores and hazardous chemical substances are left behind
- In Ion-exchange process, anion and cation exchange resins are used to remove toxic ions from waste water.

6. Electrodialysis

- This technique removes hazardous substances from waste water.
- Under the influence of applied electric field the ions migrate towards oppositely charged electrodes through ion selective membranes.
- **Metal salts from electroplating rinses are removed this way**.

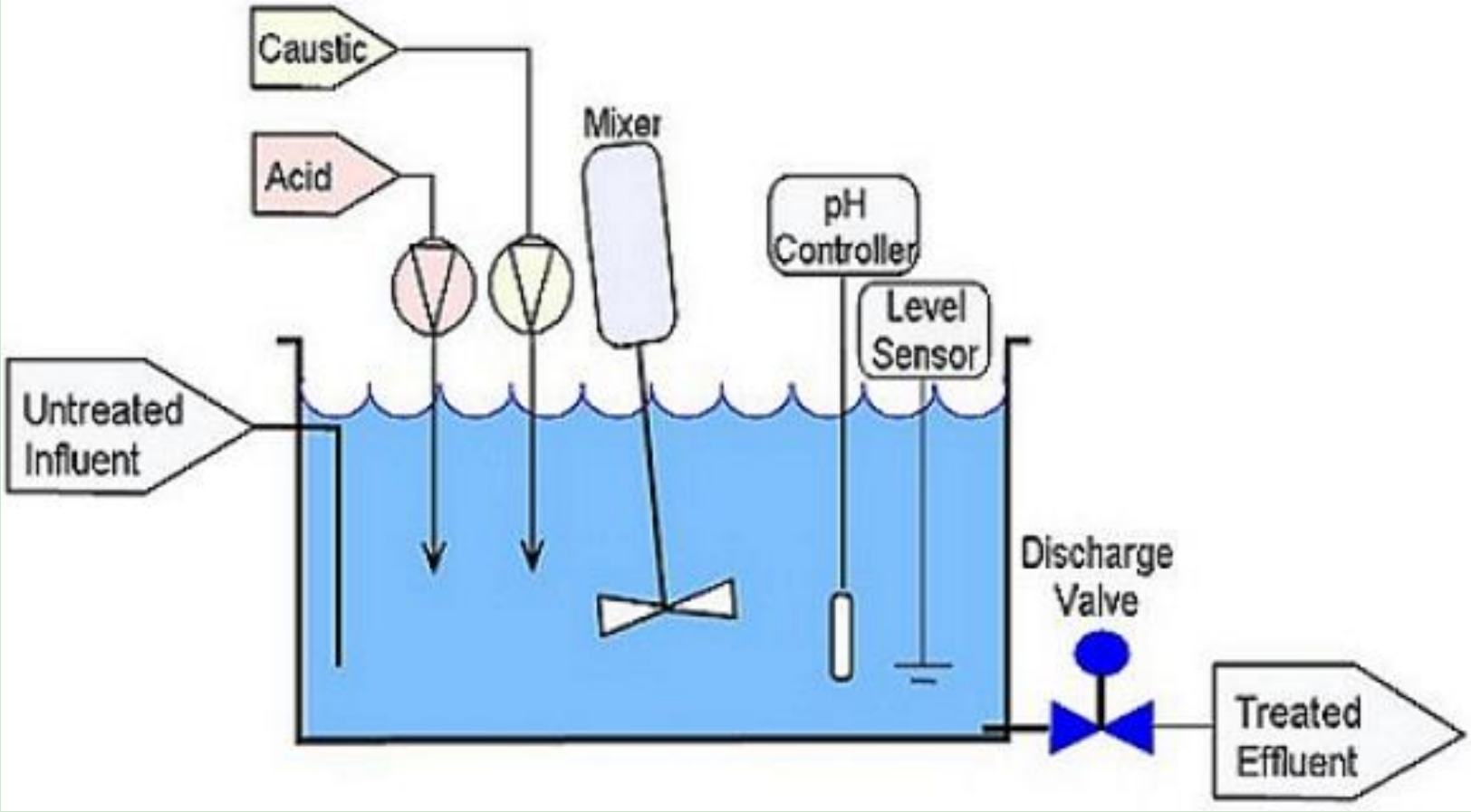
Electrodialysis



CHEMICAL PROCESSES
1. Neutralization

- Converts to less hazardous by changing their pH.
- Acidic wastes are neutralised with $Ca(OH)_2$ with continuous stirring in a chemical reactor. The pH is regularly monitored.
- Alkaline wastes are neutralized by adding acid directly or by bubbling CO_2.
- Simultaneous alkaline and acidic neutralization can also be accomplished in same vessel.

