Pollution sources

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Environmental Chemistry Module

Pollution sources and Micro-pollutant biogeochemical cycles

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Course Outline

1- What is pollution?

2- Different types of pollution

3- Sources of pollution

4- Effects of pollution

5- The case of micro-pollutants

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What is pollution?

POLLUTION

Presence of matter (gas, liquid, solid) or energy (heat, noise, radiation) whose nature, location, or quantity directly or indirectly alters characteristics or processes of any part of the environment, and causes (or has the potential to cause) damage to the condition, health, safety, or welfare of animals, humans, plants, or property.

CHEMICAL POLLUTION

Chemical pollution is defined as the presence or increase in our environment of chemical pollutants that are not naturally present there or are found in amounts higher than their natural background values. Most of the chemicals that pollute the environment are man-made, resulted from the various activities in which toxic chemicals are used for various purposes.

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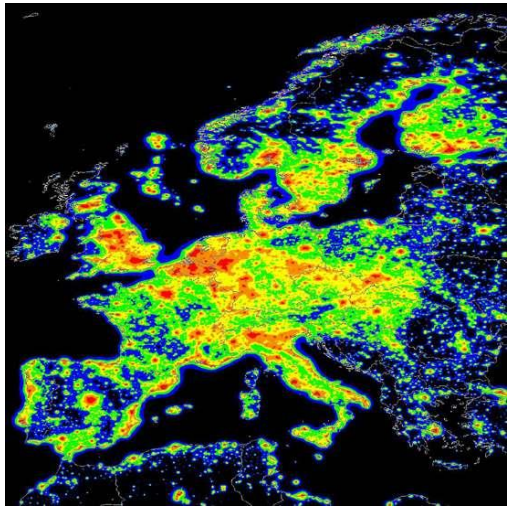
Different types of pollution

WATER POLLUTION

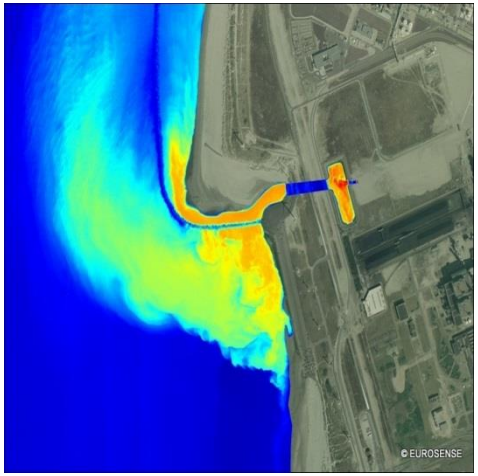
AIR POLLUTION

SOIL POLLUTION



LIGHT POLLUTION

NOISE POLLUTION



THERMAL POLLUTION

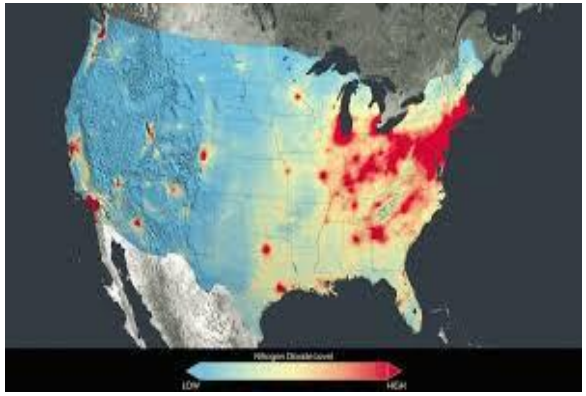
Water pollution

Water pollution is the contamination of the water on Earth. It includes contamination by pollutants such as chemical, bacterial or particulate that reduces the purity of the water.

Oil seepage is one of the most common forms of pollution. Water pollution occurs in lakes, oceans, rivers and even underground reservoirs.

Water pollution is one of the most dangerous form of pollution as it decreases the amount of drinkable water that is available. It can also reduce the amount of water that can be used for irrigation as well as harm the wildlife that depend on the water.

Air pollution



Air pollution is the contamination of the natural air by mixing it with different pollutants such as harmful fumes and chemicals. This contamination can be caused by gases emitted by vehicles or from burning material or harmful fumes emitted as a byproduct of industries.

The higher the concentration of air pollutants, the harder it is to remove it effectively through natural cycles.

The higher concentrations also result in breathing problems for living things. Some effects include increase in smog, higher rain acidity, crop depletion from inadequate oxygen, and higher rates of asthma. According to experts, global warming is one of the biggest side effects of air pollution.

Land pollution

Soil pollution, also known as land pollution is the contamination of the soil or the land that prevents growth of natural life, which includes land used for cultivating, wildlife as well as habitation.

Common causes of soil pollution includes non-sustainable farming practices, hazardous wastage and seepage into the soil, mining as well as littering.

Soil pollution can result in reduced growth of agriculture as well as poisoning of the land and nearby water.

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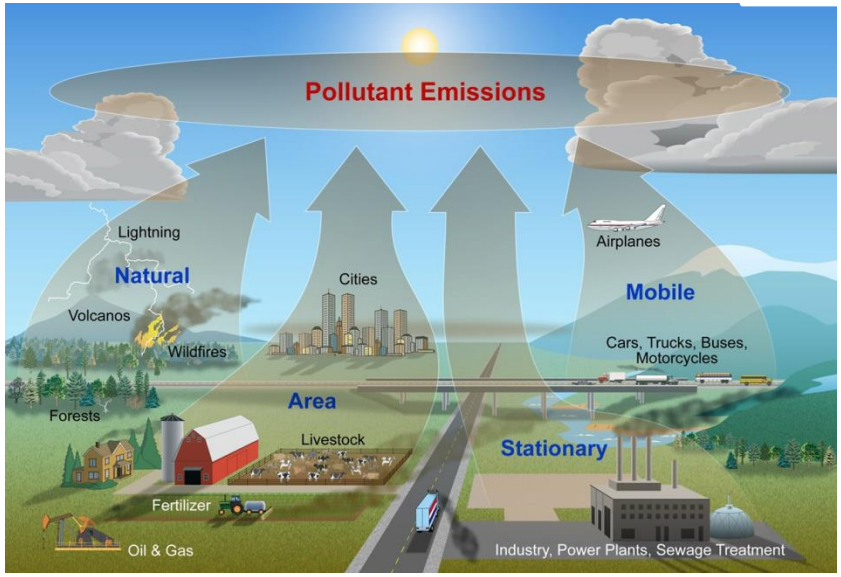
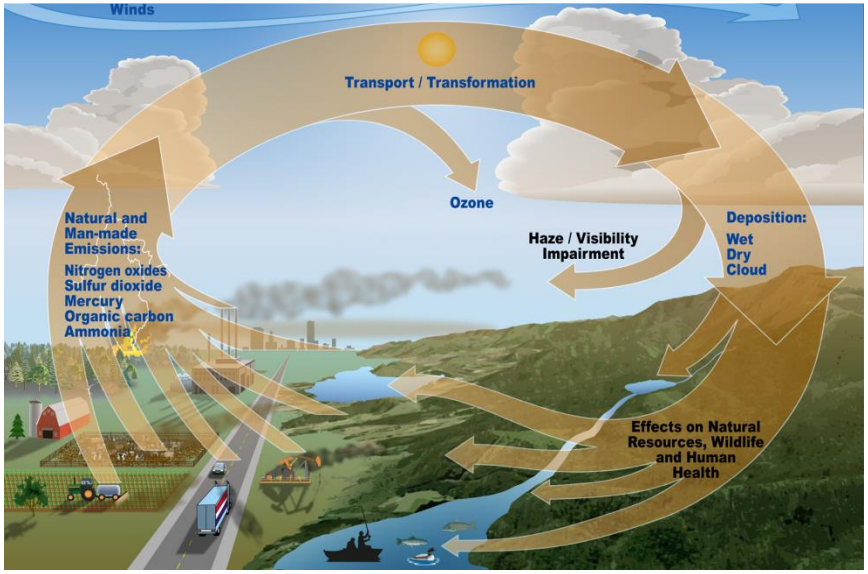
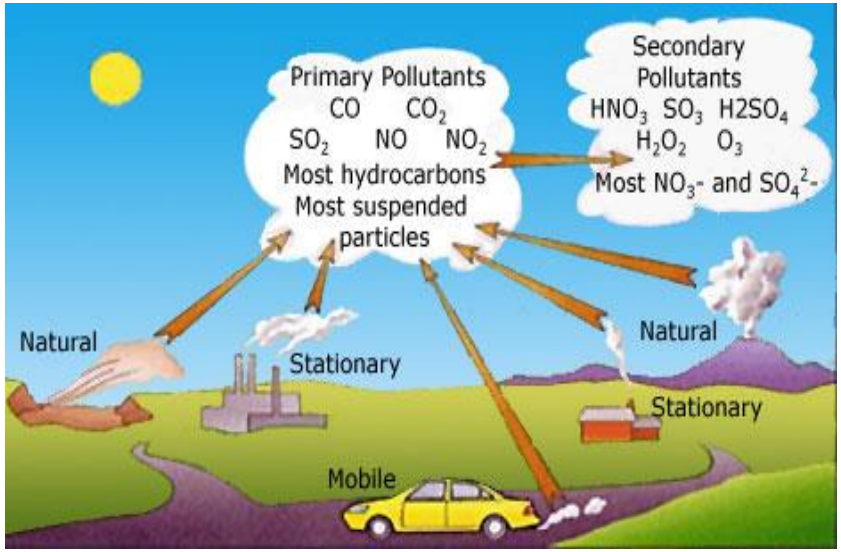
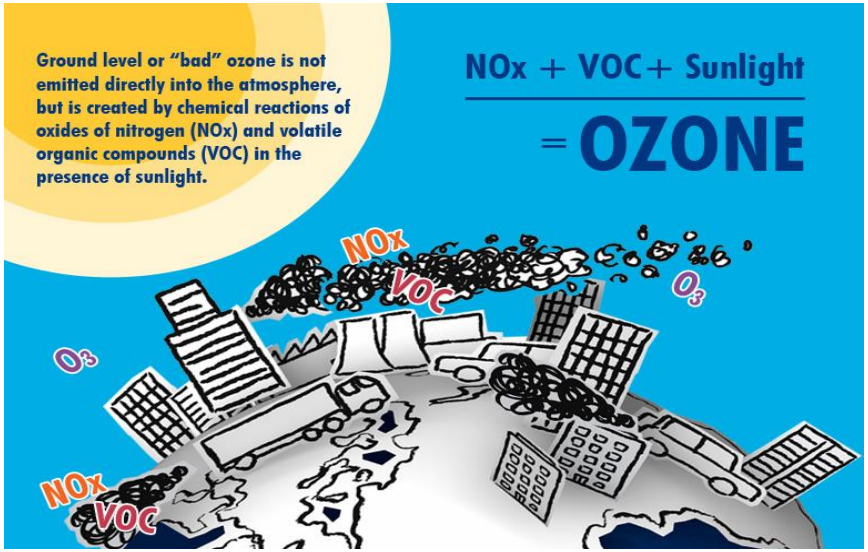
Air pollution sources



