# Environmental Chemistry

## Introduction

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# Environmental Chemistry

*Lecture outline*

- Pollution perspective
- Major pollutants
- Effects of pollutants on ecosystems
- Fate and behavior of chemicals in environment
- Environmental toxicity testing
- Environmental monitoring
- Instrumentations

Introduction

# Environmental components

**Geosphere / lithosphere**

Solid earth, including soil, which supports most plant life

**Biosphere**

Living entities on Earth

**Hydrosphere**

Earth's water

**Atmosphere**

Thin layer of gases that cover Earth's surface

**ECOLOGY**
The study of ecosystem

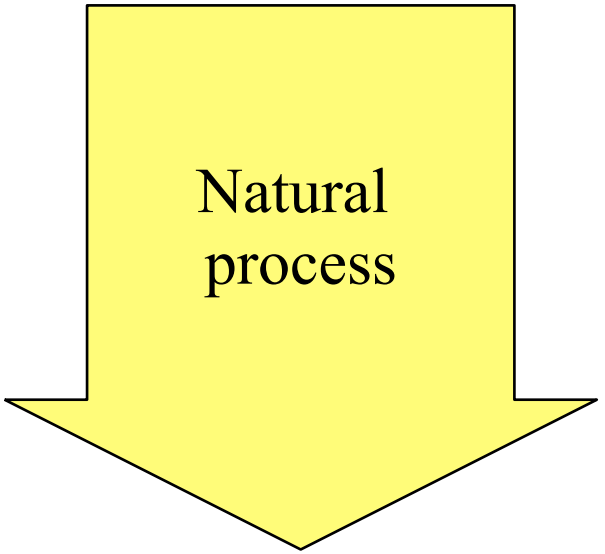
# Ecosystem

- Encompasses both living (biotic) and non-living (abiotic) components of an area – a combination of the community and physical and chemical components of the local environment.
- The major feature of this ecological level is the strong interaction between the biotic and abiotic components
- Major processes:
    - *Nutrient recycling*
    - *Energy flow*

# Ecosystem processes

Energy flow:

- Energy sources
- Photosynthesis
- Primary production
- Secondary production

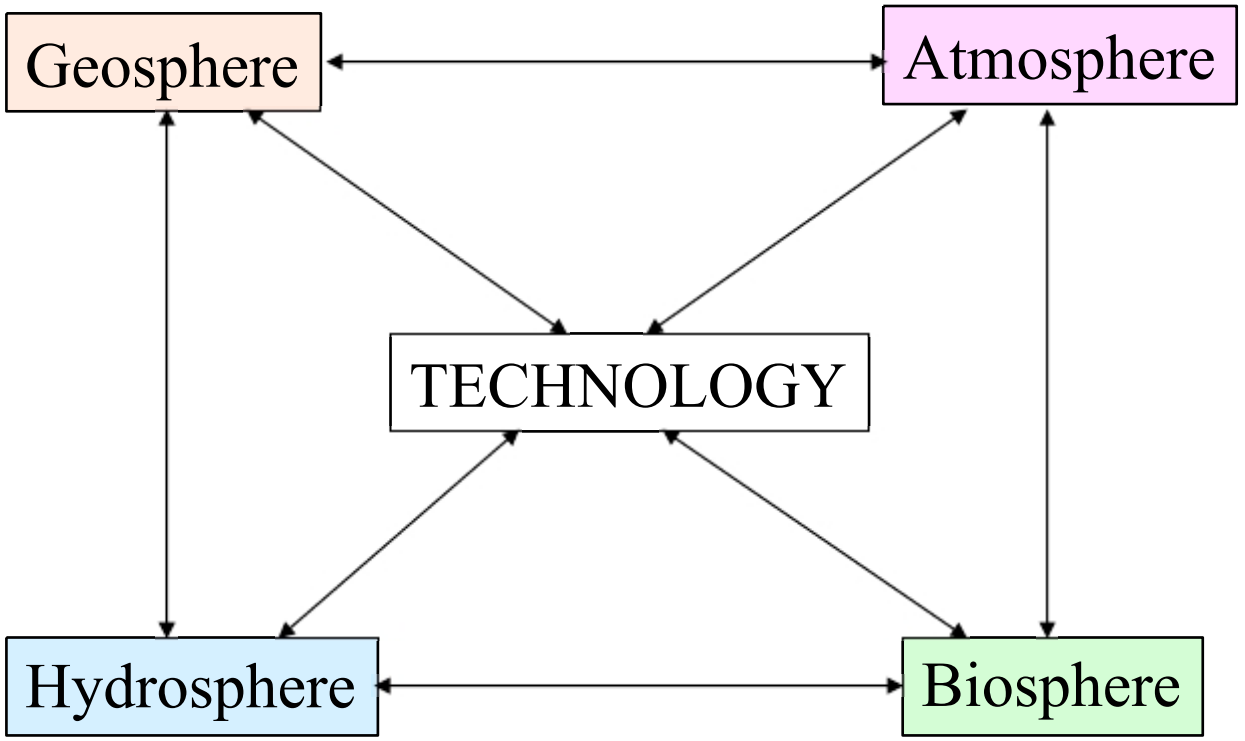


*Major components & sub somponents*

# Environmental components

| | |
|---|---|
| Abiotic | Hydrosphere (ocean, lake, river, groundwater) |
| | Lithosphere (solid earth, soils) |
| | Atmosphere |
| Biotic | Living organisms (animal, plant, fungi, bacteria, virus) |
| | Dead organic matters |

# Environmental components



# Pollution Perspective

Multiple sources

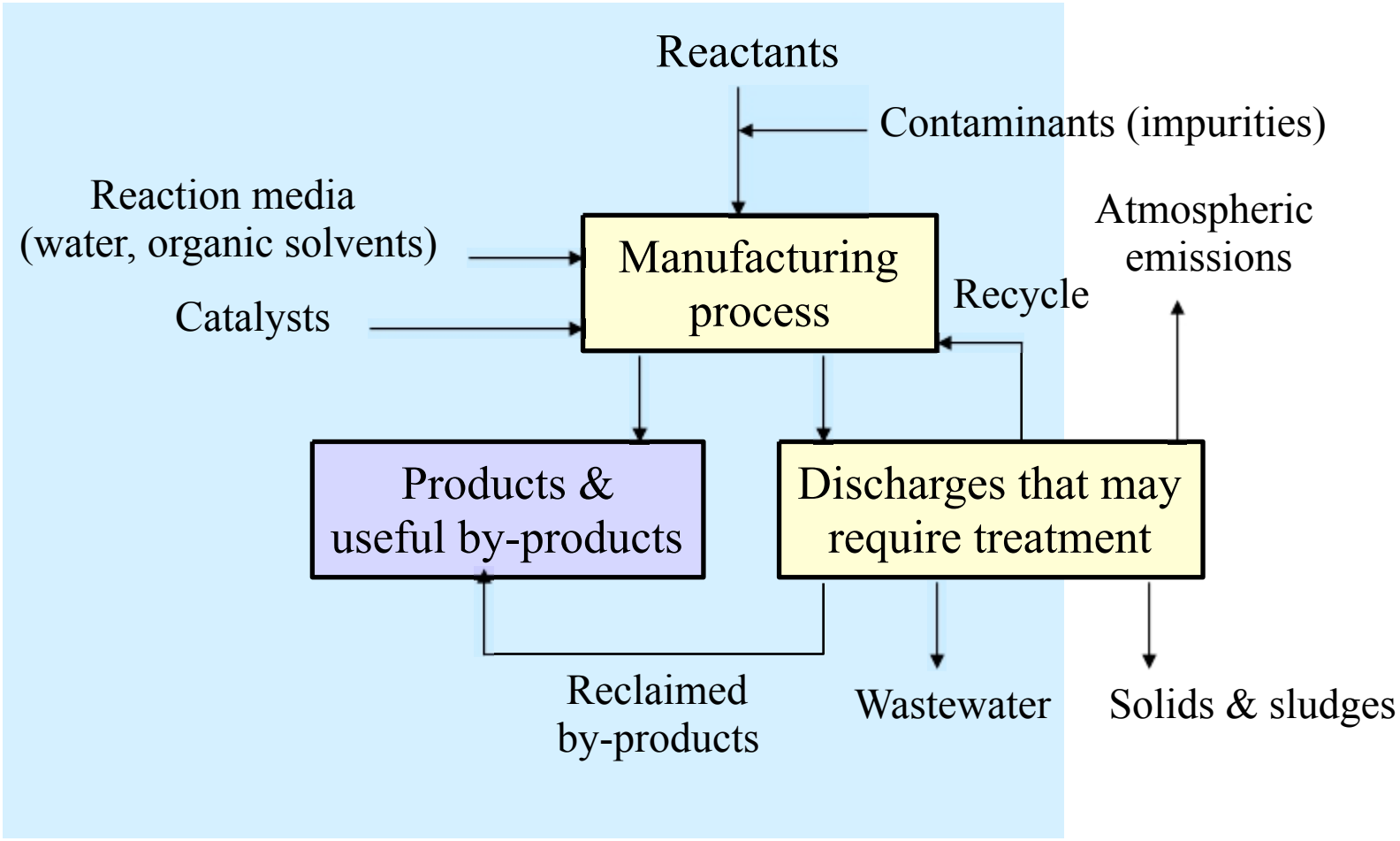
- Natural
  - *Volcano*
  - *Dust*
  - *$CO_2$ from respiration and fire*
- Man-made