Simultaneous Neutralization



2. Chemical Precipitation

The pH of waste waters is so adjusted that the solubility of toxic metals is decreased, leading to the formation of a precipitate that can be removed by settling and filteration. For example, the ion M^{2+} can be removed by converting it into its insoluble hydroxide, using lime

$$M^{2+} + Ca(OH)_2 \longrightarrow M(OH)_2 + Ca^{2+}$$

The metal hydroxides in general are relatively insoluble in basic solutions. Each metal has its own pH at which its solubility is minimum. If the waste contains several metals then it becomes difficult to control the precipitation of a mix of different metals in the same waste. In such cases more than one stage of precipitation is required to allow different values of pH to control the removal of different hazardous substances.

If the metals are present in very low concentrations in waste water then the metals are precipitated as sulphides. Metal sulphides have lower solubilities than metal hydroxides and hence can be precipitated out. The only disadvantage of precipitating metals as sulphides is the potential formation of toxic H_2S gas if alkalinity is not properly maintained. Some metals like Pb, Cd and Ni precipitate as carbonates.

2. Oxidation-Reduction Process

- Certain hazardous substances have variable oxidation states. All the states donot have the same toxicity.
- Substances can be converted to oxidation state which is less toxic by redox reactions.
- One of the most important redox treatment process is reduction of Cr^{6+} to Cr^{3+}. The trivalent Cr*, which is non-toxic can be easily precipitated. In this process SO_2 is often used as reducing agent.

[*Cr^{3+} is an essential nutrient that uses sugar, protein and fat and promotes action of insulin in the body]

Contd….

$$3SO_2 + 3H_2O \longrightarrow 3H_2SO_3$$

$$2CrO_3 + 3H_2SO_3 \longrightarrow Cr_2(SO_4)_3 + 3H_2O$$

Similarly cyanide wastes are treated using redox process. These hazardous substances which are common in effluents from metal finishing industry, are converted to less toxic cyanate using alkaline chlorination.

$$NaCN + Cl_2 + NaOH \longrightarrow NaCNO + NaCl + H_2O$$

If chlorination is continued further, the cyanate ion oxidizes to CO_2 and N_2 resulting in complete destruction of cyanide

$$2NaCNO + 3Cl_2 + 4NaOH \longrightarrow 2CO_2 + N_2 + 6NaCl + 2H_2O$$

The wastes that can be treated using redox *oxidation* include the waters which contain benzene, toluene, phenols, cyanide, arsenic ions, iron, and manganese. The wastes which can be treated using redox *reduction* include the ones containing chromium (VI) , mercury, lead, silver, and chlorinated organics.

BIOLOGICAL PROCESSES

- The biological treatment systems use microorganisms (bacteria, fungi etc.) to oxidize organic matter to CO_2 and H_2O.
- Microorganisms survive on nutrients such as nitrogen, phosphorus as well as a source of carbon and energy.
- The microorganisms get carbon and energy from the organics they consume.
- **The biological treatment stage utilizes processes already described for municipal waste water treatment plants- Trickling filters, activated sludge process etc**.

Contd…

- **Bioremediation** employs bacteria and enzymes that help destroy toxic or hazardous substances or convert them to harmless compounds.
- **Phytoremediation** involves using **natural or genetically engineered plants** to absorb, filter and remove contaminants from polluted soil and water.

In-situ biodegradation

- The bacteria are used to degrade organic compounds in the soil and ground water on site itself. Thus there is less risk associated with hazardous waste transportation.
- This method has been used to treat wastes containing gasoline and diesel. It can also be used to treat chlorinated solvents (trichloroethylene, tetrachloro ethylene etc), heavy metals etc

Contd….

In situ biodegradation can be carried out by using two approaches:

- In one approach the population of already existing microorganisms is increased by supplying necessary nutrients such as ammonium sulphate, magnesium sulphate, sodium carbonate etc, to the contaminated waste. Oxygen can be supplied by injecting an oxidant such as H_2O_2 or by forcing air.
- In another approach, the underground population of microorganism is altered by seeding with new microorganisms, which have proven to be effective to decompose the hazardous wastes under consideration, based on laboratory studies.