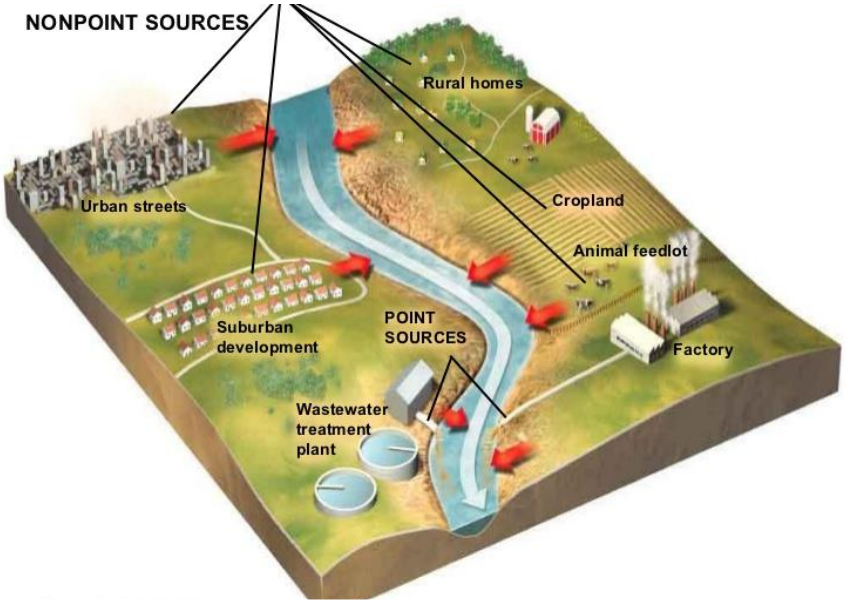




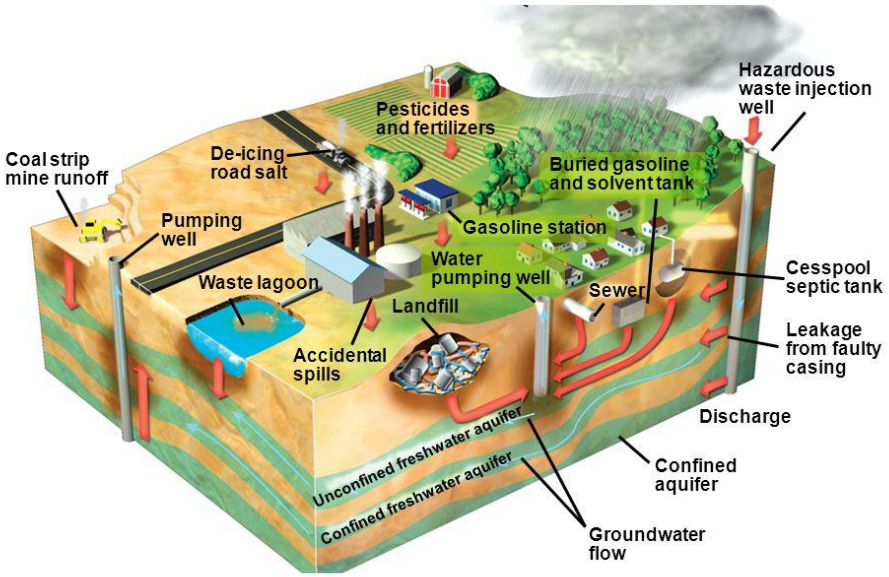


Water pollution sources

SURFACE WATER



GROUND WATER

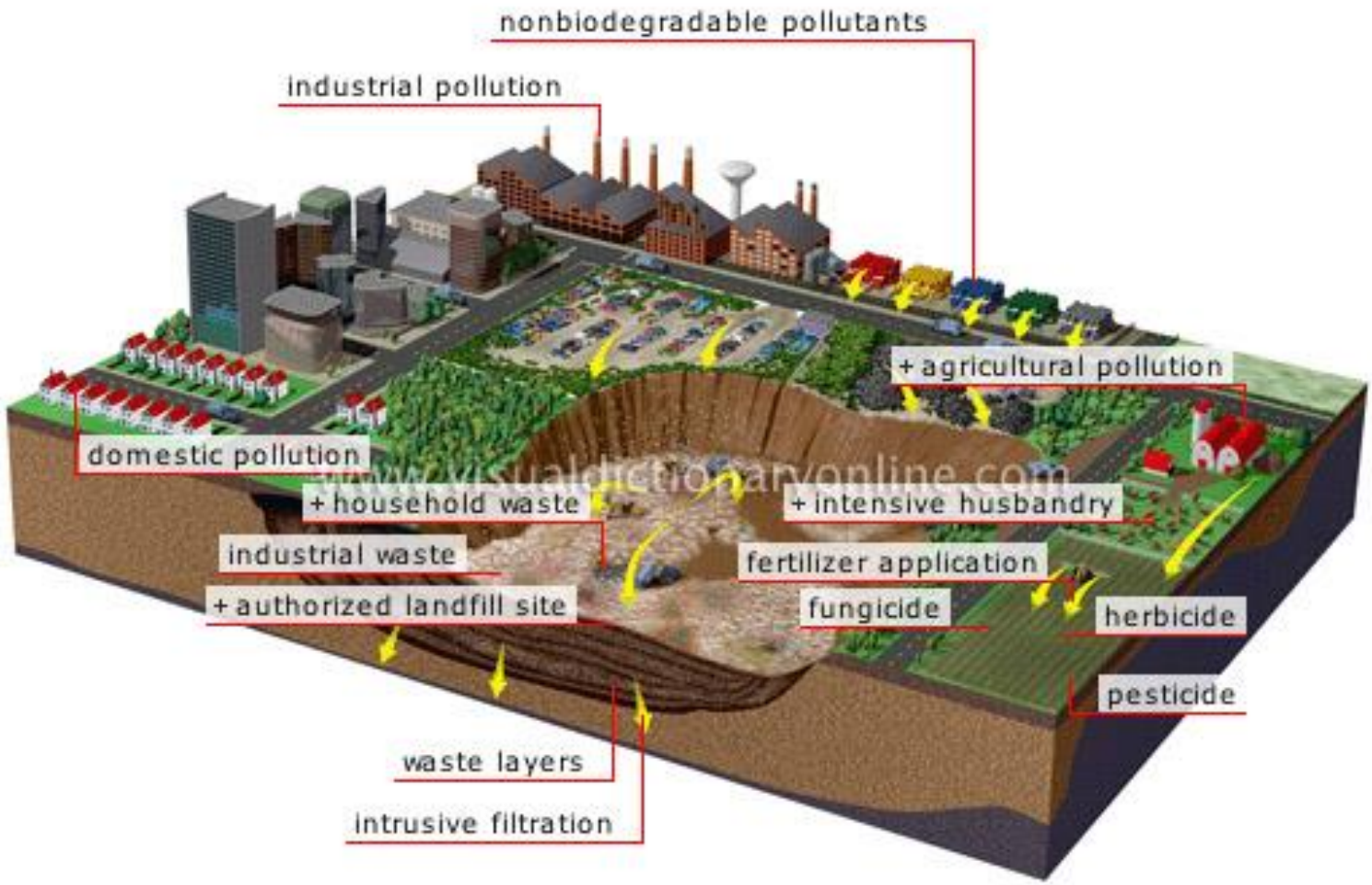


SEA WATER

OIL SPILL

PLASTIC

Soil pollution sources



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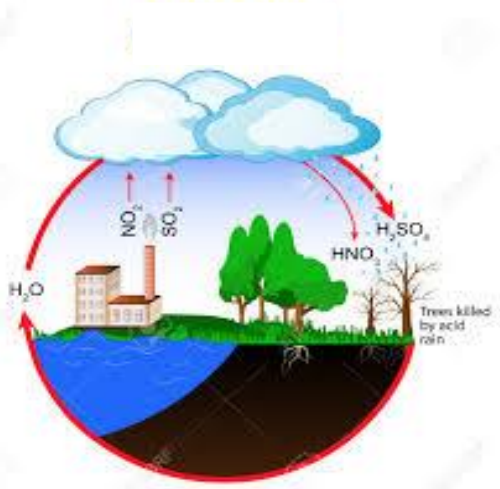
Air pollution effect