Urbanisation and industrialisation enhanced pollution

Degradation of self-purification processes

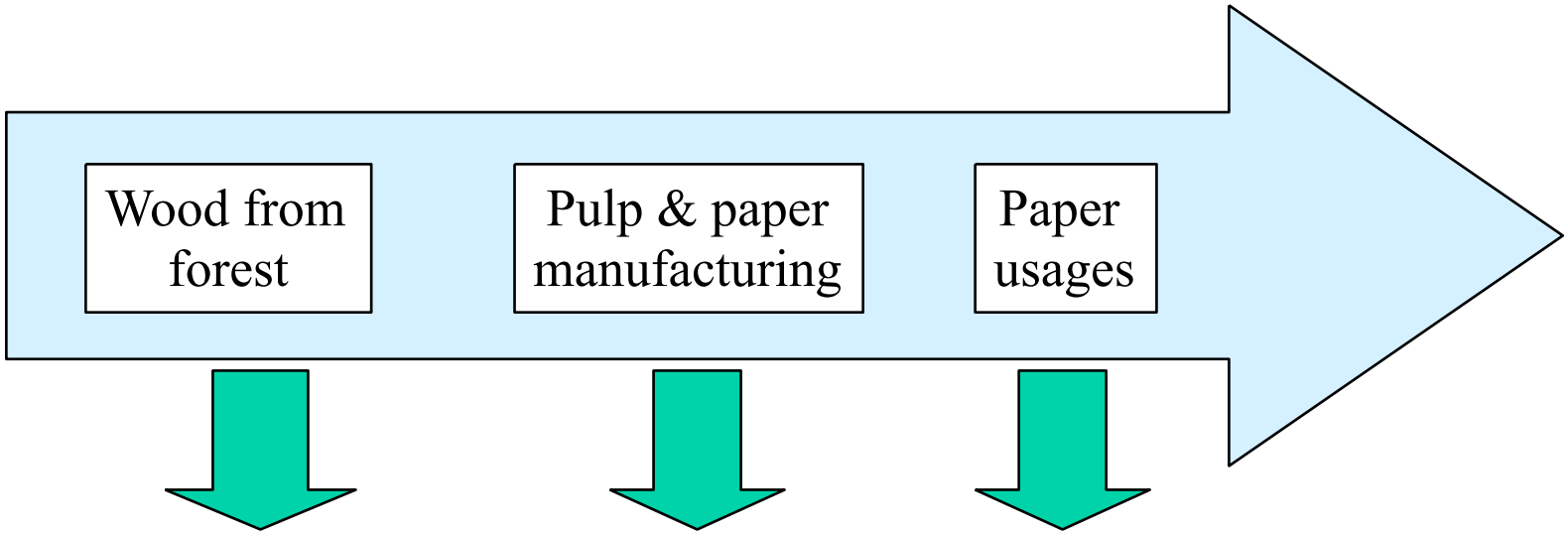
# Pollution Perspective

*Manufacturing processes- from problems maker to problem solver*



# Pollution Perspective

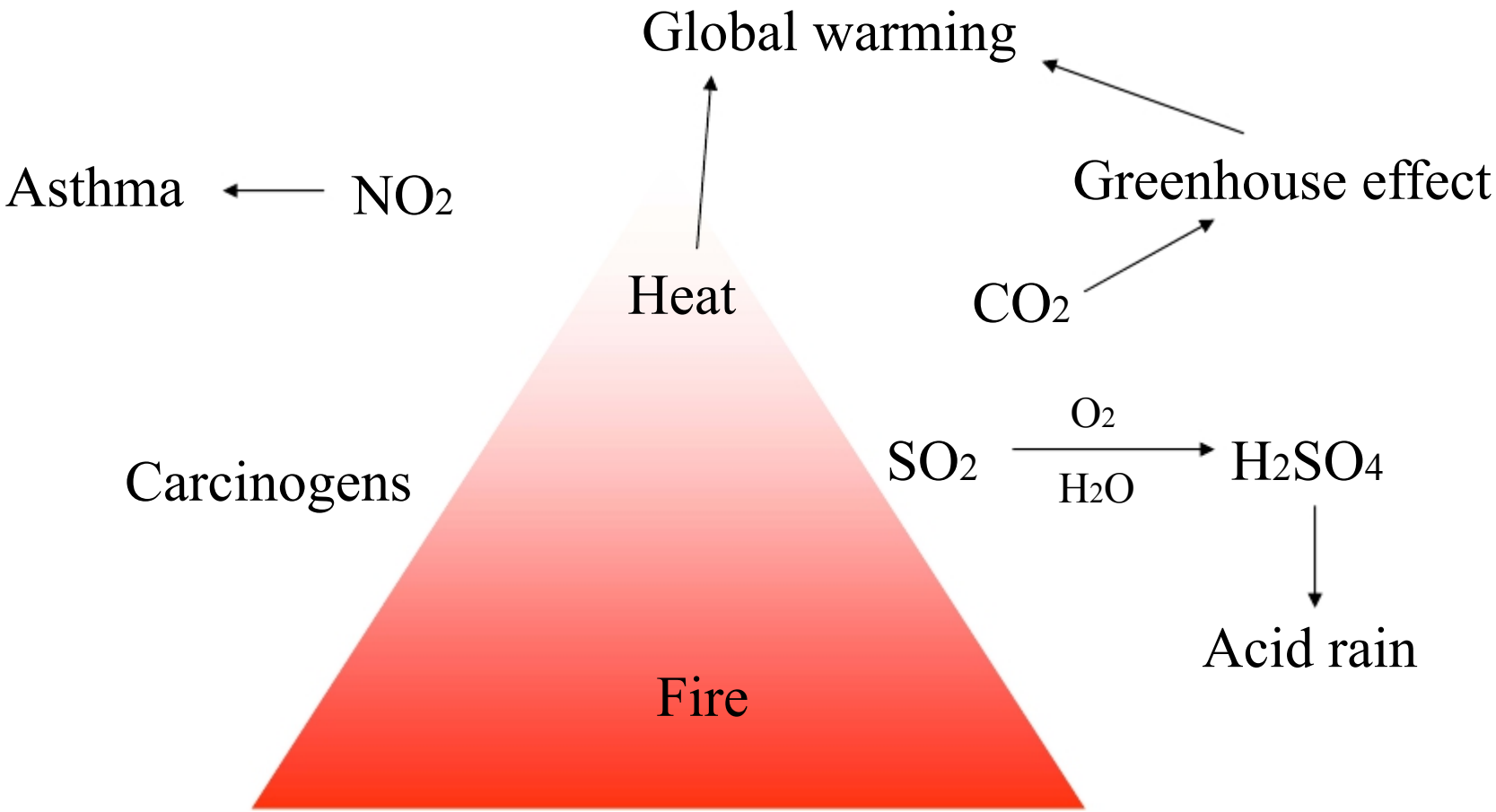
*Paper production, usage and disposal*




Environmental pollution generation

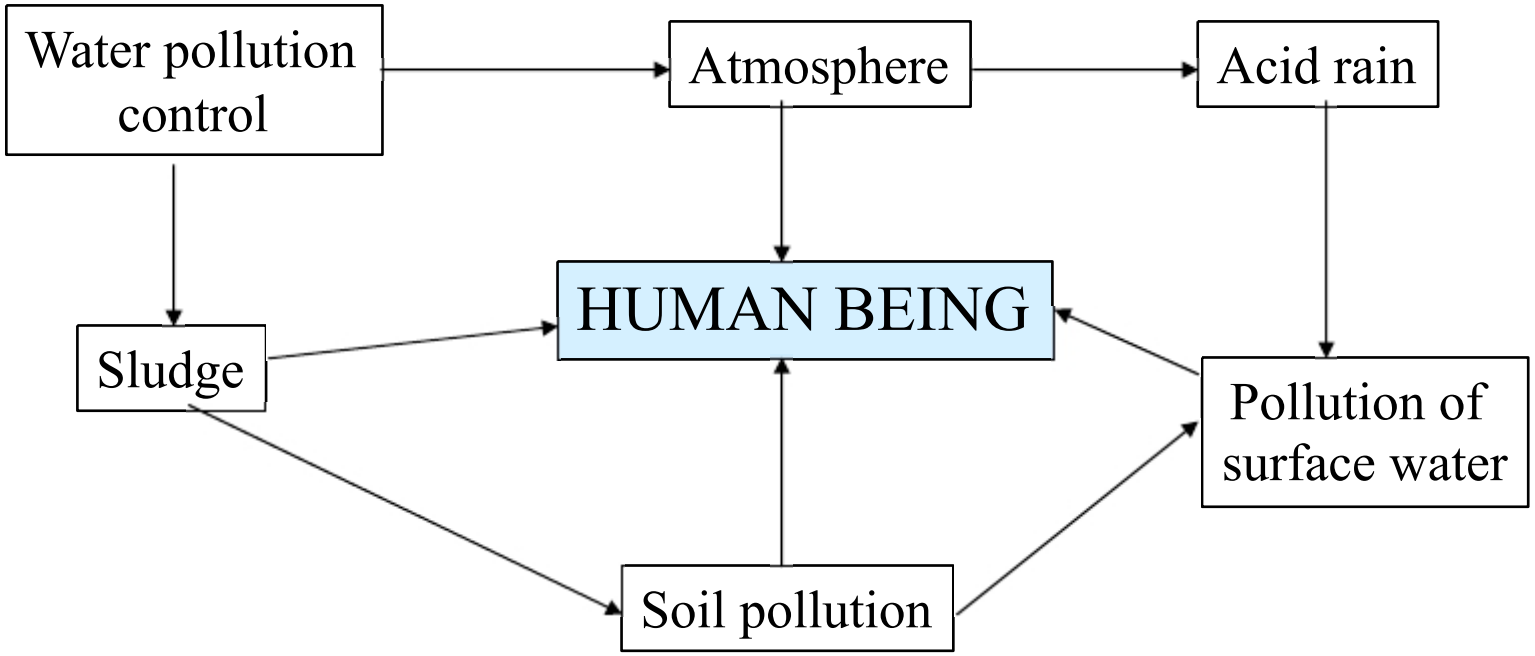
# Pollution Perspective

*Burning of paper and other organic materials*



# Pollution Perspective

*Pollution from water to air to soil to water to air to soil to …*



# Ecological systems, disturbances & pollution

## Concept of tolerance

Each species tolerate to a range of optimum for physicochemical factors:

