The water can be used for different purposes as mentioned below:

(i) Domestic use for drinking, cooking and cleaning, etc.

(ii) Irrigation for agriculture.

(iii) Power generation.

(iv) Industrial use for cooling, processing, cleaning, etc.

(v) For fisheries and acqua-culture.

(vi) Recreation.

Waste water from industries

A. Inorganic industrial wastewater

- Wastewater produced mainly from
  - ✓ *Coal and steel industries*
  - ✓ *Commercial enterprises*
  - ✓ *Industries for surface processing of metals (electroplating plants)*

Acid Mine drainage

COAL WASHING

- Coal mines release substantial quantities of sulphuric acid and iron hydroxide into local streams.
- The first step in the process is the oxidation of pyrire (FeS_2), which is common in underground coal streams.
- Thiobacillus ferrooxidans is a highly acidophilic (pH 1.5 to 2.0), autotrophic bacterium that obtains its energy through the oxidation of ferrous iron (or in other words, reduced inorganic sulfur compounds.

Overall reaction $FeS_2 + \frac{15}{4}O_2 + \frac{7}{2}H_2O \rightleftarrows Fe(OH)_3 + 2H^+ + 2HSO_4^-$

Reaction is just for your information, not to memorise

Thus one mole of pyrite produces 2 moles of sulphuric acid and one mole of ferric hydroxide , which is removed from the solution as a brown precipitate. The pH of the streams receiving this drainage can be as low as 3.0

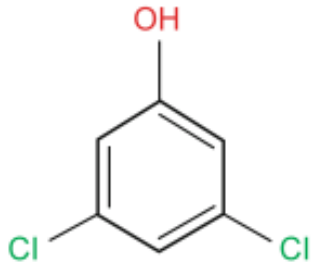
B. Organic industrial wastewater pollution

- Wastewater produced mainly from
  - ✓ Chemical industries which mainly use organic substances for chemical reactions.
  - ✓ Pharmaceutical factories
  - ✓ Tanneries and leather factories
  - ✓ Textile factories
  - ✓ Paper manufacturing industries
  - ✓ Synthetic detergents
  - ✓ Organic dye stuff
  - ✓ Glue and adhesive industries

Tanneries

- ✓ The tanning industry is known to be very polluting
- ✓ A tannery is one of the most water intensive plants.
- ✓ It may take hundreds or even thousands of years for pollutants such as toxic metals from the tanneries to be flushed out of a contaminated aquifer

- ❖ Indeed chlorinated phenols (e.g. 3, 5-dichlorophenol) as an organic pollutant used for tanning have been found to be highly toxic and affect the cellular compounds of organisms (Pasco et al. 2000) exposed to such waste.



3,5-dichlorophenol

Water pollution nay be divided into the following categories:

1. **Ground water pollution;**
2. **Surface water pollution;**

How underground water is formed?

Groundwater forms when water from the surface seeps into the ground. This process is called recharge. The water is able to move underground through the rock and soil due to connected pore spaces.

Followings are just for your information, not to memorise

(1) Ground water is threatened with pollution from the following sources:

(a) Effluents from septic tanks;

(b) Agricultural runoff like nitrates, phosphates (to fertilize plants), pesticides (insecticides, herbicides);

(c) Mine spills : Toxic substances from mining sites, and used motor oil also may seep into groundwater ;

(d) Leaky landfills to contaminate groundwater : Leaching and downward movement of pollutants like volatile organic compounds, petroleum products, metals and synthetic organic chemicals which gets into groundwater by leaching process

(e) Chemical spills at local industrial sites

Natural purification through flushing or biological decomposition is limited in groundwater. Once contaminated, groundwater is very difficult and expensive – in many cases impossible – to rehabilitate.

For eg., benzene which comes from petroleum waste of which aerobic degradation is well known, but under anaerobic condition, it can be decomposed only in presence of nitrates.

$$C_6H_6 + 9O_2 \rightarrow 6CO_2 + 3H_2O$$

$$C_6H_{6(aq)} + 6NO^-_{3(aq)} + 6H^+_{(aq)} \longrightarrow 6CO_{2(aq)} + 3N_{2(g)} + 6H_2O_{(l)}$$

(benzene)

Inorganic Species as Pollutants :

(i) Cyanide

Cyanide is a naturally occurring chemical that is found in low concentrations throughout nature including in fruits, nuts, plants, and insects. The edible parts of these plants contain much lower amounts of these chemicals.