INCINERATION

- **Wastes are subjected to combustion so as to convert them into residue and gaseous products.**
- **Reduces the volumes of waste to 70 to 80 % of the original volume.**
- **Useful material and energy can be recovered if process is done in properly equipped incinerators.**
- **Various pollution control technologies for treatment of emissions can be installed in incinerators:**
  - **Scrubbers –It uses a liquid spray to neutralize acid gases**
  - **Filters-remove tiny flyash particles from smoke.**

LAND DISPOSAL

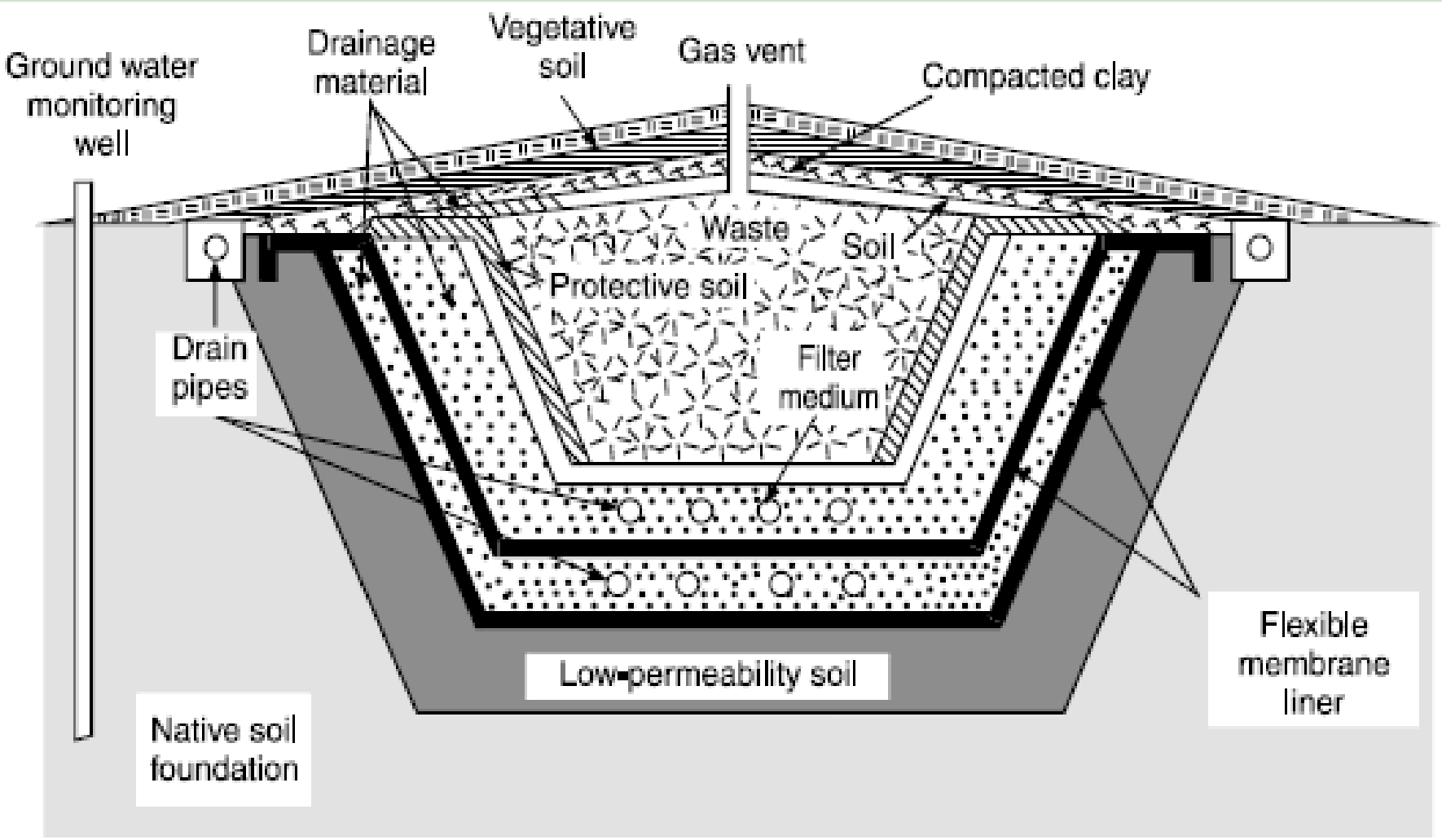
- Landfills
- Surface impoundments
- Underground injection wells

Conventionally, land disposal methods were used to dispose off hazardous wastes because this was the convenient and inexpensive method. Unfortunately, the poorly monitored disposal sites have resulted in tragic incidences. Thus, Resources Conservation and Recovery Act (RCRA), has put a ban on land disposal of some of the hazardous substances.