- temperature
- pH
- light
- nutrients
- biological factors (food, competitors and predators)

Each species is most successful in that area where ranges of optima for different factors overlap to the greatest degree

Each species within a community and habitat has different and unique niche

# Ecological systems, disturbances & pollution

## Concept of disturbance

Discrete, punctuated killing, displacement or damaging of one or more individuals or colonies that directly or indirectly creates an opportunity for new individuals to be become established (Sousa, 1984)

Causes a temporary or permanent shift in the community

Risk assessment can be used to identify the risk after disturbances

# Ecological systems, disturbances & pollution

## Concept of pollution

Any change in the natural quality of the environment brought about by the following factors:

- chemical
- physical
- biological

Normally, pollution causes by activities of man

## Physical factors

- change naturally in short term (flood, fire, storms, etc.)
- longer term change (e.g. climate change)
- man's activities (building, drainage, forest clearence)

# Ecological systems, disturbances & pollution

## Chemical factors

Changes through elevation of concentration of substances, e.g.

nutrients eutrophication
toxic substances health risk
organics reduce quality of raw water supply

## Biological factors

Biological processes like predation or grazing, non-predatory effects like digging and man-induced events like tree felling, hunting etc.

reduce species niche ecological imbalance
cutting trees reduce oxygen generation capability

***Note:***
*Eutrophication: Enrichment of nutrients in water bodies*

# Ecological systems, disturbances & pollution

Most pollution, disturbances can be recovered

The ability to recover and rate of recovery are dependent on the regime of disturbance:

Nature of disturbances
Size of the disturbed area
Magnitude and duration of the event (intensity of disturbing force)
Timing and frequency of the disturbance
Predictability of the disturbance
Turnover rate (average time required to disturb the entire area)