- Cyanide is widely used in industry, especially for metal cleaning and electroplating.
- Cyanide, in the form of a very dilute sodium cyanide solution, is used to dissolve and *separate gold from ore*.
- cyanide is used to make paper, textiles, and plastics (Manufacture of synthetic polymers, such as nylon and acrylics).
- It is present in the chemicals used to develop photographs.

Cyanide, a deadly poisonous substance, exists in water as HCN, a weak acid

Uses are just for your information, not to memorise

(ii) Ammonia

- ✓ *It is a normal constituent of groundwaters*
- ✓ *Most ammonia in water is present as* NH_4^+ rather than as NH_3.
- ✓ Excessive levels of ammoniacal nitrogen cause water-quality problems.

Ammonia is a very important industrial chemical, and is used widely in both its pure form and as a feedstock for a wide variety of other chemicals.

Ammonia **itself** is used:

- As a fertilizer, such as ammonium sulfate, ammonium nitrate, ammonium hydrogen phosphate, and urea.
- In many alkaline cleansers, such as window and floor cleaners.
- pulp and paper industry uses ammonia for pulping wood.
- synthetic textile fibers such as nylon, rayon and acrylics; and for the manufacture of certain plastics such as phenolics and polyurethanes.

(iii) Hydrogen sulfide, H_2S

It occurs naturally in crude petroleum, natural gas, sour gases, in salt mines, in volcanic gases, hot sulfur springs, lakes, salt water ponds.

- Its presence is easily detected by its characteristic rotten-egg odor.

The major industrial use of H_2S is -

- in the production of elemental sulfur and sulfuric acid.
- in metallurgy to precipitate copper, nickel and cobalt sulfides from ores (metals *are made precipitated as their sulfides*);

Wastes that come from chemical plants, paper mills, textile mills, and tanneries may also contain H_2S.

(iv) Toxic effect of Nitrites

- Nitrite is added to some industrial process water as a corrosion inhibitor.
- It causes "Blue baby syndrome".

Non-Biodegradable ORGANIC Pollutants : REFRACTORY ORGANICS

1. Volatile Organic Compounds (VOCs)
2. Persistent Organic Pollutants (POPs) :

1. Volatile Organic Compounds (VOCs) :

❖ These are volatile compounds (evaporate or vaporize readily under normal conditions).

❖ The compounds, the nose detects as smells, are generally VOCs.

❖ These compounds are of low-molecular weight and have high vapor pressure.

❖ VOCs may be natural or synthetic (man-made).

Examples:

Methane, chloroflurocarbons, trichloroethylene, formaldehyde, Acetone, Ethylene glycol, 1,3-butadiene
vinyl chloride, tetrachloroethylene ,
carbon tetrachloride,
1,2-dichloroethane ,
Benzene, Toluene and Xylene ⇨ widely used as solvent etc.

Uses :

1. They are used as solvents in laboratories, industrial processes

2. Many household products emit VOCs

Sources:

- (i) VOCs are released from burning fuel (gasoline, oil, wood coal, natural gas, etc.), automobiles are a major source of VOCs.
- They are found at airports and automobile service stations, machine print and paint shops, electronics and chemical plants.

(ii) Volatile organic compounds are produced naturally through metabolism (called *metabolites*).

Plants synthesize many organic molecules and release some VOCs (*terpenes, isoprene, which give them characteristics smell*) into the atmosphere.

Trees emit VOCs for a variety of reasons:

- To repel harmful insects and animals.
- To attract pollinators.

Toxic effects of VOCs:

- A number of VOCs are either known or suspected carcinogens. Some organics can cause cancer in animals, while some are suspected to cause cancer in humans.
- Most toxic of the five is vinyl chloride (chloroethylene), is a known human carcinogen.

2. Persistent Organic Pollutants (POPs)

(i) Mostly these are chlorinated aromatic compounds.