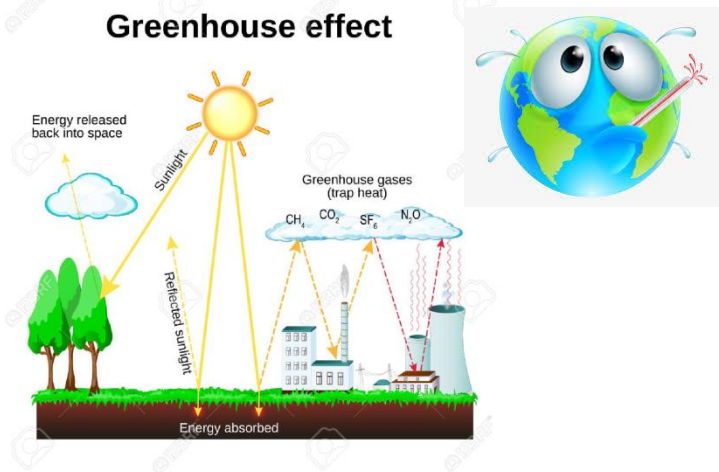
Smog

Respiratory problems

Acid Rain



Greenhouse effect



Water pollution effect

- About 40 % of deaths world wide are caused by water pollution
- People are getting desease like Cholera, Typhoid, Diarrhoea…
- Aquatic life gets disturbed

- Water pollution affect the food web chain
- Fresh water not available

Soil pollution effect

➢ Endangering Human Health

Soil pollutant can be carcinogenic, intensifying the chances of developing cancer

Soil pollutants can also cause skin diseases, muscular blockage, and central nervous system disorders

➢ Air and Water Contamination

Polluted soil by natural means contributes to air contamination by discharging volatile compounds into the atmosphere.

Soil pollution can also lead to water pollution if the toxic chemicals and materials like dangerous heavy metals leach into groundwater or contaminate storm water runoff, which reaches lakes, rivers, streams, or oceans

➢ Effect on Plant Life

When soils are repeatedly contaminated and accumulate large amounts of poisonous materials and chemicals, the soil reaches a point where it cannot support plant life. Soil pollutants interfere with soil chemistry, biology, and structure. When these changes occur, beneficial soil bacteria, soil microorganisms, soil nutrients, and soil chemical processes begin to deteriorate to an extent where they diminish soil fertility.

➢ Effect on biodiversity

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How to define micro-pollutants?

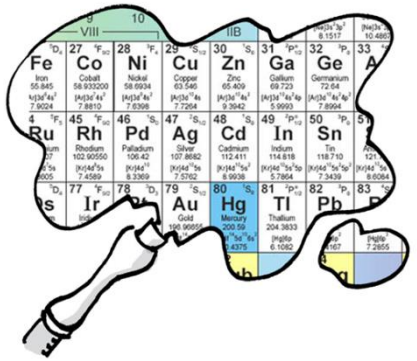
The term **"micropollutants"** means organic or mineral substances whose toxic, persistent and bioaccumulative properties may have a negative effect on the environment and/or organisms even at low concentration.

They are present in many products that we consume daily (drugs, cosmetics, phytosanitary products, insecticides, etc.), at the home or in industry.

Progress in laboratory analysis is increasingly highlighting their **presence in the aquatic environment** at extremely low concentrations, in the order of one nanogram per litre or microgram per litre (hence the term micropollutants).

Some of these substances are liable to have potentially chronic **direct or indirect effects on ecosystems** (e.g. the feminisation of fish due to endoctrine-effect substances in the aquatic environment), and even on human health.

What are the micro-pollutants families?



- **Metals and metalloids, radioactive elements**

  Lead, cadmium, mercury, arsenic, antimony, radon, uranium

- **Organic micropollutants**

Pesticides

Hydrocarbons

Plastics

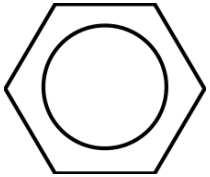
Detergents

Cosmetics

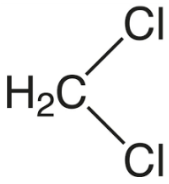
Pharmaceutical products

Exemples of micro-pollutants

Volatile Organic Compounds (VOCs)

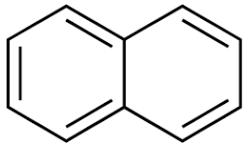


Benzene

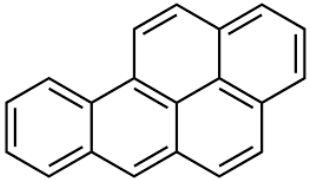


Dichloromethane

Polycyclic Aromatic Hydrocarbons (PAHs)



Naphtalene



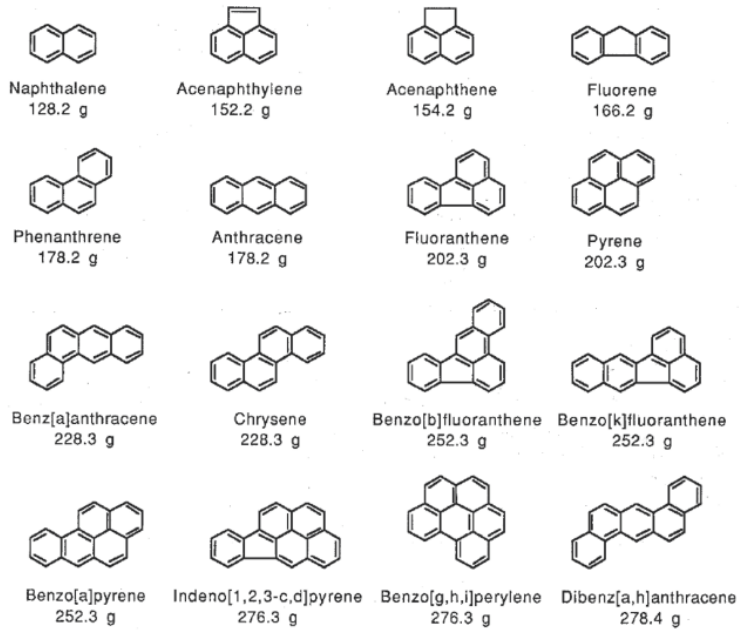
Benzo(a)pyrene

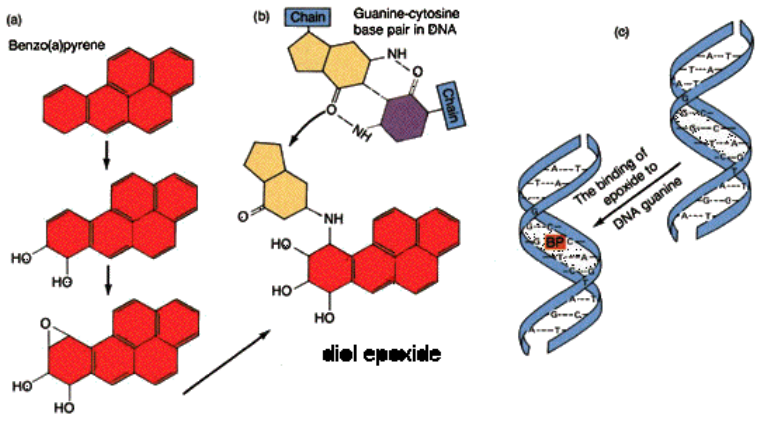
Polycyclic Aromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons are organic compounds containing only carbon and hydrogen—that are composed of multiple aromatic rings

PAHs are uncharged, non-polar molecules found in **coal and in oil** deposits. They are also produced by the **incomplete combustion of organic matter** (for example, in engines and incinerators or when biomass burns in forest fires).

Some **carcinogenic PAHs** are genotoxic and induce mutations that initiate cancer; others are not genotoxic and instead affect cancer promotion or progression

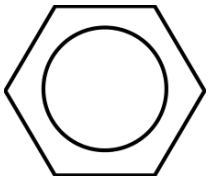




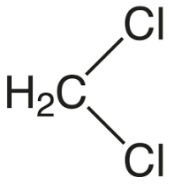
An adduct formed between a DNA strand and an epoxide derived from a benzo[*a*]pyrene molecule (center); such adducts may interfere with normal DNA replication.