# Major pollutants

*Water, Atmosphere, Soil*

Sulphur dioxide

Nitrogen oxides and nitrate

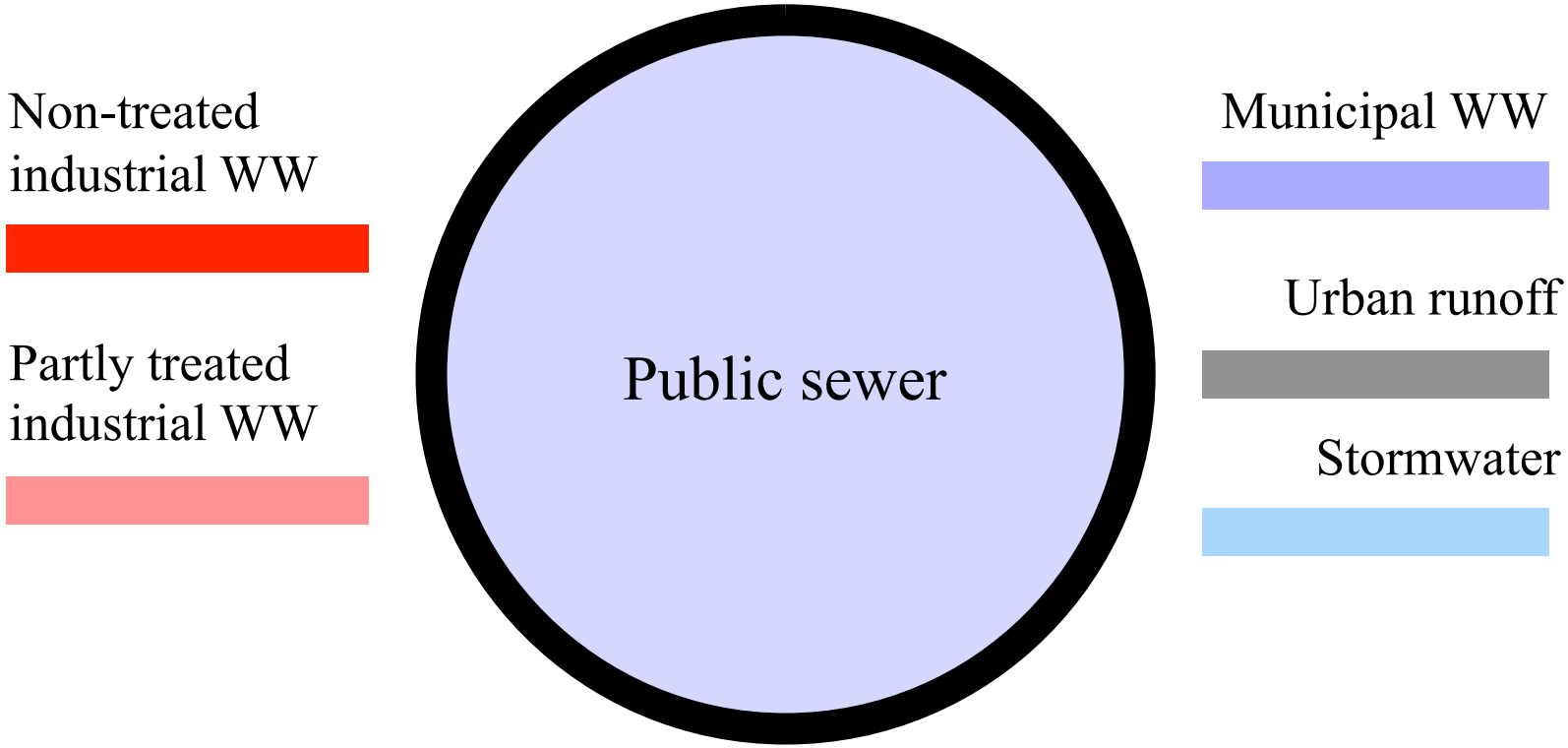
Sewage

Agricultural waste

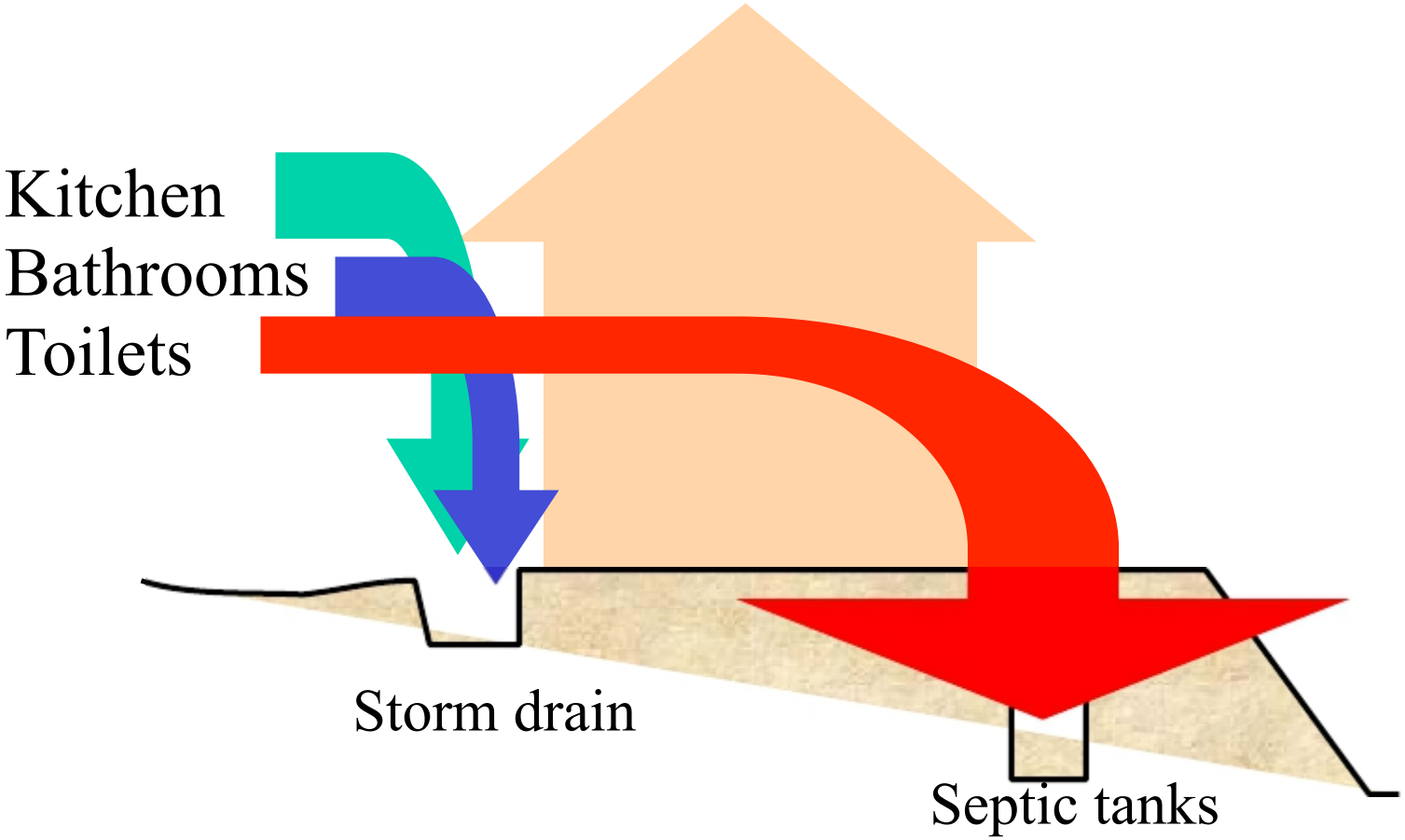
Warfare

Pesticides

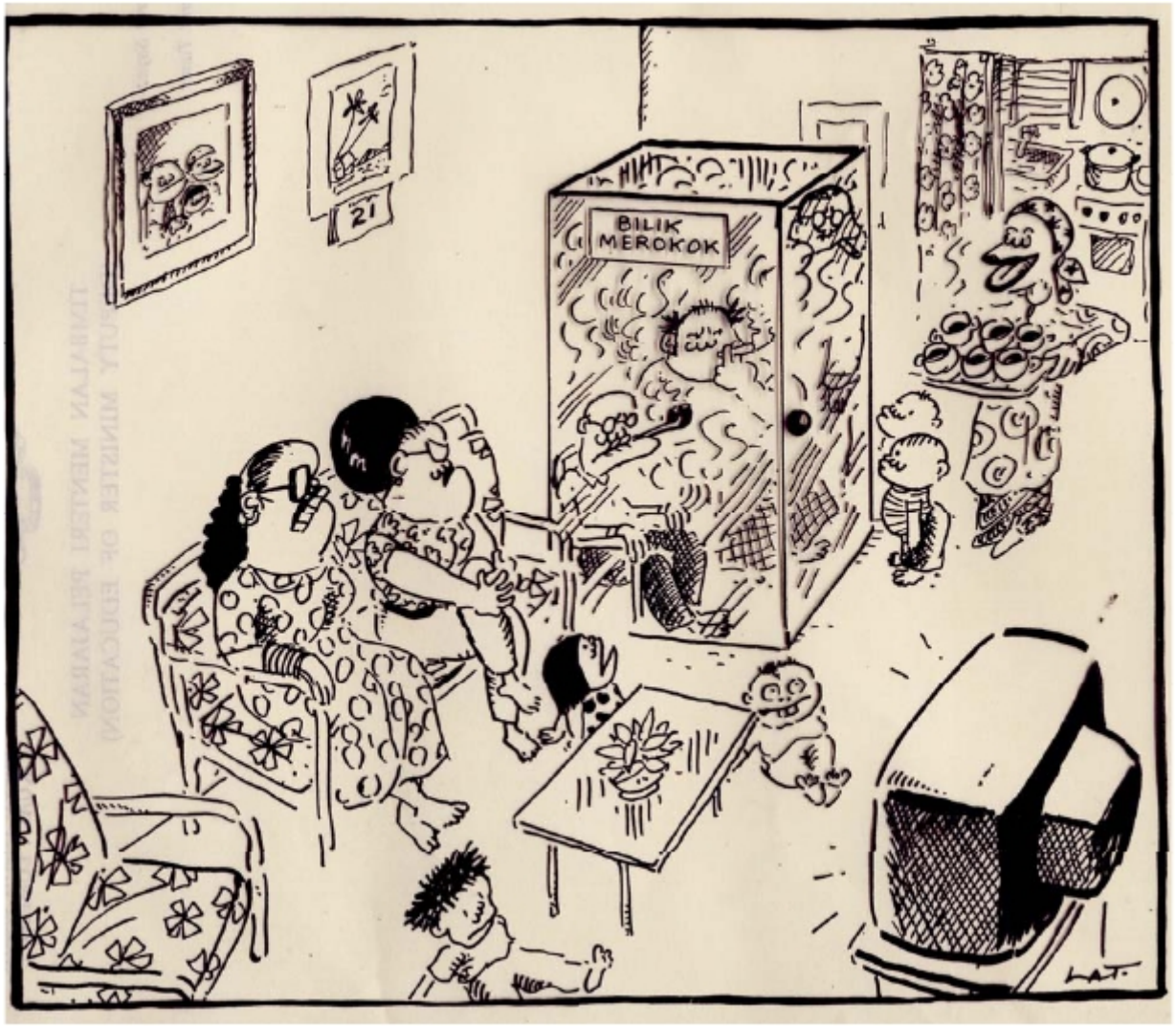
# Centralized (and combined) WWTP



# Sewage in rural and remote areas



# Major pollutants *Water, Atmosphere, Soil*