(ii) Very stable, so do not break down into simpler less toxic form very easily in the environment -- Poorly biodegradable. These are resistant to environmental degradation through chemical, biological, and photolytic processes. Hence persists in the environment for long period of time.

(iii) Soluble in fat , hence, bioaccumulative, ie., they accumulate in the fatty tissues of the organisms and can pass from one species to the next through the food-chain.

Persistent Organic Pollutants (POPs) :

10 intentionally produced POPs are as follows:

(i) PAHs, (Polynuclear Aromatic Hydrocarbons)

(ii) PCBs, (Poly Chlorinated Biphenyls)

(iii) DDT etc. and

2 unintentionally produced POPs are –

(i) Polychlorinated dioxins and

(ii) Polychlorinated dibenzofurans (PCDF).

(i). Polynuclear aromatic hydrocarbons, PAHs

The polycyclic aromatic hydrocarbons (or polynuclear hydrocarbon or poly-aromatic hydrocarbons) contain two or more fused aromatic rings and neither contain heteroatoms nor substituents.

Examples:

Naphthalene, anthracene, phenanthrene, chrysene, Benzo[α]pyrene etc.

How do PAHs get in the Environment?

- PAHs are released to the environment through natural and man made processes.
- Produced from incomplete combustion of organic compounds
- Anthropogenic sources includes:
- Burning of wood
- Vehicle exhaust
- Coal burning power plants
- Grilled/smoked foods
- Cigarette smoke

Uses :

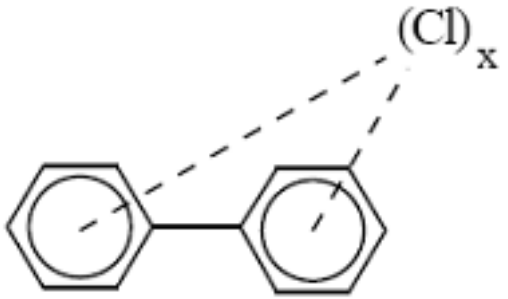
- In the making of pharmaceuticals, dyes, plastics, and pesticides.
- Naphthalene most commonly used is as a household fumigant against moths (hence the name mothballs), Cockroaches Repeller.
- A mixture of phenanthrene and anthracene is used to coat water storage tanks to prevent rust

PAHs and Your Health

- Some PAHs have been shown to be cancer causing: These compounds directly damage DNA and initiate mutations that can lead to the development of cancer.

(ii). POLYCHLORINATED BIPHENYLS

- Polychlorinated biphenyls (PCBs) are a class of organic compounds with 1 to 10 chlorine atoms attached to biphenyl.



- The chemical formula of PCB's can be presented as : $C_{12}H_{10-x}Cl_x$ where x is a number of chlorine atoms within the range of 1 to 10
- These compounds have been found throughout the world in water, sediments, bird tissue, and fish tissue.
- PCB production was banned by the Stockholm Convention in 2001.

Sources:

- PCBs, a by-product of coal tar..

Uses:

PCBs were widely

(i) Used as insulating materials.

(ii) Coolants and lubricants in electrical equipment

(iii) Plasticizers.

(iv) Inks

(v) lubricants,

(vi) adhesives,

Toxic effects:

There is growing concern that many of PCBs

(i) These chemicals interfere with the endocrine system (they mimic, block or otherwise interfere with naturally occurring hormones) in both animals and humans

(ii) Disrupt reproduction and fetal development.

(iii) Most important, these chemicals can be transferred from mother to fetus through the placenta and from mother to infant through breast milk

(iv) In birds, PCBs make eggshell thin ⇨ reduction in birds' population

Pesticides :

These are chemicals or biological agents used to control, repel, attract or kill pests.

Pests are organisms that include insects, weeds or other unwanted plants, birds, mammals, fishes and microorganisms that compete with humans for food, destroy properties, spread disease or are considered a nuisance.

Pesticides includes –

- Insecticides are used to kill the insects.
- Herbicides are used in the control of weeds and to kill plants.

