Module 4

Environmental Pollution

Dr. Priyadharshini. B
Department of Civil Engineering,
Bennett University.

Definition

Pollution may be defined as addition of undesirable material into the environment as a result of human activities. The agents which cause environmental pollution are called **pollutants**.

A pollutants may be defined as a physical, chemical or biological substance unintentionally released into the environment which is directly or indirectly harmful to humans and other living organisms.

Classification of pollutants – Ecological perspective

- **Degradable or non-persistent pollutants:** These can be rapidly broken down by natural processes.

  Eg: domestic sewage, discarded vegetables, etc.

- **Slowly dégradable or persistent pollutants:** Pollutants that remain in the environment for many years in an unchanged condition and take decades or longer to degrade. Eg: DDT and most plastics.

- **Non-degradable pollutants:** These cannot be degraded by natural processes. Once they are released into the environment, they are difficult to eradicate and continue to accumulate. Eg: toxic elements like lead or mercury.

Types of pollution

Pollution may be of the following types:

1. Air pollution
2. Noise pollution
3. Water pollution
4. Soil pollution
5. Thermal pollution
6. Radiation pollution

Air pollution

- Air Pollution History
- What is air pollution?
- Sources
- Air pollution: Indian scenario

Air Pollution – History

King Edward – I: 1273

Anti-pollution law to restrict people from using coal

01

Bhopal Gas Tragedy: 1984

Union Carbide India Limited pesticide plant in Bhopal, Madhya Pradesh.

Methyl Isocyanate Gas

02

London Smog: 1952

4000 deaths due to accumulation of air pollutants – 1956 Clean Air Act.

03

Till date

Many more incidents

04

What is air pollution?

Air pollution - the presence of contaminants or pollutant substances in the air that interfere with human health or welfare or produce other harmful environmental effects (U.S. Environmental Protection Agency (EPA).

When does science consider the atmosphere to be unpolluted versus polluted?

- Compare the condition of the atmosphere currently against some type of baseline, e.g. pre-industrialized atmosphere prior to the nineteenth century.
- Another approach is to consider the principles by which materials are released into the atmosphere, move, transform, and are removed from the atmosphere, and based on this assessment determine the extent of atmospheric pollution.

Criteria pollutants

In the United States, the Clean Air Act of 1970 established the National Ambient Air Quality Standards (NAAQS) to address six so-called **"criteria air pollutants"**:

1. Particulate matter (PM)
2. Ozone (O_3)
3. Carbon monoxide (CO)
4. Sulfur dioxide (SO_2)
5. Nitrogen dioxide (NO_2)
6. Lead (Pb)

Directly emitted or indirectly emitted – Primary or Secondary source?

A handful of commonly found air pollutants are known to cause three specific types of harm. They impair health, destroy and adversely affect environmental resources, and damage property.

Classification based on criteria pollutants

When an urban area or other geographic area has concentrations of a criteria pollutant below the standard it is said to be "**in attainment**" and the area is declared to be an "attainment area".

Conversely, any area that has concentrations of a criteria pollutant above the standard is called a "**non-attainment area**".

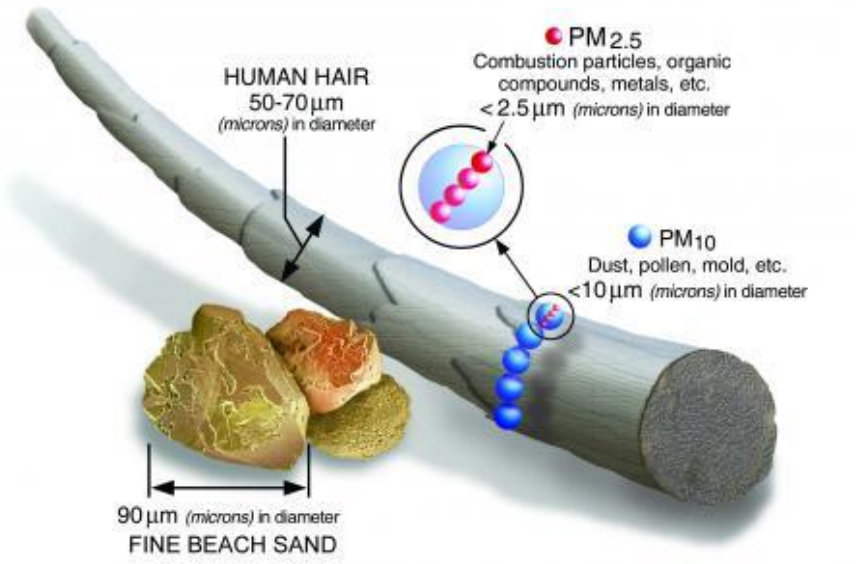
There are currently 102 non-attainment cities in our country.