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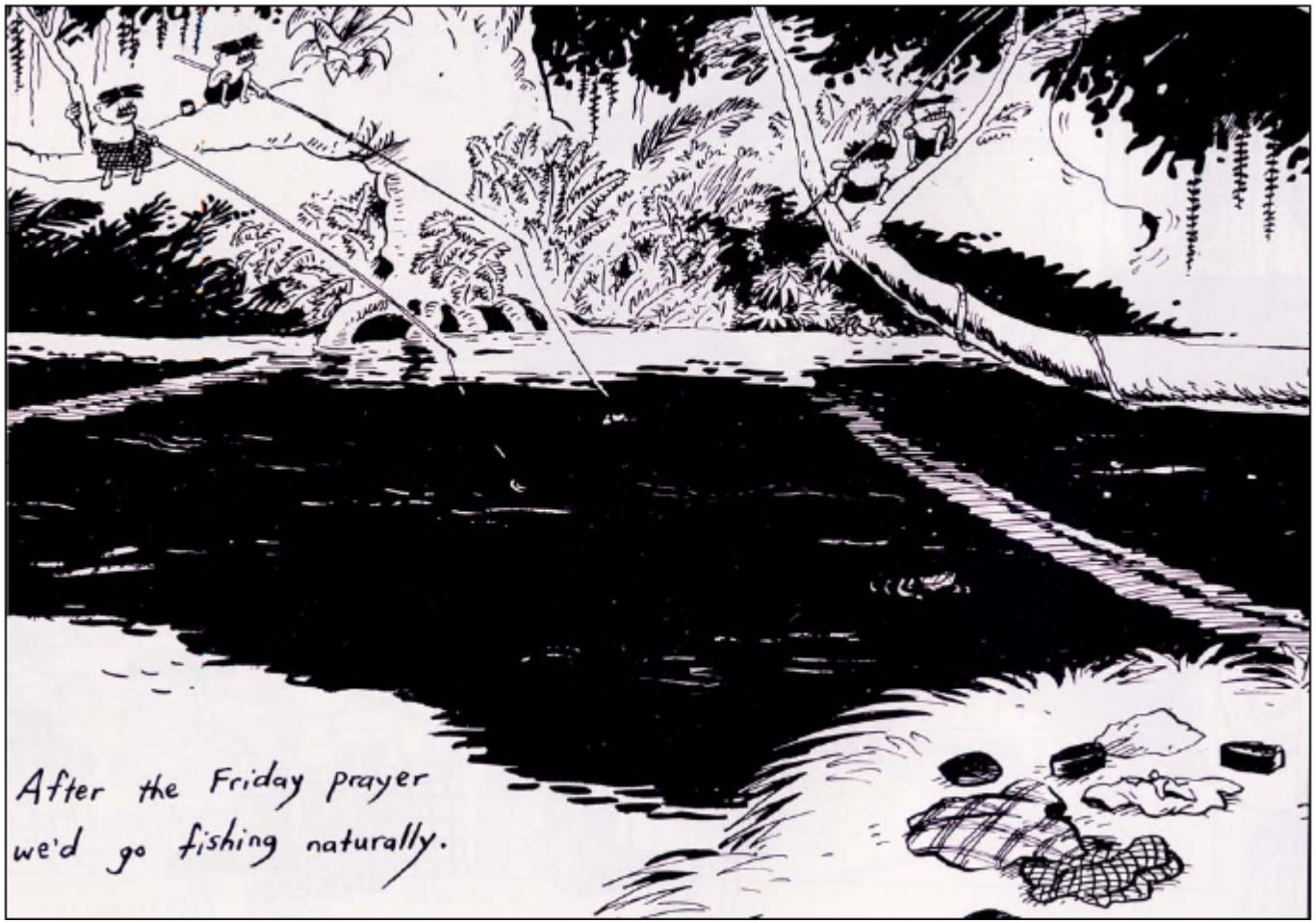
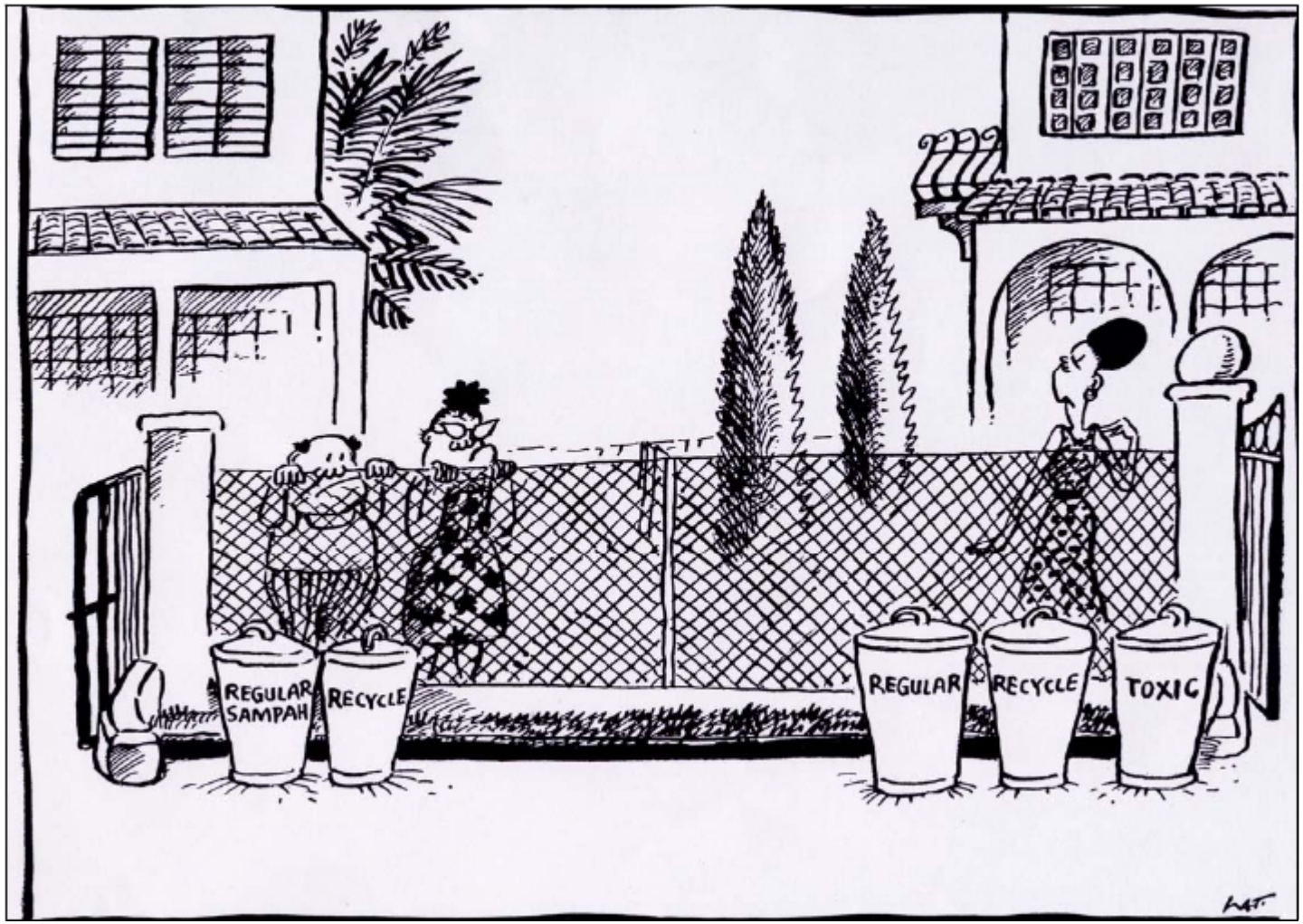


# Major pollutants *Water, Atmosphere, Soil*



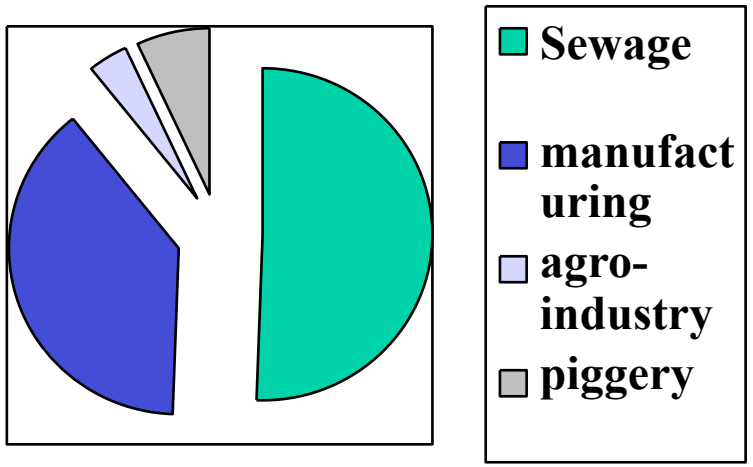
# Number of water pollution sources by sector to Malaysian rivers *(DOE, 2001)*

Sewage plants (6,693)

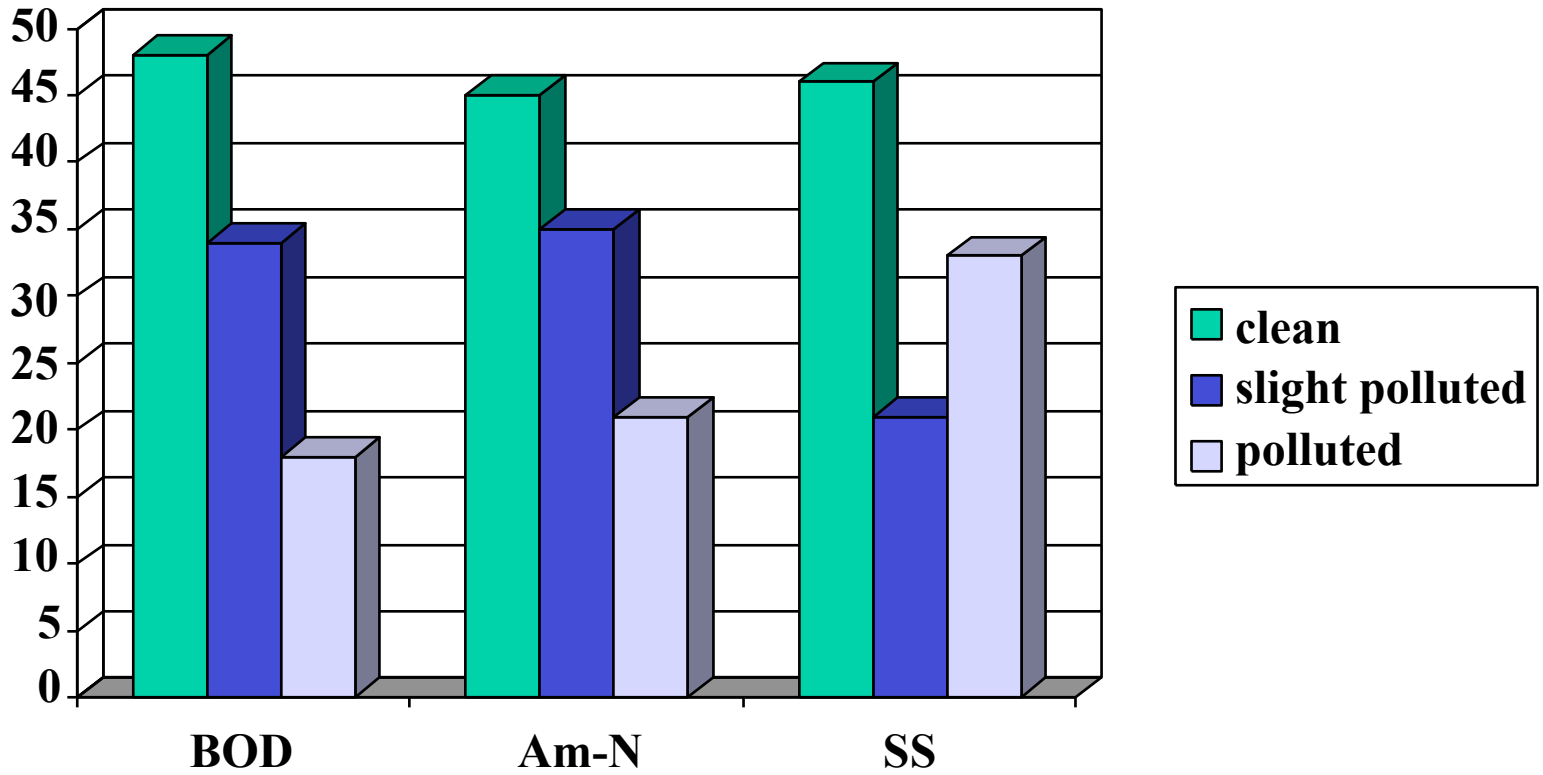
Manufacturing industries (5,086)

Pig farming (909)