Exemples of micro-pollutants

Volatile Organic Compounds (VOCs)



Benzene



Dichloromethane

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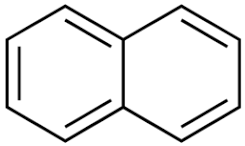
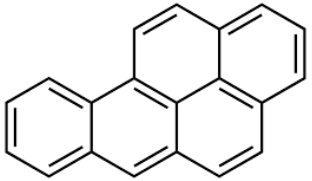
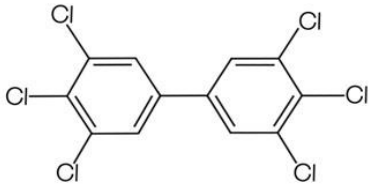


Naphtalene



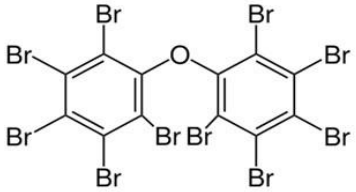
Benzo(a)pyrene

PolyChlorinated Biphenyls (PCBs)



PCB
(3,3',4,4',5,5'-hexachlorobiphenyl)

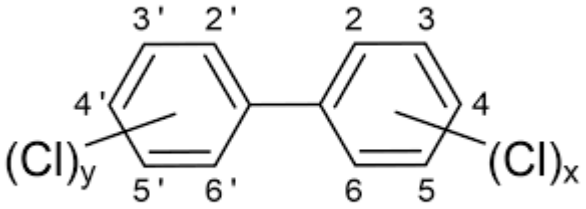
PolyBrominated Diphenyl Ethers



PBDE
(decabromodiphenyl ether)

PolyChlorinated Biphenyls PCBs

A mixture of compounds containing the bisphenyl structure with different numbers (one to ten) and arrangements of chlorine atom attached



PCBs were widely used as dielectric and coolant fluid, in transformers, capacitors

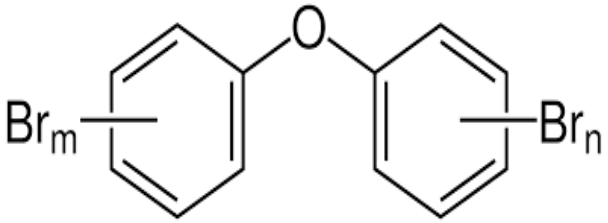
PCBs are persistents in environnent (non biodegradable hydrophobic…)

PCBs are carcinogenic

Dredging of PCBs contaminated sediments

PolyBrominated Diphenyl Ethers (PBDE)

Polybrominated diphenyl ethers or PBDEs, are organobromine compounds that are used as flame retardant.



The family of PBDEs consists of 209 possible substances, which are called congeners.

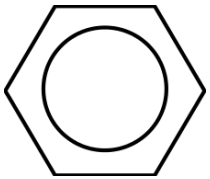
PBDEs have been used in a wide array of products, including:
- building materials,
- electronics,
- furnishings,
- motor vehicles,
- airplanes,
- plastics,
- polyurethane foams,
- and textiles.

PBDEs share the environmental long life and bioaccumulation properties with PCBs

PBDEs can cause cancer in people

Exemples of micro-pollutants

Volatile Organic Compounds (VOCs)



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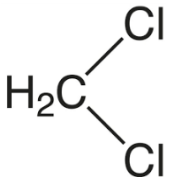
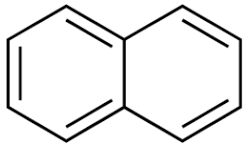
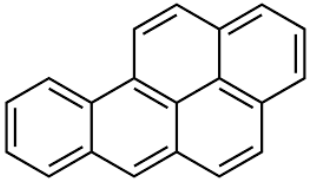


Dichloromethane

Polycyclic Aromatic Hydrocarbons (PAHs)



Naphtalene



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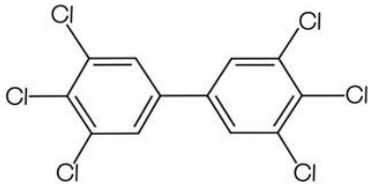

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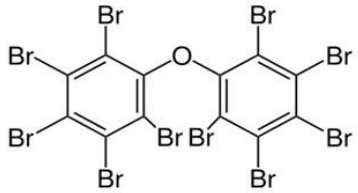
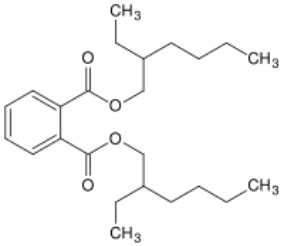


PBDE
(decabromodiphenyl ether)

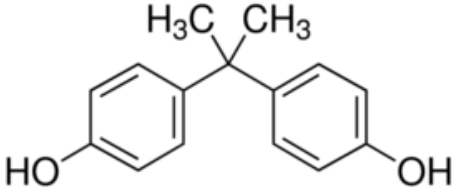
Plastic additives

Plasticizers



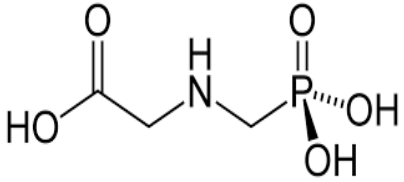
Phtalate

Anti oxydant



Bisphenol A

Pesticides



Glyphosate

Pesticides

A pesticide is a substance or mixture intended for preventing, destroying, repelling the damage caused by pest.

Classification of pesticides :

1. **Herbicide-**These are the chemicals used to kill weeds (i.e., unwanted plants) e.g. Borax, Nitrofen.
2. **Insecticide-**These are used to kill insect. E.g. DDT, BHC.
3. **Rodenticide-**These are used to kill rodents. e.g. Warfarin, Zinc phosphide.
4. **Nematicide-**These are used to kill namatodes e.g. DBCP, Phorate
5. **Molluscicide-**These ar used to kill molluscs e.g Sodium pentachloridephenate.
6. **Fungicides-**These are used to kill fungus e.g. Bordeaux mixture
7. **Algaecides-**These are used to kill algae e.g. Copper sulphate, Endothal
8. **Bactericide-**These are used to kill bacteria e.g. Dichlorophen,Oxolinic acid
9. **Piscicides-**These are used to kill fishes e.g. Trifloro methyl nitrophenol(TFM)

Exemples of micro-pollutants

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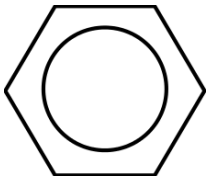

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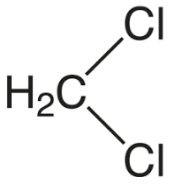

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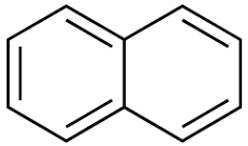

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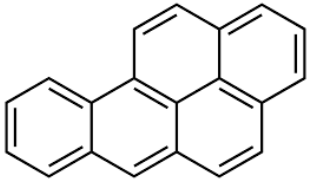

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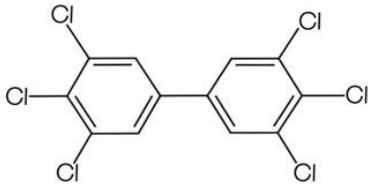

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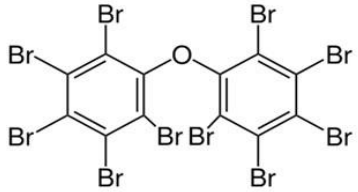

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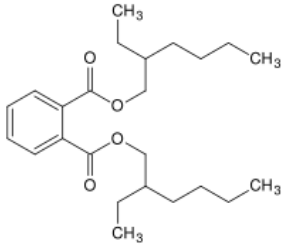
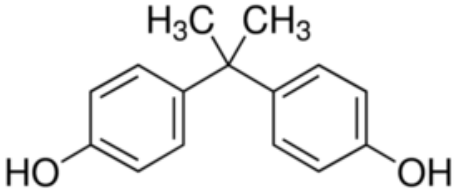
Plastic additives