Before, 1940, only a few insecticides were available. Many of them were naturally occurring insecticides extracted from plants, these are

(i) nicotine sulfate from tobacco,

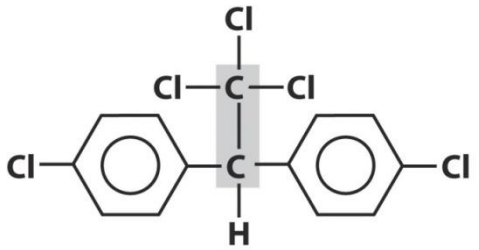
(ii) pyrethrins from pyrethrum flower,

(iii) rotenone extracted from certain legume roots

(iv) Azadirachtin from Neem etc.

DDT

- Insecticidal activity discovered by Müller in 1939
- Between 1940 - 1960, DDT was a commonly used pesticide
- Broad spectrum usefulness
- Found to be effective against malaria and typhus (carried by lice)
- Saved lives of millions of people
- Even its creator earned a Nobel Prize in 1948



(DDT): *para-d*ichloro*d*iphenyl*t*richloroethane

Unnumbered Figure, pg 313
Environmental Chemistry, Third Edition

- It was cheap to produce
- Stable
- DDT is very persistent and remained in the environment for long periods without being broken down
- Apparently it was non-toxic to humans and other mammals
- Banned in 1973 in most countries for agricultural use

Devastating effect on fishes, fish-eating birds

- DDT interferes with the calcium metabolism in birds,
- and as a result, eggshells become thin and
- break when parent birds attempt to incubate the eggs.
- As a result of this, population of fish-eating birds was decreasing at high rate.

Less persistent insecticides : Narrow-spectrum insecticides

(a) organophosphates and (b) carbamates

Organophosphates insecticides

- Unlike the organohalide compounds they largely displaced, the organophosphates readily undergo biodegradation and do not bioaccumulate.
- Toxic to humans and other animals.
- Exposure occurs when farmers spray pesticides
- Ingestion of organophosphates by humans can result in irregular heartbeat, convulsions and even death
- Examples : Parathion, Malathion, Paraoxon
- Mammals possess an enzyme that accomplish malathion hydrolysis, but not the insects, so mammals can detoxify malathion and insects cannot. The result is that malathion has selective insecticidal activity unlike parathion.

Carbamate insecticides

- Carbamate pesticides have lower dermal toxicities than organophosphate pesticides.
- kill honeybees along with the target insects
- Examples : Carbaryl, Carbofuran, Pirimicarb

Herbicides

- In addition to animal pests, farmers also need to control weeds.
- Earlier inorganic chemicals used for weed examples:
- sulfuric acid,
- Paris Green $Cu_3(AsO_3)_2$, arsenic trioxide, lead arsenate.
- Arsenic is non-biodegradable, hence arsenic polluted surface water and groundwater

Organic arsenicals, such as cacodylic acid, have also been widely applied to kill weeds (Structure is only for your information)

- Most selective herbicides are systemic herbicides.
- These molecules work by inhibiting the enzymes necessary for the synthesis of essential amino acids. By stopping this essential biosynthetic pathway kills the plant.
- Animals are unaffected by these systemic herbicides because, their biosynthetic pathways are different from those of plants.
- Examples :
- Chlorophenoxy Herbicides
- Triazines herbicides
- Dalapon

(a) Chlorophenoxy Herbicides

- Create excessive growth hormone in weeds, examples include
- 2,4-dichlorophenoxyacetic acid (2,4-D) and
- 2,4,5-trichlorophenoxyacetic acid (2,4,5-T)

- Mixture of 2,4-D and 2,4,5-T in equal quantities is known as Agent orange.
- The U.S. military sprayed millions of gallons of Agent Orange on trees and vegetation during the Vietnam War (1961-1971) to destroy the forest.
- Because of health problem associated with its use and TCDD is produced as byproduct during its manufacture, it has been banned in 1985.