Non-Attainment cities with respect to Ambient Air Quality India (2011-2015) & WHO report 2014/2018.

Types of particulates – size based terminologies

Term	Meaning	Examples
Aerosol		ed cans
Mist		
Dust		
Smoke		oke from burning
Fume		
Plume		
Fog	Aerosol consisting of water droplets	
Smog	Term used to describe a mixture of smoke and fog	

Particulate Matter - PM



Particulate matter (PM) is the term used to describe solid or liquid particles that are airborne and dispersed (i.e., scattered, separated).

Particles are aggregates of many molecules, sometimes of similar molecules, often of dissimilar ones.

They form and transform in the air by several processes. Some particles serve as nuclei upon which vapors condense. Some particles react chemically with atmospheric gases or vapors to form different compounds.

Sources of PM

1. Natural
   - Wind-borne dust
   - Sea spray
   - Volcanic
   - Biogenic aerosols

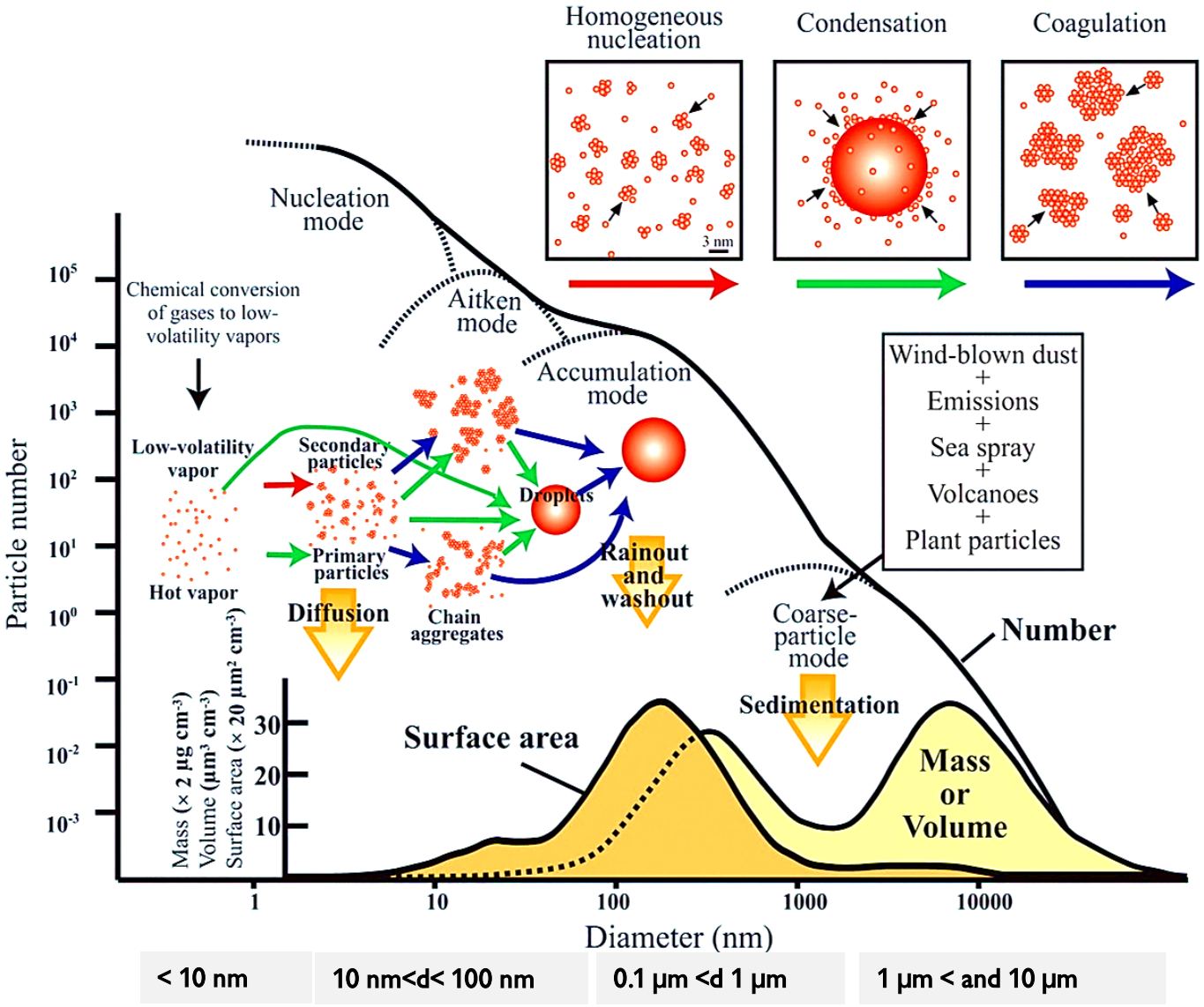
2. Anthropogenic
   - Industrial emissions
   - Fossil fuel combustion
   - Agricultural activities
   - Waste and biomass burning