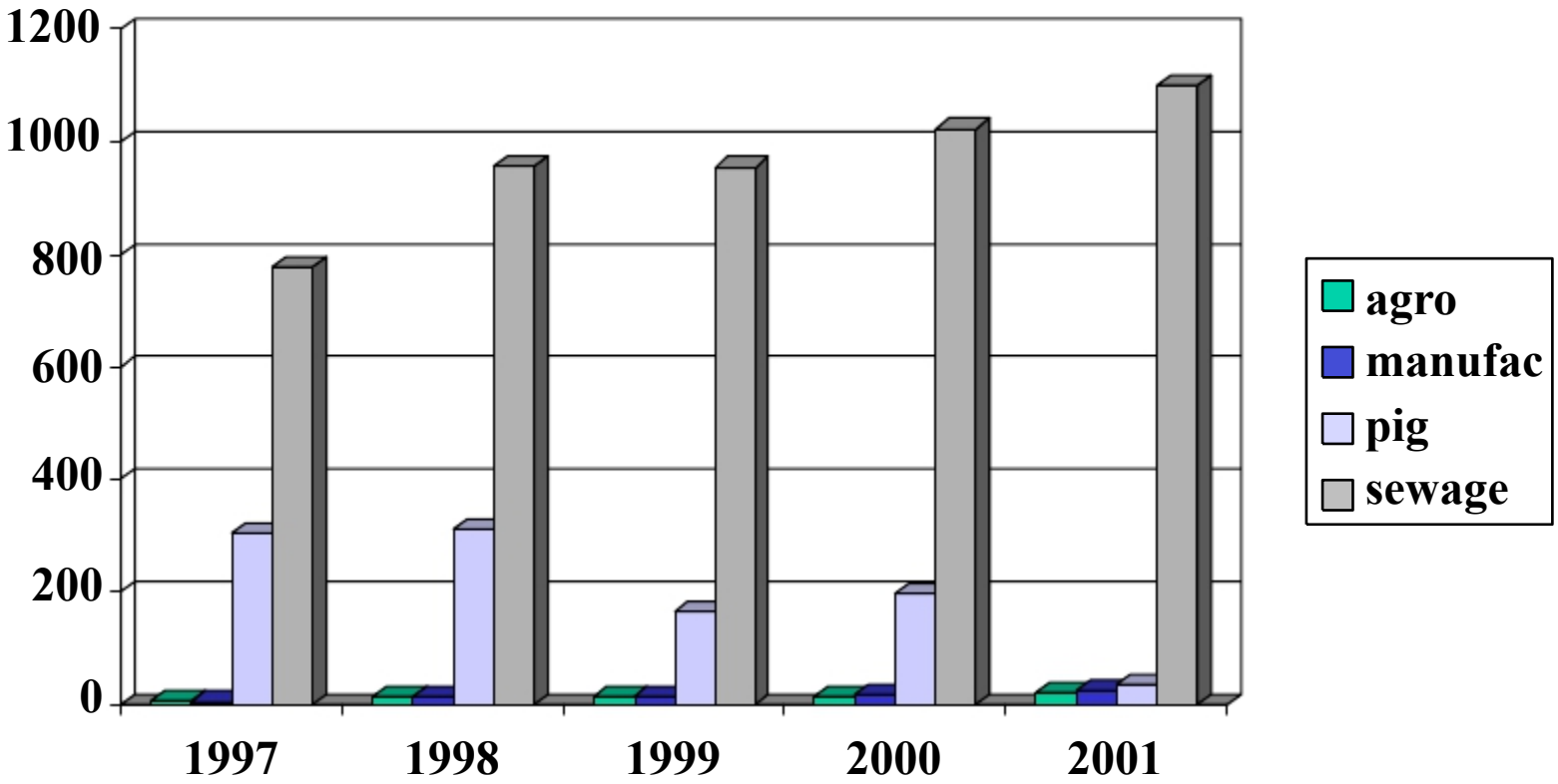
Agro-based industry (472)



# Status of river basin water quality *(DOE, 2002)*



# BOD loading by major sources, 1997-2001



# Water pollution in perspective …

# Water pollution in perspective …

# Interim River Water Classes

| Parameters | Classes | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| Am-Nitrogen | 0.1 | 0.3 | 0.9 | 2.7 | >2.7 |
| BOD | 1 | 3 | 6 | 12 | >12 |
| COD | 10 | 25 | 50 | 100 | >100 |
| DO | 7 | 5-7 | 3-5 | <3 | <1 |
| pH | 6.5 - 8.5 | 6-9 | 5–9 | 5–9 | - |
| Color (TCU) | 15 | 150 | - | - | - |
| TDS | 500 | 1000 | - | 4000 | - |
| TSS | 25 | 50 | 150 | 300 | >300 |
| FC(per 100ml) | 10 | 100 | 5000 | 5000 | - |
| TC(per 100ml) | 100 | 5000 | 20,000 | 50,000 | >50,000 |

# Pollution Distribution in Segget Catchment, JB

| Locations | Contributors | Loading (Ton/d) | Percentage (%) |
|---|---|---|---|
| Before Rubbish Trap | Industries | 0 | 0 |
| | Sewage | 0.9 | 26 |
| | Non Pollution Sources | 0.4 | 11 |
| Estuary | Industries | 0 | 0 |
| | Sewage | 1.5 | 43 |
| | Non Pollution Sources | 0.7 | 20 |
| Total | | 3.5 | 100 |

# Effects of pollutants on ecosystem

Introduction to food webs

Some specific examples

Risk versus benefits

Development of safer chemicals

# Effects of pollutants on ecosystem

*Introduction to food webs*

Food chains are dependent upon primary producers which input energy

Primary energy input is derived from photosynthesis ($CO_2$ converted to complex carbohydrates utilising sun's energy:

$$CO_2 + H_2O \xrightarrow{\text{sunlight}} CH_2O + O_2$$

The problem: energy transfer is not efficient (energy loss as heat)

# Effects of pollutants on ecosystem

## *Introduction to food webs*

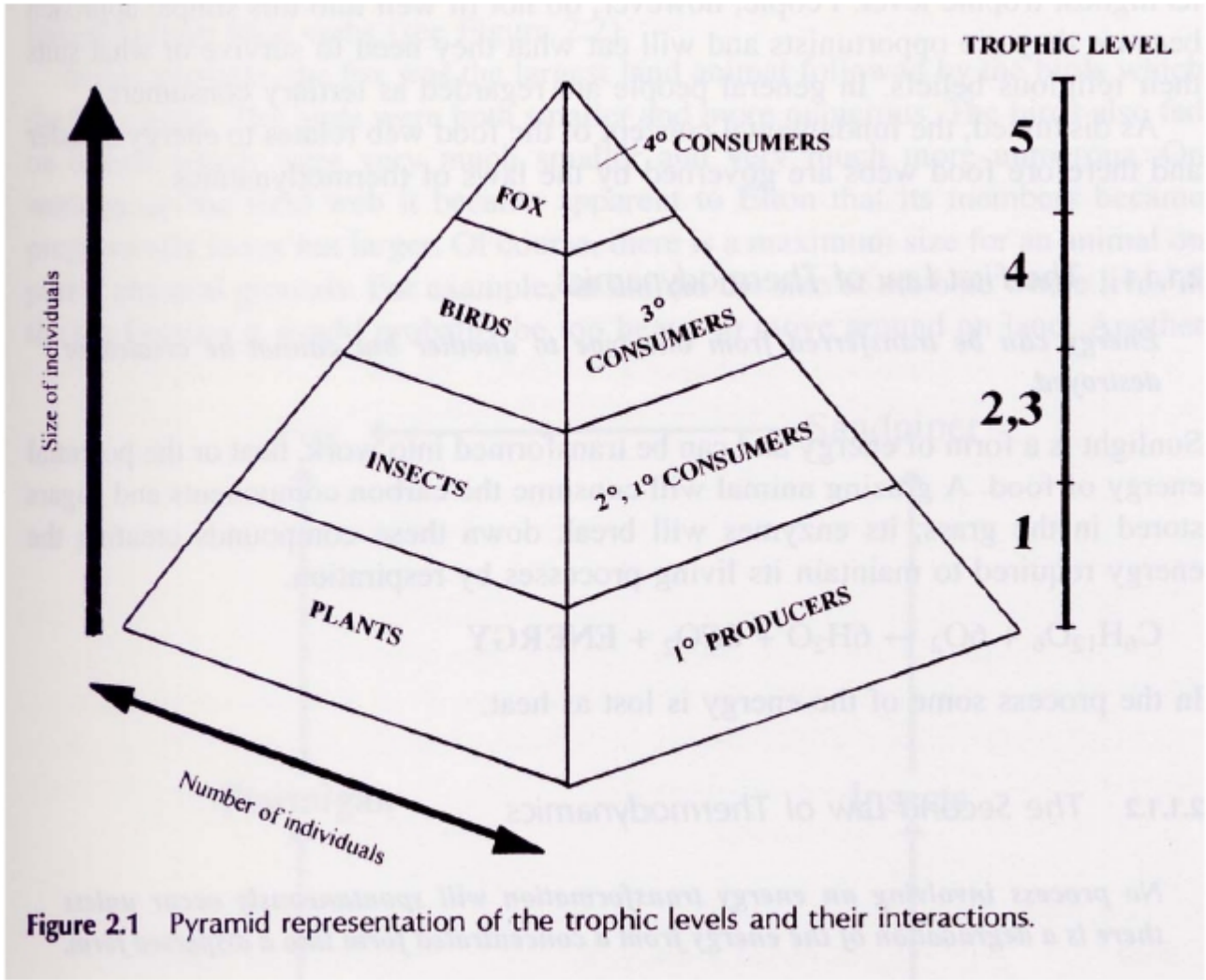



**Figure 2.1** Pyramid representation of the trophic levels and their interactions.

# Effects of pollutants on ecosystem

*First law of thermodynamics*

Energy can be transferred from one type to another but cannot be created or destroyed