Plasticizers



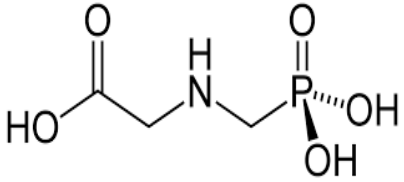
Phtalate

Anti oxydant



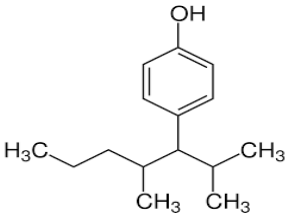
Bisphenol A

Pesticides



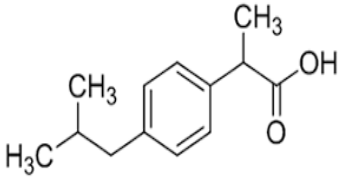
Glyphosate

Surfactants

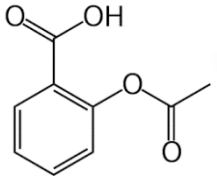


Nonylphenol

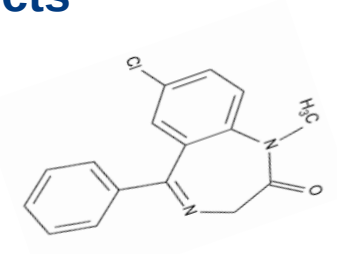
Pharmaceutical products



Ibuprofen



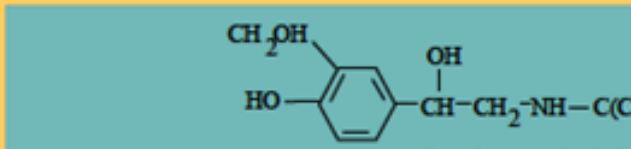
Aspirin

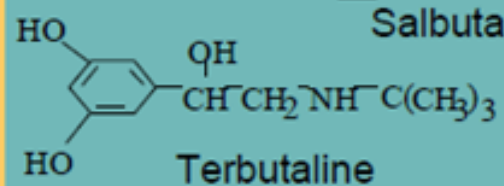


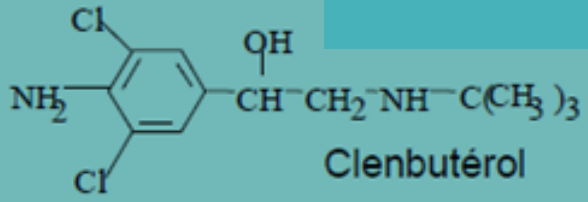
Diazepam

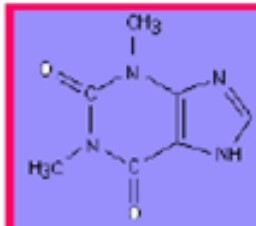
Pharmaceutical products

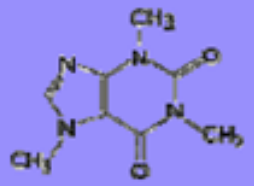
Bronchodilators









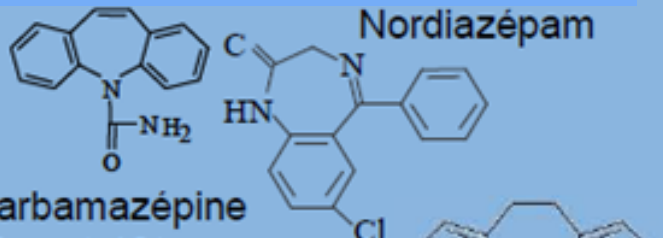


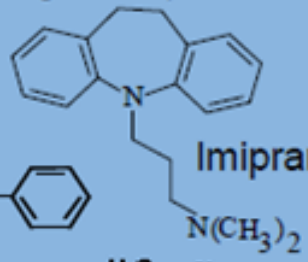
Caféine

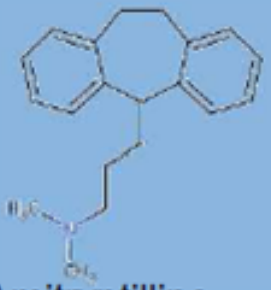
Théophylline

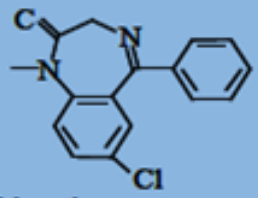
Stimulating agents

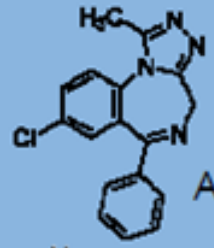
Anxiolytics/antidepressants

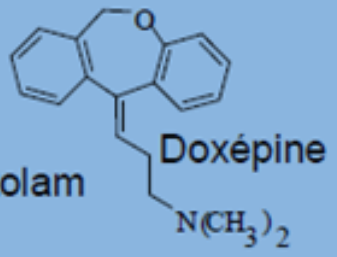


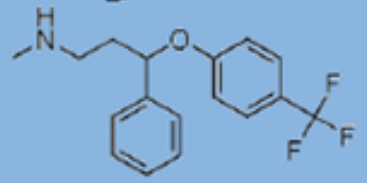


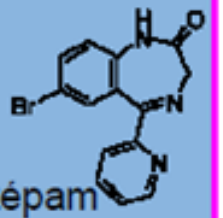






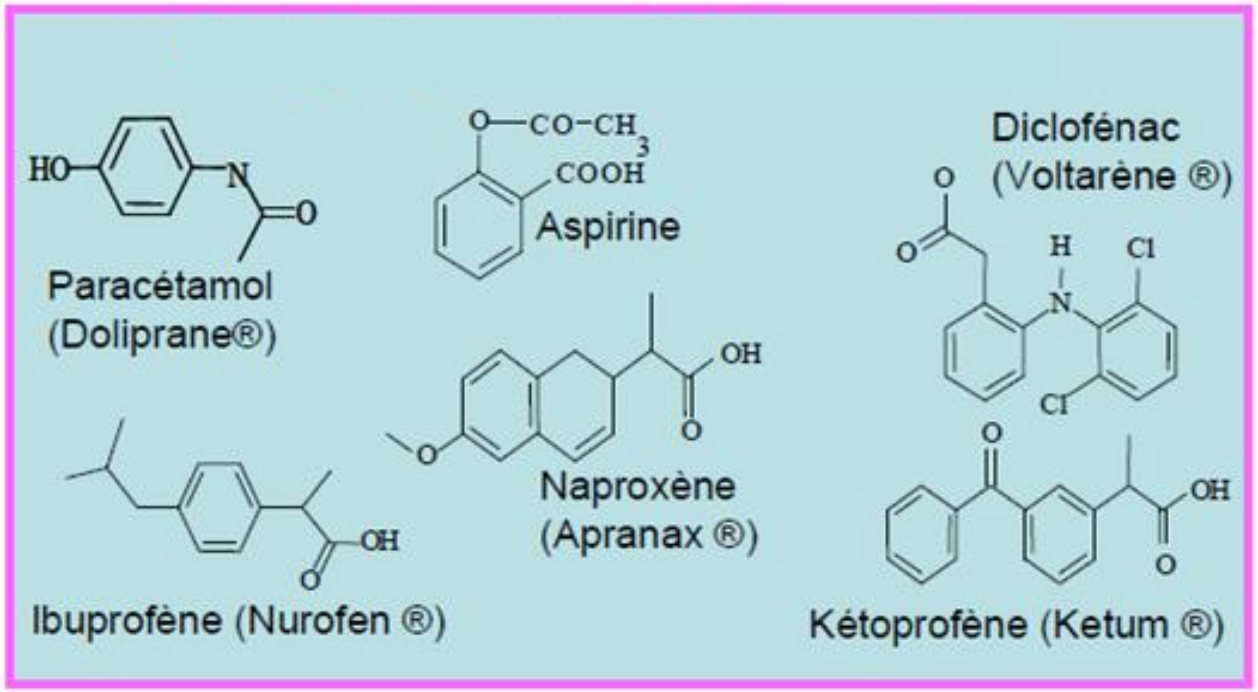


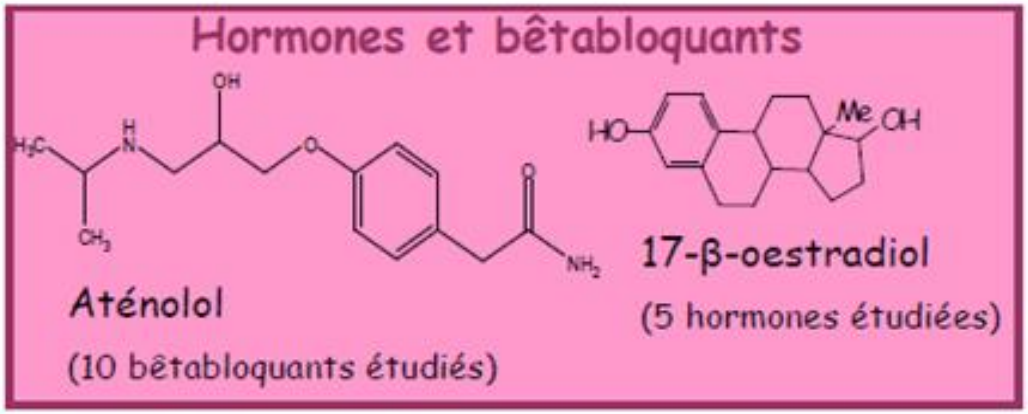




Pharmaceutical products

Analgesic/ anti inflammatory





Hormones / beta blockers

Fate of micro-pollutants

The fate of a micro-pollutant will depend on certain properties :

- Volatility/solubility : Henry's Law Constants
- Polarity: Octanol/water partition coefficient (Log Kow)
- Biodegradability : Half life time

VOLATILITY/SOLUBILITY : HENRY'S LAW

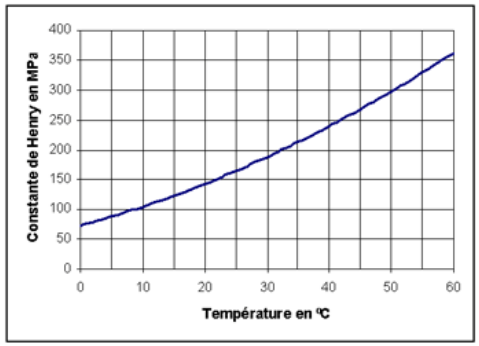
This law establishes a relation between the partial pressure Pi of a pure gaseous body and its molar fraction X^L in a solvent :

Pi = X^L. Ki ***Ki** is the Henry's law constant*

This law allows to determine the solubility of a volatile substance in a liquid solvent with which this gas is in contact.

The more Ki is great the more the substance is volatile

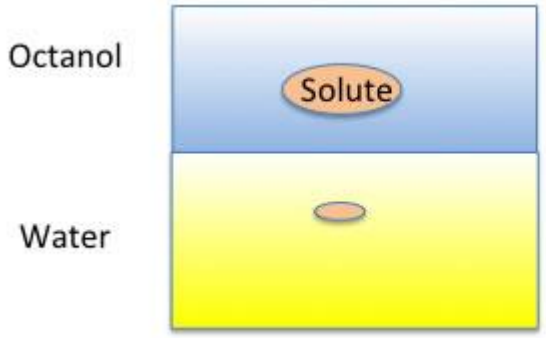
The Henry's law constant depends on the temperature:



Important property to know the mode of exposure of pollutants

Polarity: Octanol/water partition coefficient

Log Kow, is a measure of the differential solubility of chemical compounds in two solvents (octanol / water partition coefficient).