Primary

Bulk to particle conversion

Secondary

Gas to particle conversion



Classification of PM sources

Sources of particles are highly variable on temporal and spatial scale.

PM can be emitted from direct and/or indirect sources.

They may be emitted directly to the air from stationary sources, such as factories, power plants, and open burning, and from moving vehicles (known as "mobile sources").

Point sources includes stack emissions or from vehicles and Area or nonpoint sources of particles include construction, agricultural activities such as plowing and tilling, mining, and forest fires.

Atmospheric transport and fate

Three perspectives:

1. The sources - The sources of air pollutants vary in size (e.g. tons emitted per year), type (e.g. stationary or mobile) and composition (e.g. coke oven emissions include thousands of compounds, but many smelters include a handful of metals).

2. The movement – molecular diffusion to continental and global transport in winds aloft.

3. The receptors - humans, ecosystems, and materials.

Sources and sinks

- The places from which pollutants emanate are called sources.

  (a) Natural

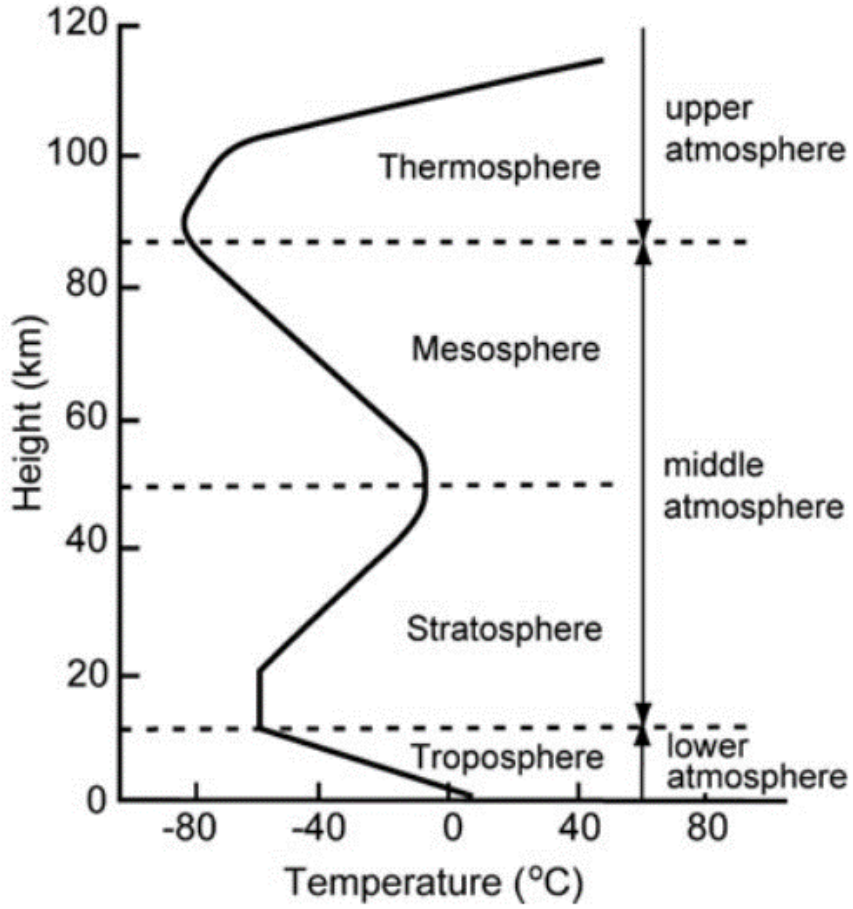
  (b) Anthropogenic