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2 + \text{Energy}$$

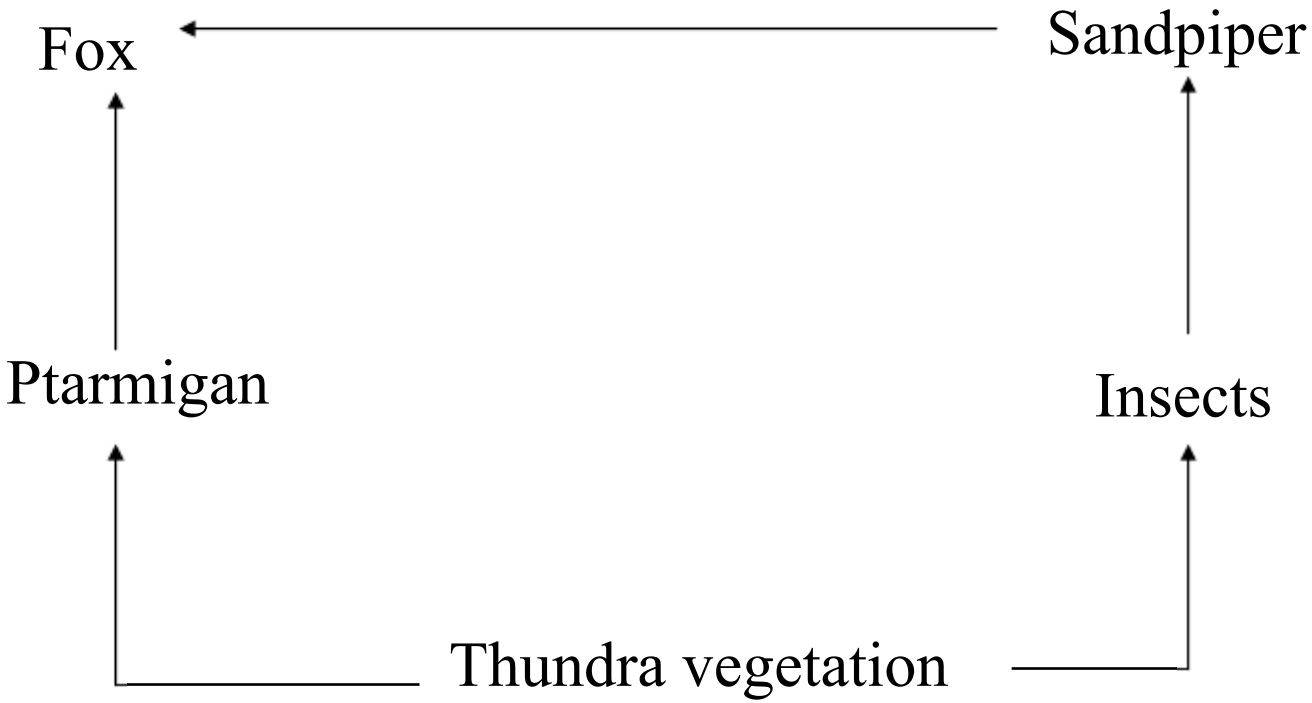
# Effects of pollutants on ecosystem

*Second law of thermodynamics*

No process involving an energy transformation will spontaneously occur unless there is a degradation of the energy from a concentrated form into a dispersed form