(b) Triazines herbicides

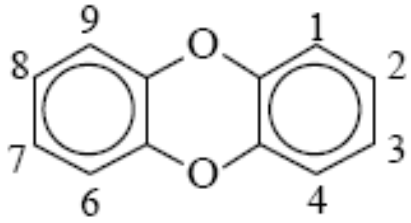
- Inhibit photosynthesis in weeds, as a result of this weeds quickly die
- but has no effect on the other crop plants because these plants have the ability to change the herbicide into a harmless form.
- Examples : Atrazine, Metribuzin

(c) Dalapon

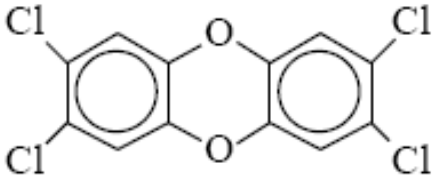
- It is an organochlorine herbicide. Used to control annual and perennial grasses including couch.
- It is highly soluble in water and is moderately persistent in soil systems.
- Dalapon is relatively non-toxic to mammals but has a low toxicity to birds and fish but is moderately toxic to honeybees. Kills soil microorganisms

DIOXINs : Polychlorinated dibenzo-p-dioxins (PCDD)

These Compounds are not commercially produced (not produced intentionally) but are formed as byproduct of some industrial procedure.



Dibenzo -*p*-dioxin



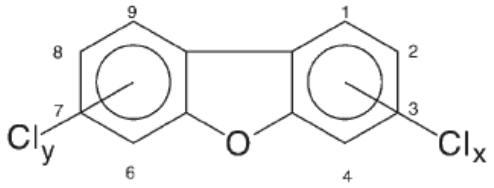
2,3,7,8-Tetrachlorodibenzo-*p*-dioxin

Of the dioxins, the most toxic chemical in the compound is 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD). It is stable thermally up to about 700°C

Sources:

- Dioxins and furans are produced in the manufacture of 2,4,5-T, PCBs etc. the use of 2,4,5-T has been banned in 1985
- During burning of chlorine containing medical and municipal wastes in municipal incinerator.

Polychlorinated dibenzofurans (PCDF)



Polychlorinated dibenzofurans

PCDF

Environmentally attractive approach to control the pests

- By applying pheromones & VOCs (naturally occurring chemical substances)
- Biological controls

A. Natural Chemical Defenses: Application of PHEROMONES

- Pheromones are the chemical substances that released by insects and other animals as a means of communication;
- they differ from species to species, hence they are species-specific.
- Pheromones can be used as bait,
- it will be kept (placed) in a trap; and these traps are coated with a sticky substance.
- The insects follow the pheromone trail into the trap. Insects will be attracted towards the trap and thus insects are trapped.
- Since these traps are coated with a sticky substance, thus insects are trapped.

A. Natural Chemical Defenses

- Volatile organic compounds are produced naturally through metabolism (called metabolites).
- Plants synthesize many organic molecules and release some VOCs (terpenes, isoprene, which give them characteristics smell) into the atmosphere.
- Trees produce nearly 1,000 different chemical compounds (VOCs)

Botanical insecticides : Limonene and linalool

- Extracted from orange and other citrus fruits
- Limonene, a terpene (VOC)
- Linalool, found in small quantities in citrus peel
- Target pests: Fleas, aphids, mites, flies, paper wasp
- Mode of action:
- Limnonene act as nerve toxin and stomach poisons
- Linalool affects ion transport and release of acetyl choline esterase

Radioactive isotopes

The radionuclides (radioactive isotopes) produced by

i) weapons

ii) As waste products in nuclear power plants.

iii) From natural sources – as a result of cosmic ray interactions.

- Radionuclides emit radiation — alpha & beta particles, and gamma rays.
- When radiation interact with the materials in their path is able to remove electrons from other atoms. Hence ions are produced by radioactive isotopes.
- Therefore, this radiation is known as ionizing radiation

$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$ •He nucleus; ${}^{4}_{2}\alpha$

Effects of ionizing radiation :

(i) Radiation-induced genetic damage is of great concern.

(ii) Ionizing radiation can injure any tissue in the human body by initiating harmful chemical reactions in tissues; for example, bonds are broken in the macromolecules that carry out life processes.

(iii) In cases of acute radiation poisoning, bone marrow (produces red blood cells) is destroyed and the concentration of red blood cells is diminished. Such damage may not become apparent until many years after exposure.