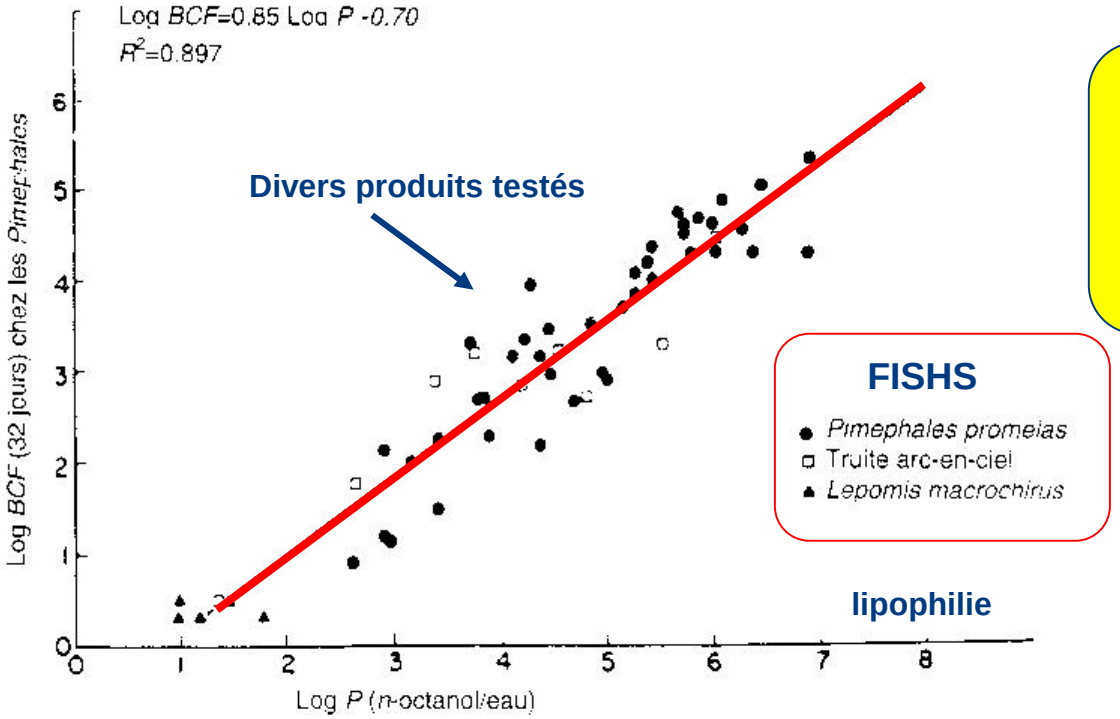
$$\text{Log Kow} = \text{Log}(C_{oct}/C_{eau}).$$

This value makes it possible to apprehend the hydrophilic or hydrophobic nature of a molecule.

Indeed, if the Log Kow is positive and very high, it expresses the fact that the molecule considered is much more soluble in octanol than in water, which reflects its lipophilic or hydrophobic character, and vice versa.

Relationship between polarity and bioaccumulation

Log P = Log Kow = Log (Coct/Ceau)

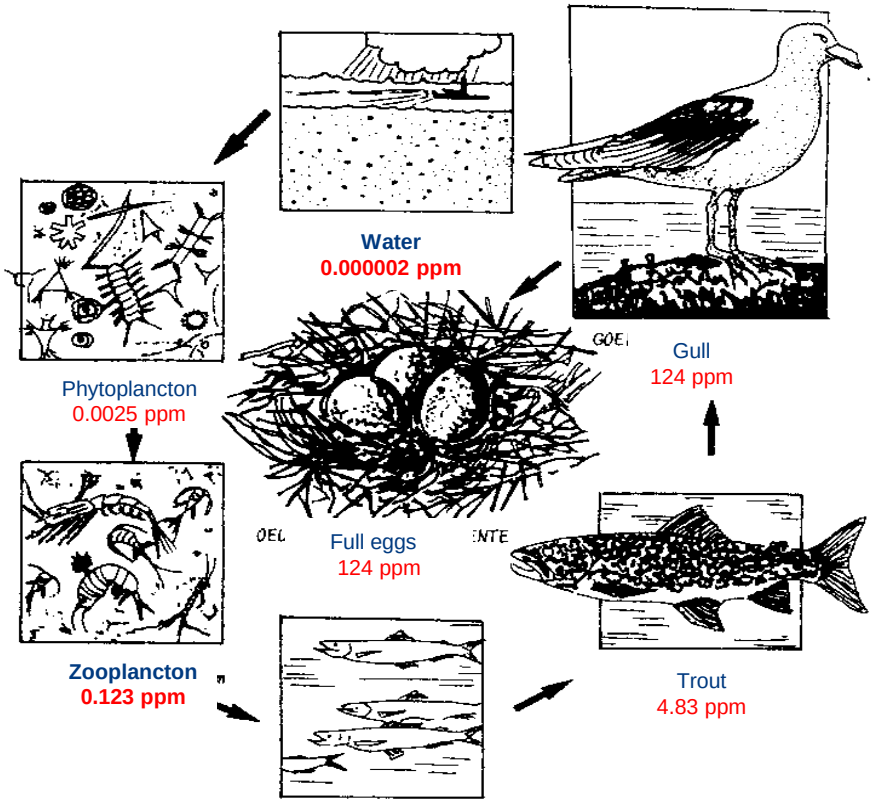


Log BCF = a log Kow + b

BCF = bioconcentration factor
= Corganism / Cwater

Figure 6-2 — *Corrélation entre le facteur de concentration biologique de trois espèces de poissons d'eau douce et le coefficient de partage n-octanol-eau.* La corrélation a été calculée pour divers produits de lipophilie croissante. ● = *Pimephales promelas* (Fathead minnow), □ = *Salmo gairdneri* (Truite arc-en-ciel), ▲ *Lepomis macrochirus* (Bluegill) (d'après VEITH *et al., Journ. Fish. Res. Board Canad.*, **36**, 1979, p. 1040). **(in Ramade F.)**

Bioamplification of PCBs



(Modifié d'après G. Tyler Miller, Jr., *Living in the Environment*, Wadsworth Publishing Company, Belmont, Etats-Unis, 1994.)

Fig. 5. — Exemple de bioamplification des PCBs montrant l'augmentation de leur concentration au fur et à mesure qu'ils s'intègrent dans les maillons supérieurs d'une chaîne alimentaire aquatique.

(in Chassard-Bouchaud)

EFFECT OF ORGANIC MATTER ON BIOAVAILABILITY

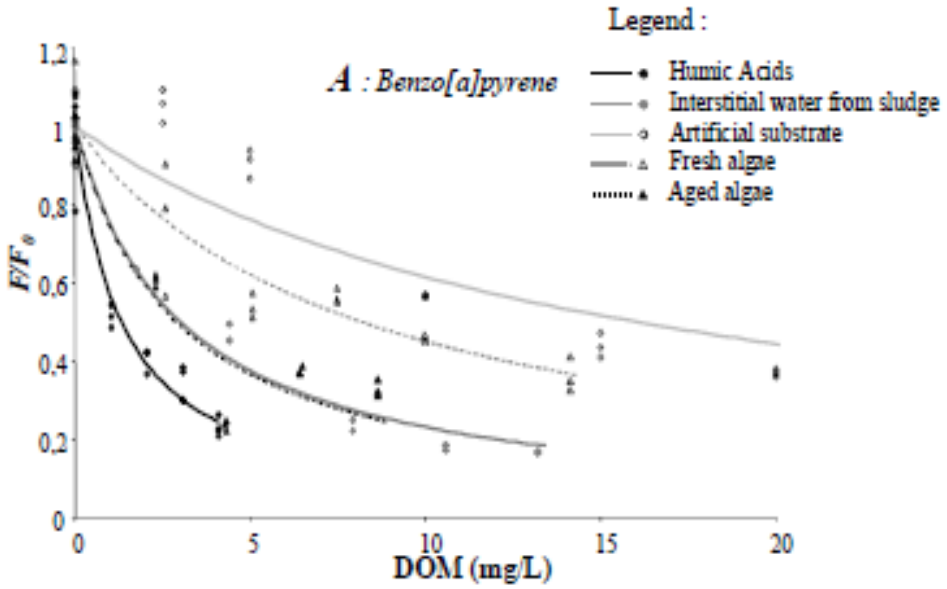


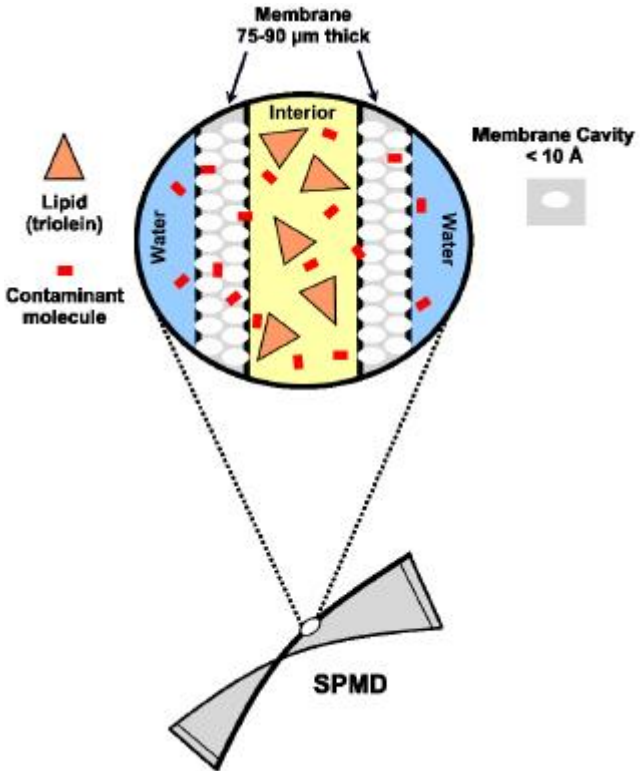
Figure 42. Bioaccumulation du Benzo(a)pyrène en présence de matière organique dissoute de différentes origines, normalisée à la bioaccumulation de Benzo(a)pyrène en eau minérale. D'après Gourlay et al., 2003.