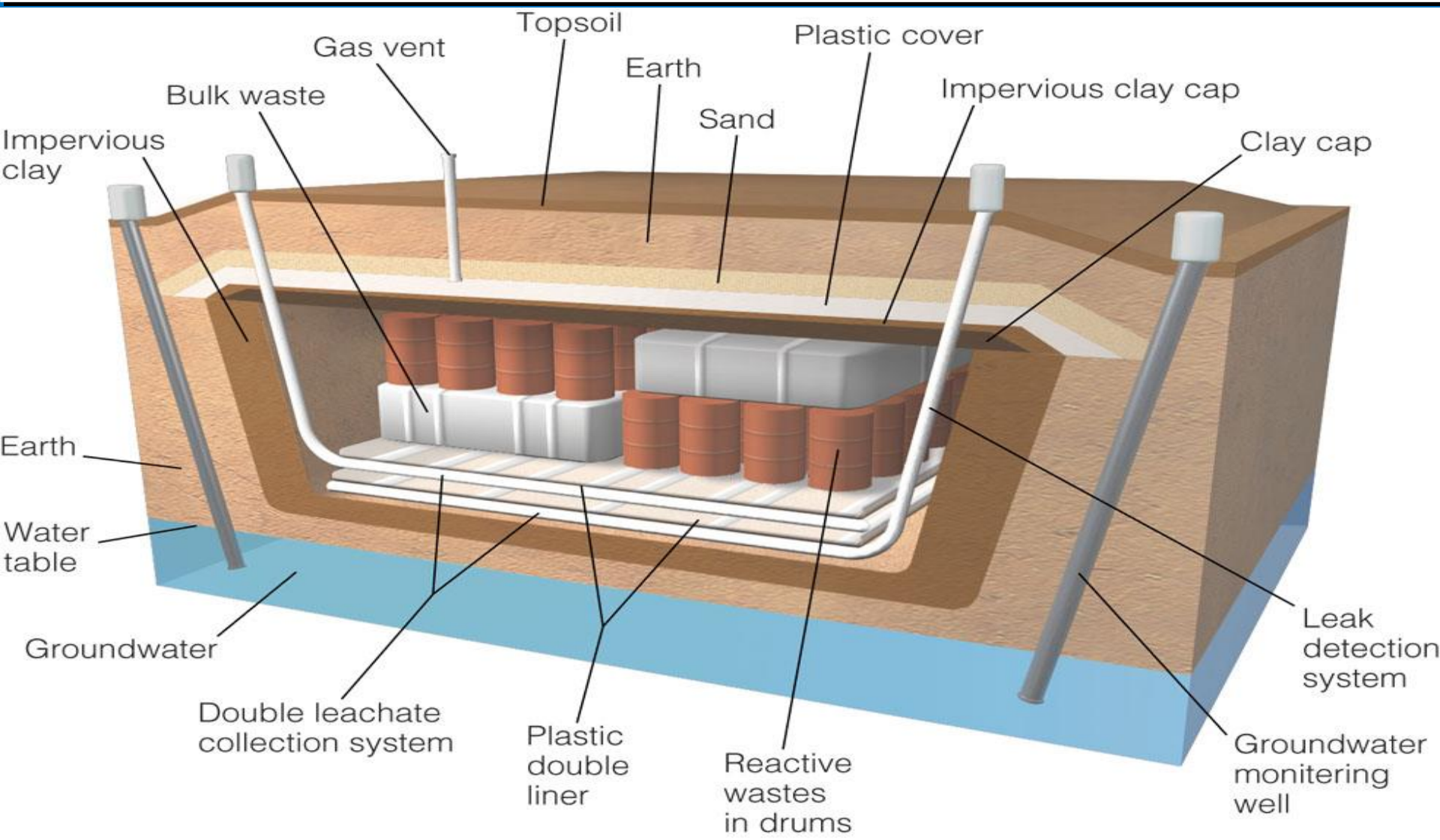
Hazardous waste landfill

Liquid and solid hazardous wastes can be put into drums or other containers and buried in carefully designed and monitored secure hazardous waste landfills.