- The mechanisms whereby pollutants are removed from the atmosphere are called scavenging mechanisms (wet or dry), and the measure used for the aging of a pollutant is its half-life time it takes for half of the quantity of a pollutant emanating from a source to disappear into its various sinks.

- Fortunately, most pollutants have a rather short half-life (i.e. days rather than decades) that prevents their accumulation in the air.

Structure of Atmosphere

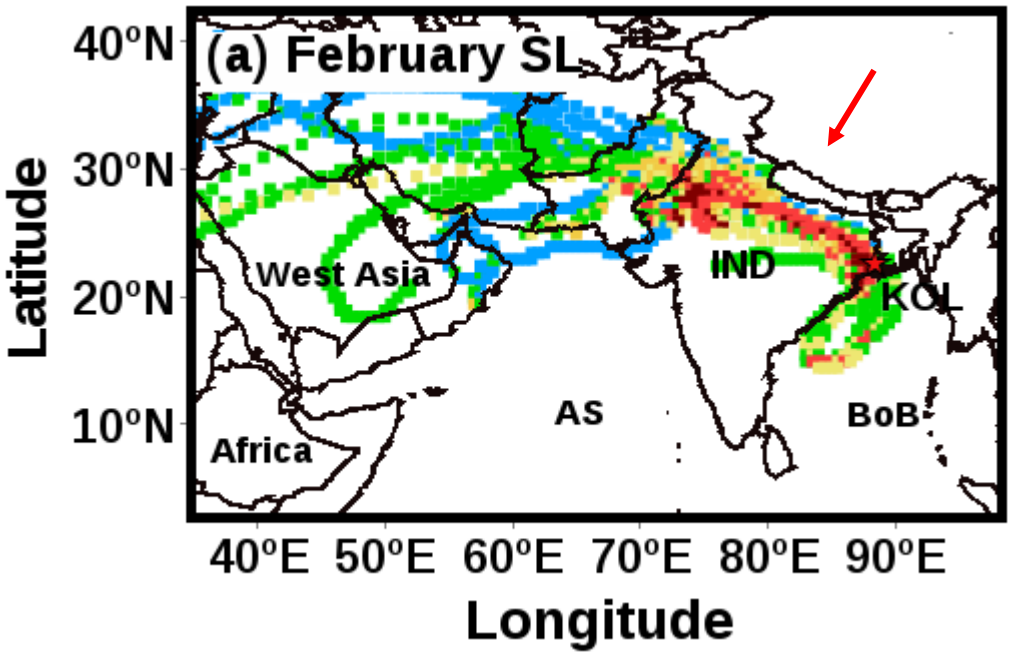
To understand how pollutants travel and cause an impact



Receptors

- A receptor is something that is adversely affected by polluted air. A receptor may be a person or animal that breathes the air and whose health may be adversely affected thereby, or whose tissue may be irritated, or whose surfaces (e.g. skin, leaf cover, roof) may be coated or discolored.
- **Transport and Dispersion -** Transport is the mechanism that moves the pollution from a source to a receptor.
- The wind is the means by which the pollution is transported from the source to the receptor.
  – Short and Long range transport.

Example!



Priyadharshini et al., 2018, ESPR

Receptor site: Kolkata

The color shaded regions represent the air mass trajectories which have travelled from far and near regions and reached the receptor site Kolkata.