Notion of Bioavailability

EVALUATION OF BIODAVAILABILITY

Apolar organic pollutants

Semipermeable Membrane Device, SPMD



Polar organic polluants

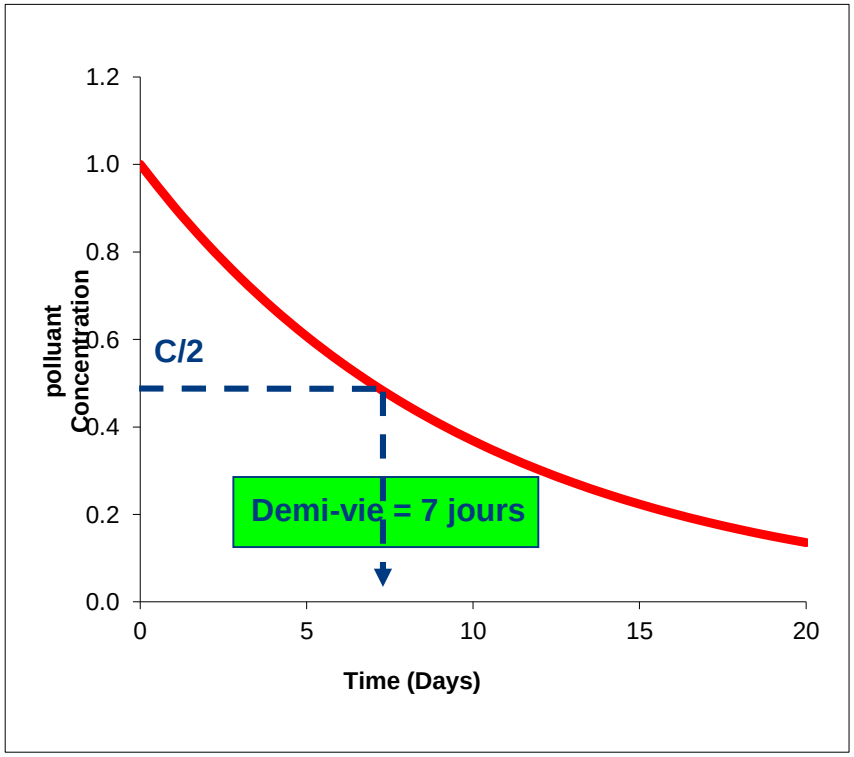
Polar Organic Chemical Integrative Sampler, POCIS

Metals

Diffusive Gradient in Thin film, DGT

Biodegradability: Half life time

Time required for half of a quantity or concentration of a pollutant to disappear from the biotope or a contaminated organism



Pollutant	Half life time
DDT	15 years
Lindane	2 years
Parathion	130 days
Malathion	11 days

Evaluation of pollutants persistence

Formation of degradation products

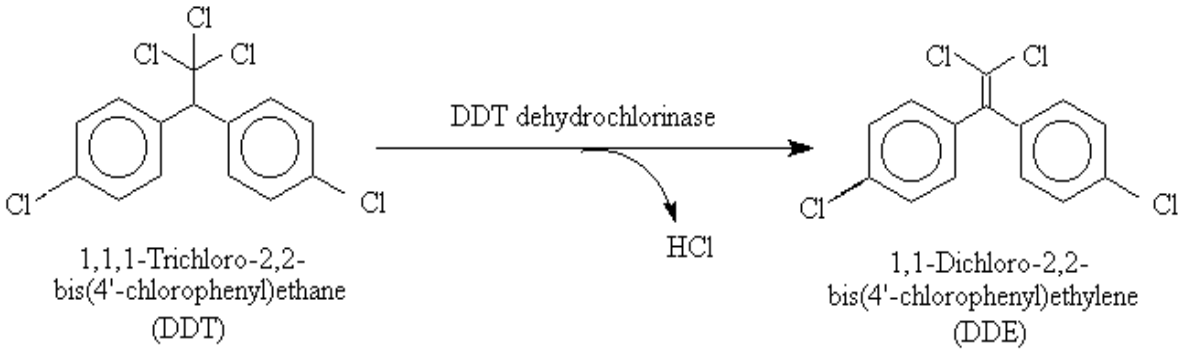
Degradation

Physicochemical action (photooxidation, thermooxidation ...) leading to the more or less complete disappearance of a molecule.

Biodegradation

Biological degradation carried out by bacteria, fungi and obtaining metabolites of lower molecular weight.

Primary biodegradation = partial attack of molecules; may result in more persitant, more bioavailable, and sometimes more toxic metabolites than the initial molecule



Ultimate biodegradation: complete degradation of the molecule; leads to CO_2, CH_4, water, mineral elements.