Hazardous waste landfill



Hazardous Waste Landfill



Hazardous Waste Landfills

- A double liner system is placed beneath the hazardous wastes to stop the leakage of liquids from the waste.
- The upper liner must be flexible membrane lining made up of sheets of plastics (PVC, HDPE) or rubber.
- The lower lining can be re-compacted clay having a thickness of atleast three feet. Flexible plastic membranes are also often used in lower lining.
- Collected leachate undergoes further treatment.
- The site must include monitoring facilities to check the possibility of contamination from soil.

A few restrictions are:

- Banning liquids from landfills
- Banning underground disposal of hazardous waste within 1/4 mile of a drinking water well.
- Requiring more stringent structural designs for landfills, impounds
- Requiring corrective action, if hazardous substance leaks from a facility
- Requiring disposable facilities to be constructed only in suitable hydrogeolic settings.

Surface Impoundments

- Surface impoundments are ponds, pits or lagoons in which wastes are stored.
- May have liners to help contain the waste.
- Eventually all impoundment liners are likely to leak and could contaminate groundwater.

Trade-Offs

Surface Impoundments

Advantages

Low cost

Wastes can often be retrieved

Can store wastes indefinitely with secure double liners

Disadvantages

Groundwater contamination from leaking liners (and overflow from flooding)

Air pollution from volatile organic compounds

Output approach that encourages waste production

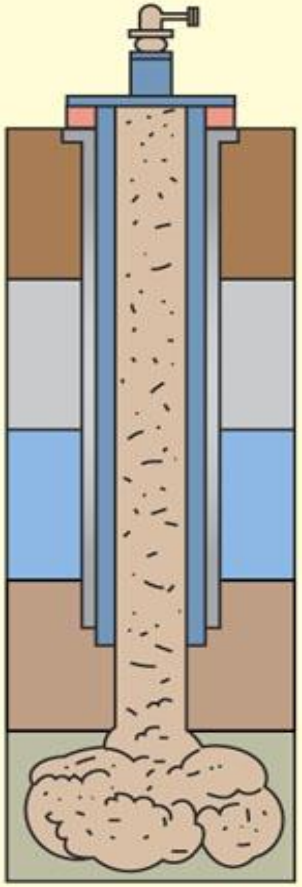
Underground Injections or deep-well disposal

- **Burial or long-term storage of hazardous and toxic wastes should be used only as the last resort.**
- **Liquid hazardous wastes are pumped under pressure through a pipe into dry, porous rock formations far beneath aquifers** that are tapped for drinking and irrigation.
- **Cost is low and the wastes can often be retrieved if problems develop.**
- Problems with deep-well disposal are that **wastes can leak into groundwater from the well shaft or migrate into groundwater** in unexpected ways.

Trade-Offs

Deep Underground Wells

Advantages	Disadvantages
Safe method if sites are chosen carefully	Leaks or spills at surface
Wastes can be retrieved if problems develop	Leaks from corrosion of well casing
Easy to do	Existing fractures or earthquakes can allow wastes to escape into groundwater
Low cost	Encourages waste production



CASE STUDY

- **Dumping of Radioactive Material In Delhi's Mayapuri, Asia's biggest Scrap market -February 2010**
- **Gamma Irradiator was bought in 1968 from Canada through the UGC for professor B.K.Sharma's research which was about the "effect of Gamma rays on compressed cyanide,"**

Origin of Cobalt-60 that Caused the Exposure

- **The Cobalt-60 was in a "Gamma Irradiator", at Delhi University which was not in use since 1985.**
- **Cobalt-60 is a radioactive isotope, which is a hard, lustrous, grey metal.**
- **It was bought by scrap dealers in Mayapuri through an auction in Feb 2010.**
- **The scrap dealers dismantled the equipment and in the process, the lead covering on it was pealed off leading to radiation exposure and casualties.**

February 2010

Panic triggered in the locality on that night after the news of a radiation leak broke out with five persons falling ill after coming in contact with a "mysterious shining object" in a scrap shop.