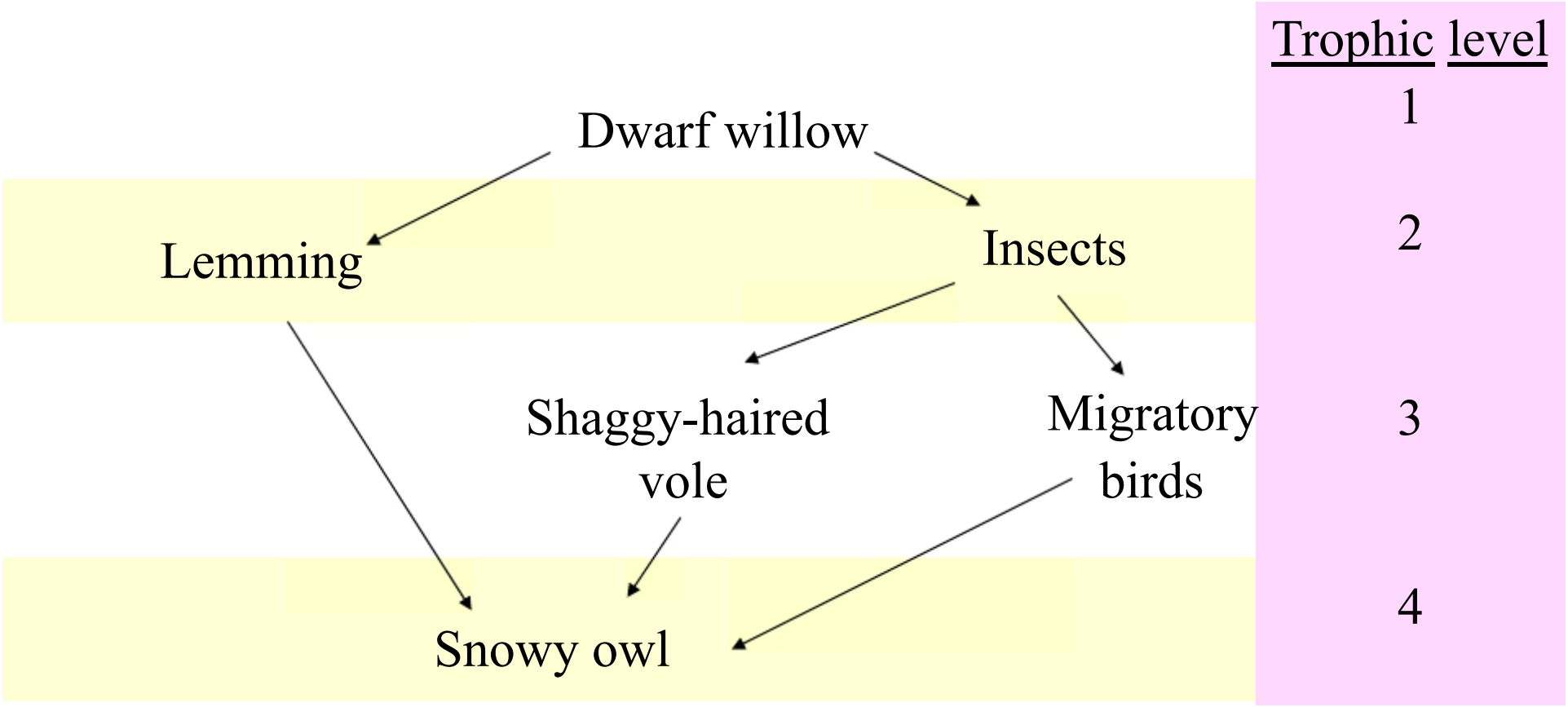
# Effects of pollutants on ecosystem

*Schematic representation of interrelationship between 2 food chains*



# Effects of pollutants on ecosystem

*Complex food web showing the trophic levels*



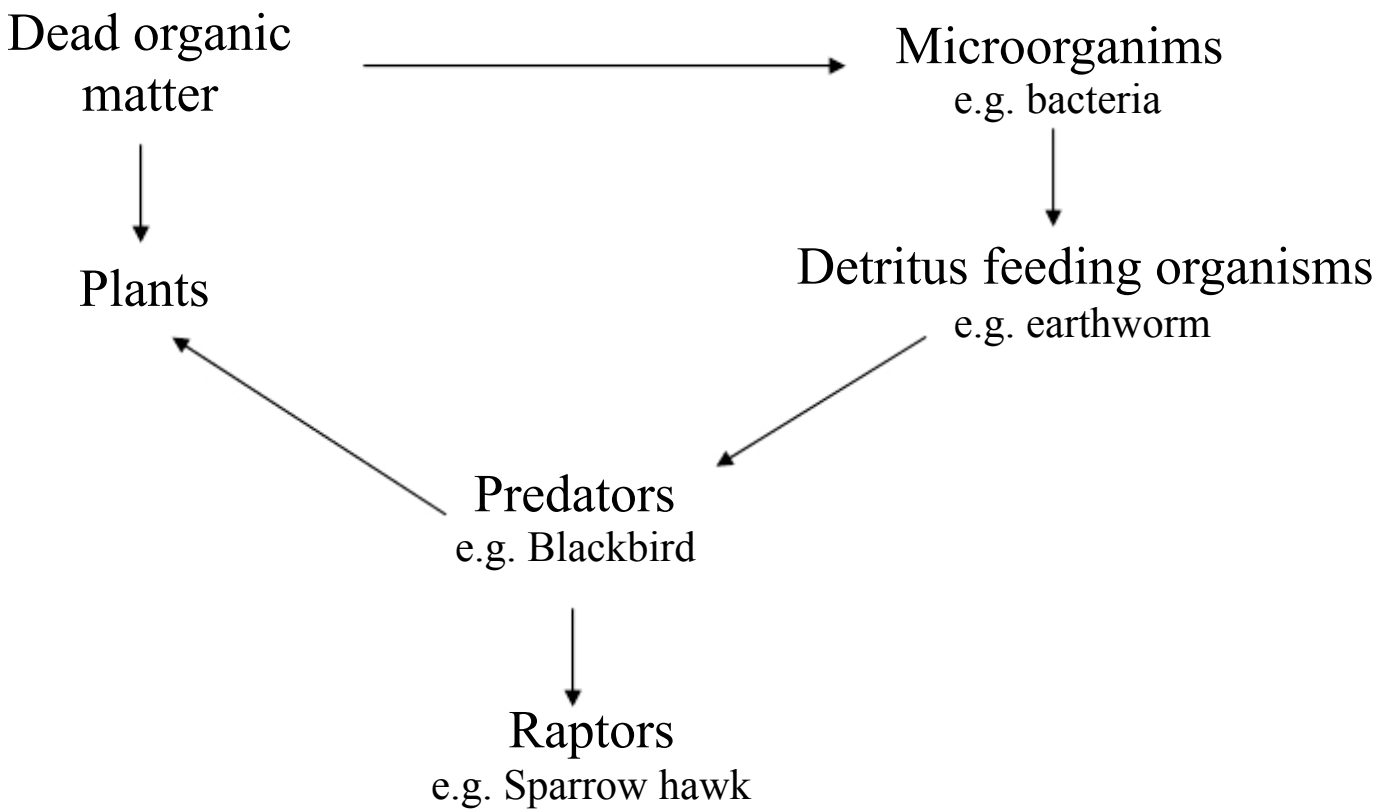
# Effects of pollutants on ecosystem

*7 trophic levels showing examples of organisms*

| Trophic level | Description | Example |
|---|---|---|
| 1 (P) | Primary producer | Spyrogyra, oak tree |
| 2 (C1) | Primary consumer (herbivores) | Daphnia, elephant |
| 3 (C2) | Secondary consumer (carnivores) | Water spider |
| 4 (C3) | Tertiary consumer | Trout, wolf |
| 5 (C4) | Quarternary consumer | Birds of prey |
| S | Saprophytes | Bacteria, fungi |
| D | Decomposers | Bacteria, earthworm |

# Effects of pollutants on ecosystem

*The use of dead organic matter*



# Fate & behaviour of chemicals in environment

*E.g. Dichlorodiphenyltrichloroethane (DDT)*

Very hydrophobic molecule which acts by interfering with ion transport systems in neuronal cell membrane

Inhibits neurotransmission → kills animals at certain dose

DDT (introduced in 1950s) is not species specific in its effects

DDT and related insecticides, endrin, dieldrin and aldrin are called ORGANOCHLORINE PESTICIDES

DDT revolutionised farming practices

DDT was developed by Swiss entomologist – Paul MÜller

Nobel Prize in 1948!

Banned in the mid-1960s in most developed countries

# Fate & behavior of chemicals in environment

*DDT in food chain in the USA*

| | Diet | DDT residues (ppm) |
|---|---|---|
| Water | NA | 0.0005 |
| Plankton | NA | 0.04 |
| Sheepshead minnow | Plankton | 0.94 |
| Pickeral | Predatory fish | 1.33 |
| Heron | Small fish | 3.57 |
| Herring gull | Scavenger | 6.00 |
| Osprey (eggs) | Larger fish | 13.8 |
| Merganser | Fish | 22.8 |
| Cormorant | Larger fish | 26.4 |

Woodwelll et al. (1967) *Science*, 156, 821

# Risk versus benefits …

Life is a risky business!

Concept of risk is complex

RISK = HAZARD x CHANCE (OF EXPOSURE)

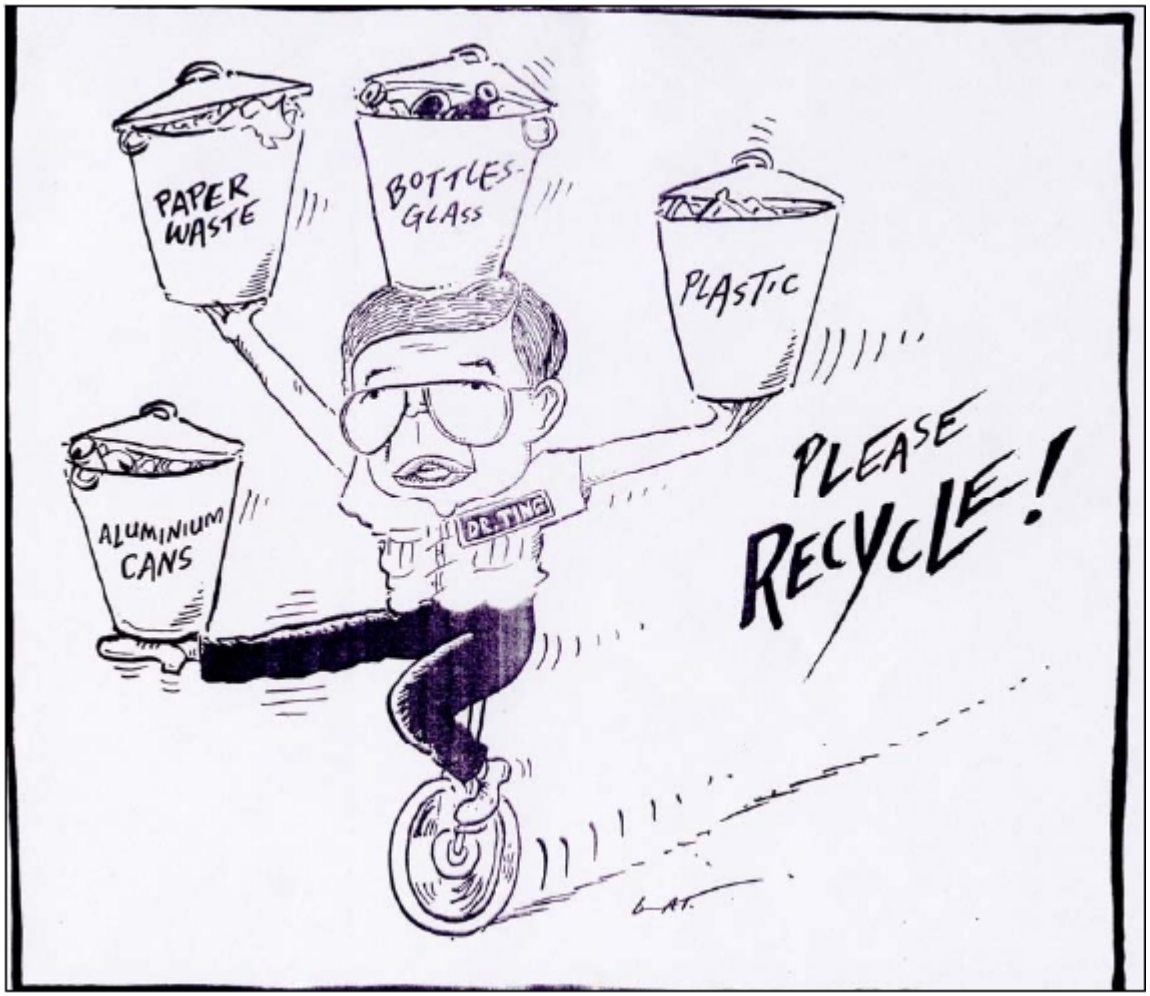
Hazard = intrinsic property of a substance or an activity

Occupational Safety and Health Act

Risk associated with exposure to chemicals is recent

Risk and benefit is not similar to all

# Risk versus benefits …




Is recycle is the solution to sustainable waste disposal and management?

# Development of safer chemicals

Organochlorines (OCs) are dangerous to environment because of its indiscriminate toxicity

Environmental friendly chemicals?

E.g. pyrethroid insecticides

Pyrethrum is a mixture of several pyrethroids present in powdered *Chrysanthemum cinerariaefolium*, including pyrethrin, pyretol, pyrethrotoxic acid, pyrethrosin and chrysanthemine

Widely planted in Kenya

Pyrethroids act by modulating the gating characteristics of the sodium channel on neuronal membrane although the exact mechanism of the interaction between pyrethorid molecule and membrane sodium channel is not fully understood

# Development of safer chemicals

Chemicals and products are to be disposed at high cost, or discharge to environment without proper treatment at all

# Environmental toxicity testing

*Toxicity testing in perspective*

Extrapolating the results of toxicity test in rats (& other animals to humans)

The best is to use human body

Ethical problems, especially in pharmaceutical industry

Scope and limitations

Oestogenicity assay

Toxicity tests on animals and plants

Environmental impacts assessment

# Environmental monitoring

Why monitor environmental contaminants

Methods

Meaning of analytical results

Analytical techniques

Identification of environmental contaminants

Inorganic contaminants

Immunoassays