Indian Scenario: Air pollution

tions and timeline
host polluted cities

next five years

- **Incentivise waste processing** over landfilling by 2019
- **Mandate compulsory mechanised dust removal** in the most polluted cities by 2019
- Establish **accurate and comprehensive air quality monitoring systems** in the worst affected cities by 2019

NITI AAYOG'S BREATH INDIA ACTION PLAN

JAN'2018	2018 AVG	DEC'2018
133.6	Gurugram 145.6	208.2
255.1	Ghaziabad 144.6	247.2
178.8	Faridabad 123	202.6
212.2	Noida 134	228.1

BIG CITIES OR DEATH TRA

MIRRORNOWNEWS.

yrs, Delhi air will be world's deadl

er 10 years, the world's of prema- ally due to among all world. By 0 people in ly due to in- r. ll be Kolka- the highest deaths an- olkata will premature ween 2025 ill record to air pollu- han Delhi ai (33,100). e three ci- t of prema- to harmful .5 and O3 in 3.3 million

DEATH BY BREATH

PREMATURE MORTALITY (DEATHS PER YEAR) IN THE MOST POLLUTED MEGA

INTERNATIONAL CITIES

	2010	202
London	2800	340
Paris	3100	380
Moscow	8600	108
Beijing	13700	173
Los Angeles	4100	520
New York	3200	420
Hong Kong	2600	370

people worldwide die prematurely from the effects of air pollution. This number will double by 2050 to 6.6 million if emissions continue to rise, according to a team of scientists at the Max Planck Institute for Chemistry in Mainz.

In 2010, 75% tality occurred million in Chin in India.

pollution causes 8m death

ccounts For 1.5m Fatalities From Indoor Pollution, India For

sgroup.com

hs due to air reased four- obe over the atest assess- d Health Or- s. The data- he report is China and he worst af-

is one of the auses of dis- bally. About s each year, g countries, th exposure oor) air pol- 3.7 million attributed to r) air pollu- y the WHO The report, the environ- the health lution', is to e 68th World ly which y in Geneva. he risks of an

© Stephen Shaver/ZUMA Press/Corbis

WHO has warned of rising pollution in developing countries by 2030 along with advancement of transportation, housing and infrastructure

increasing disease burden due to polluted air at home and outside.

WHO'S 2005 global update on air quality noted that more than two million premature deaths each year can be attributed to the effects of urban outdoor air pollution and indoor air pollution (from the burning of solid fuels).

The latest report does not give details, but the datasets on which it is based do give break-ups of deaths due to indoor air pollution country-wise and those due to outdoor or 'ambient' air pollution region-wise.

What the data shows is that of the 4.3 million deaths globally from indoor air pollution, China accounted for nearly 1.5 million and India for close to 1.3 million. Between them, the two Asian giants accounted for nearly two-thirds of the global total.

As for outdoor pollution, the south-east Asian region, which includes India in the WHO categorisation, accounted for about 9.4 lakh deaths and the category that includes China had 1.7 million. The two regions were home to over two-thirds of global deaths due to this cause. While developing countries were found bearing the maximum disease burden due to air pollution even in 2005, the WHO report then had warned of rising pollution in developing countries by 2030 along with advancement of transportation, housing and other infrastructure.

The latest report talks in details about the adverse effects of both indoor and outdoor air pollution on health. For instance, exposure to air pollution is a leading risk factor for non-communicable diseases,

in part cardia chroni ry dise Lu air pol ased s Accord around deaths joint e ambie in 200 deaths lion d wide w outdoo Hea around ate on the re in the ing W where presid years. are als pollut annua

INACTION ON POLLUTION

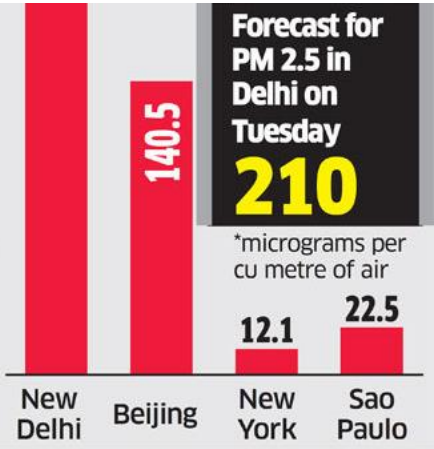
	Action taken (in %)	Violations observed
Delhi	421	4.92%
Noida	77	7.36%
Ghaziabad	61	3.76%
Faridabad	159	5.17%
Gurugram	63	3.59%

Prominent factors that lead to pollution (Figures in %)

21.8	18.6	14.7	13.2	10.1	21.6 Others
Open storage of construction material & debris	Construction work	Open waste burning	Unpaved roads	Open dumping of construction and demolition debris	

WHAT YOU CAN DO: Use Sameer app to report activities that lead to pollution

Delhi's air quality is expected to improve on Tuesday, but the overall air quality index is likely to remain in the 'very poor' category. Increase in wind speed Monday night onwards should help in dispersal of pollutants.