TOXICITY OF DEGRADATION PRODUCTS

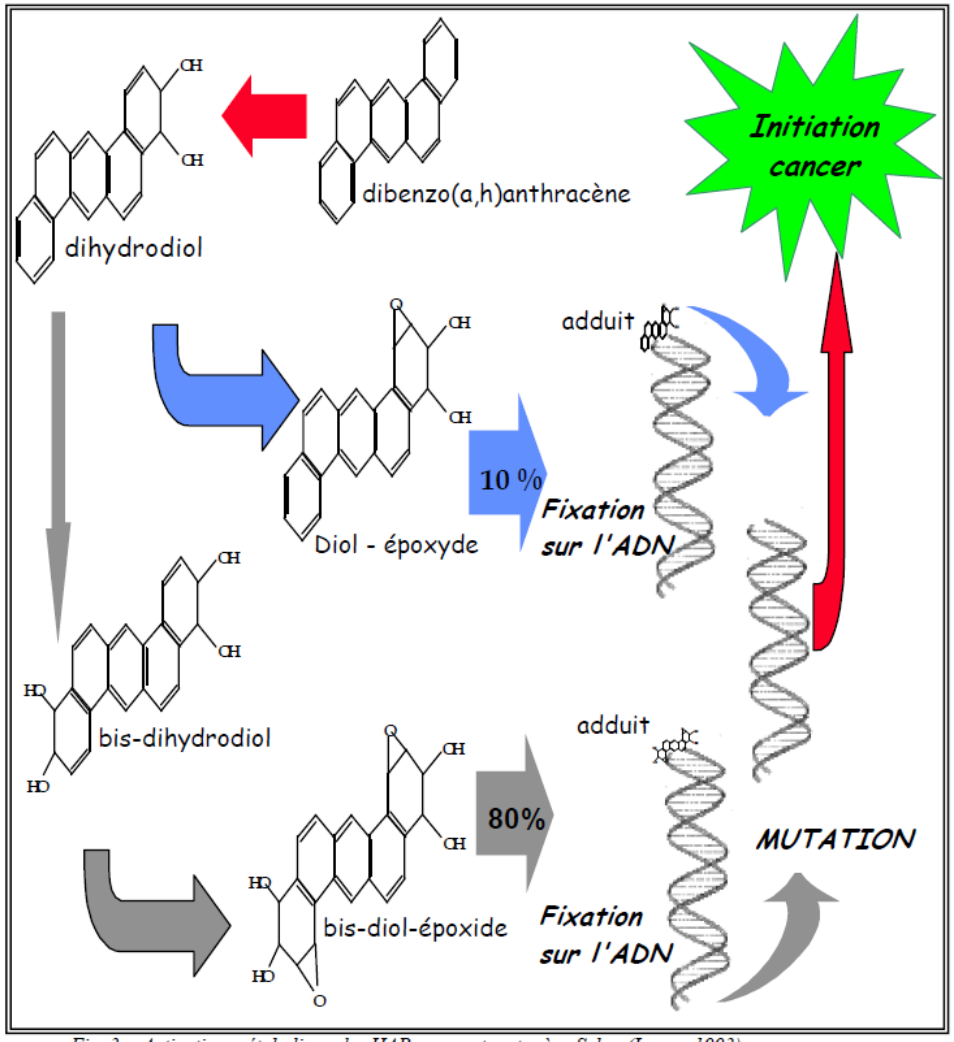
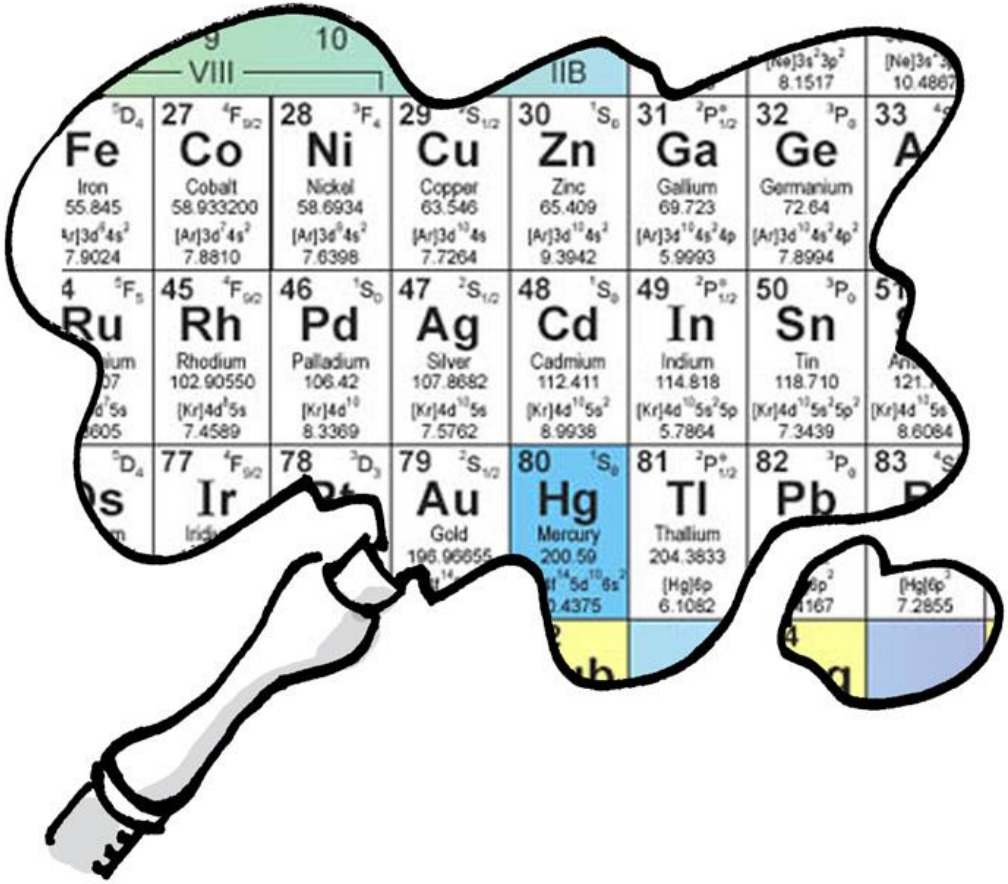
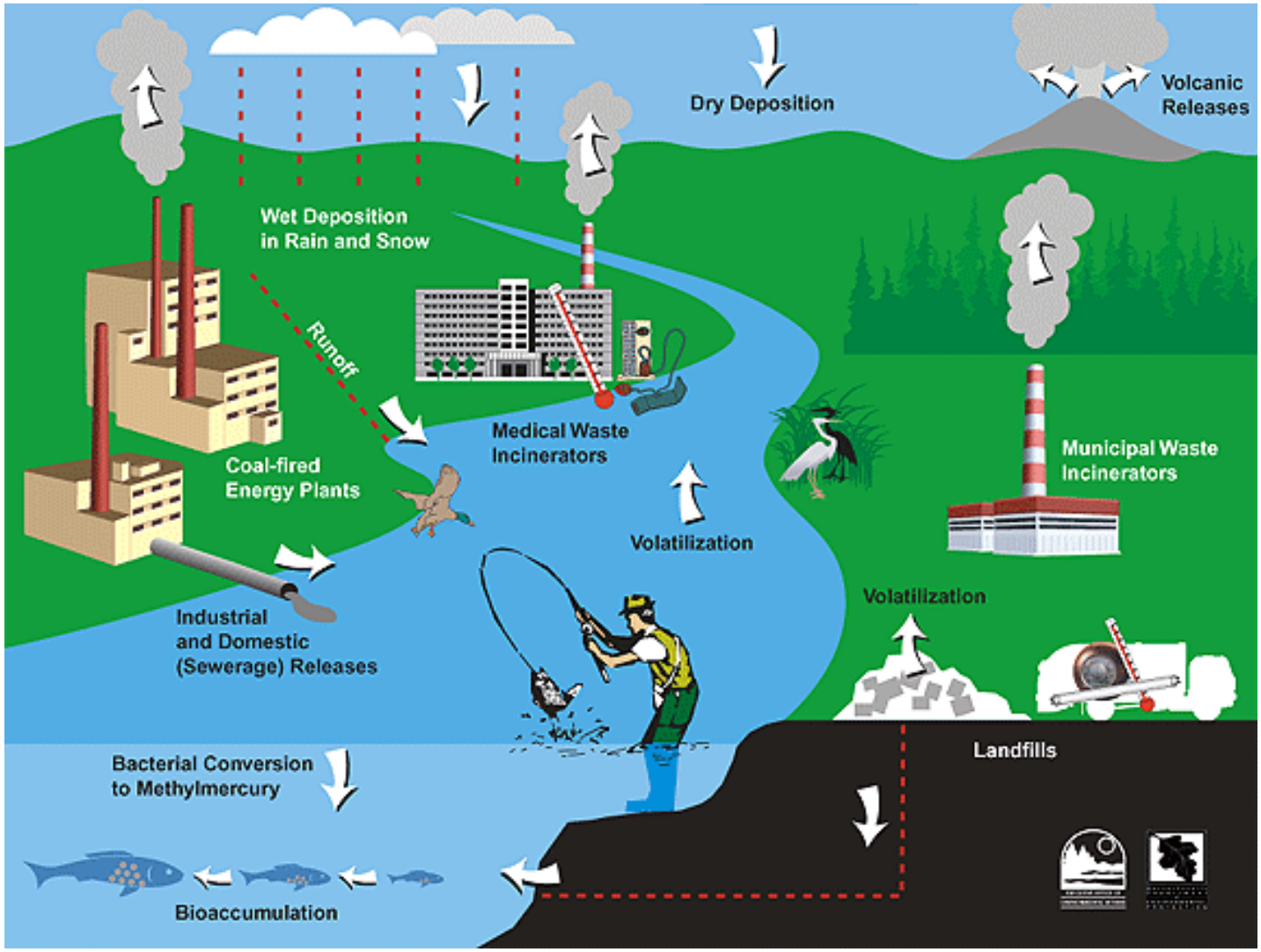


Fig. 3. : Activation métabolique des HAP en agent mutagène Selon (Lecoq, 1993)

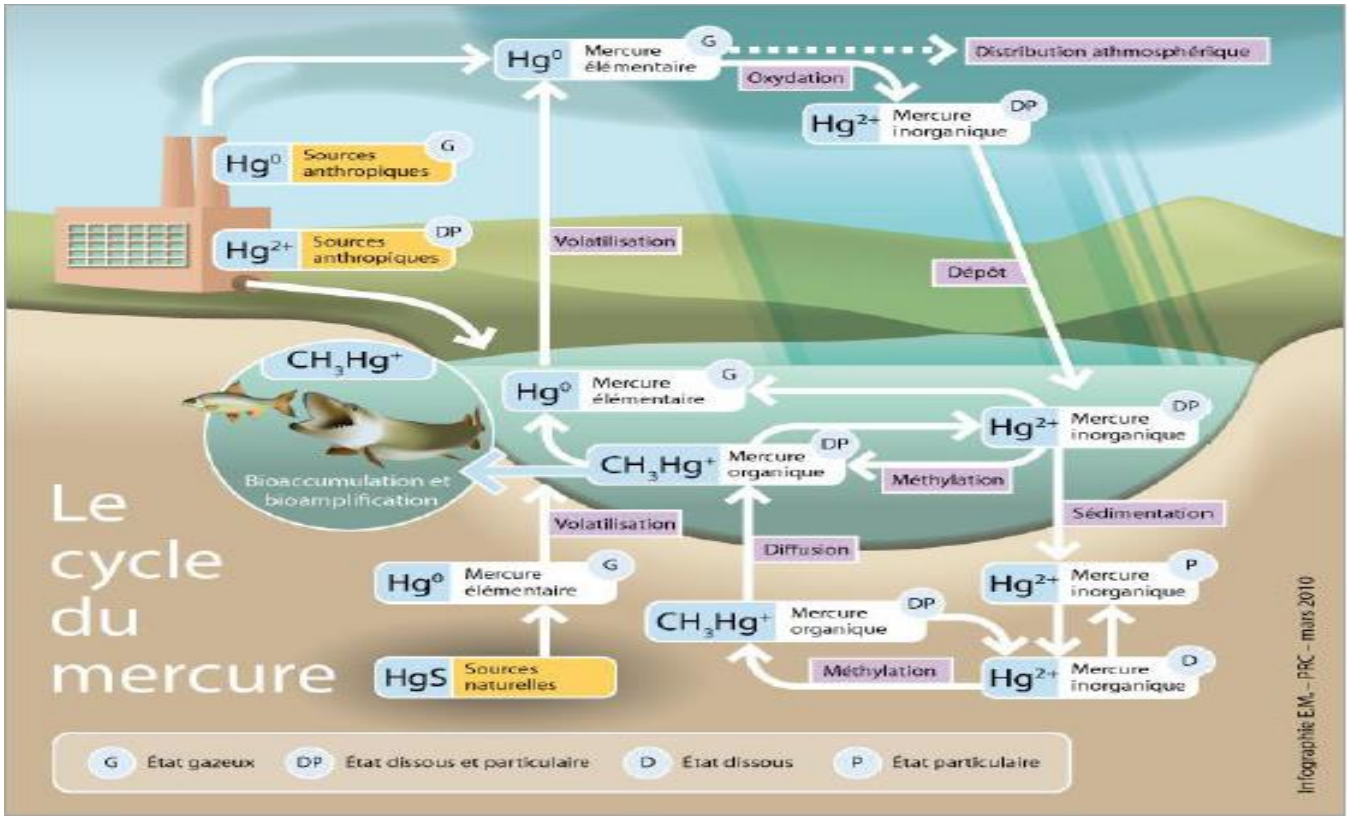
Metallic micropollutants



Source of mercury contamination



Biogeochemical cycle of mercury



Speciation consists, beyond the measurement of the total concentration of an element in a sample, to separate, identify and measure individually all the chemical forms of this element

Why use ICP-MS for metal speciation analysis ?

- It can measure almost the whole periodic table in just about everything

- Analysis of:
  - Elemental concentrations
  - High precision isotope ratio determinations
  - **Species information** when coupled to separation devices