Overall Air Quality Index across Indian Cities

Level of various pollutants in Delhi's Lodhi

Mon, Nov 12, 2018 17:36:01 pm

Pollutant	AQI	
PM10	240	Poor

Government initiative

- National Air Quality Monitoring Programme (NAMP)
- **Frequency and Parameters Monitored:** Under N.A.M.P., three air pollutants viz., Sulphur Dioxide (SO_2), Nitrogen dioxides (NO_2) and Respirable Suspended Particulate Matter (RSPM/PM_{10}) have been identified for regular monitoring at all the locations.
- The monitoring of meteorological parameters such as wind speed and direction, relative humidity and temperature was also integrated with the monitoring of air quality. The monitoring of pollutants is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week, to have 104 observations in a year.

- **Monitoring Agencies:** The monitoring is being carried out by Central Pollution Control Board; State Pollution Control Boards; Pollution Control Committees; National Environmental Engineering Research Institute (NEERI), Nagpur. CPCB co-ordinates with the other agencies to ensure the uniformity, consistency of air quality data and provides technical and financial support to them for operating the monitoring station.

- **Number of Monitoring Stations:** There are 731 operating stations in 312 cities/towns in 29 states and 6 Union Territories of the country.

National clean air programme - NCAP

Goal of NCAP is to meet the prescribed annual average ambient air quality standards at all locations in the country in a stipulated timeframe.

Objectives

1. To augment and evolve effective and proficient ambient air quality monitoring network across the country for ensuring comprehensive and reliable database
2. To have efficient data dissemination and public outreach mechanism for timely measures for prevention and mitigation of air pollution and for inclusive public participation in both planning and implementation of the programmes and policies of government on air pollution
3. To have feasible management plan for prevention, control and abatement of air pollution.

Table 1: National Ambient Air Quality Standards

Pollutant	Time Weighted Average	Concentration in Ambient Air	
		Industrial, Residential, Rural and Other Areas	Ecologically Sensitive Area (notified by Central Government)
Sulphur Dioxide (SO_2), $\mu g/m^3$	Annual* 24 hours**	50 80	20 80
Nitrogen Dioxide (NO_2), $\mu g/m^3$	Annual* 24 hours**	40 80	30 80
Particulate Matter (size less than 10 µm) or PM_{10} $\mu g/m^3$	Annual* 24 hours**	60 100	60 100
Particulate Matter (size less than 2.5 µm) or $PM_{2.5}$ $\mu g/m^3$	Annual* 24 hours**	40 60	40 60
Ozone (O_3) $\mu g/m^3$	8 hours* 1 hour**	100 180	100 180
Lead (Pb) $\mu g/m^3$	Annual* 24 hours**	0.50 1.0	0.50 1.0
Carbon Monoxide (CO) mg/m^3	8 hours* 1 hour**	02 04	02 04

Air Quality Index - AQI

https://cpcb.nic.in/national-air-quality-index/ - Suggested task

Calculation of AQI						
Date			Station	NSIT		
DD-MM-YYYY			City	Delhi		
			State	Delhi		
Pollutants		concentration in µg/m3 (except for CO)	Sub-Index			Air Quality Index
				check		
PM10	24-hr avg	230.00	187	1		
PM2.5	24-hr avg	34.00	57	1		
SO2	24-hr avg	0.00	0	0		
					AQI =	187
NOx	24-hr avg	8.00	10	1		
*CO (mg/m3)	max 8-hr	0.00	0	0		
O3	max 8-hr	57.00	57	1		
NH3	24-hr avg	34.00	9	1		
* Concentrations of minimum three pollutants are required; one of them should be PM10 or PM2.5						
* The check displays "1" when a non-zero value is entered						

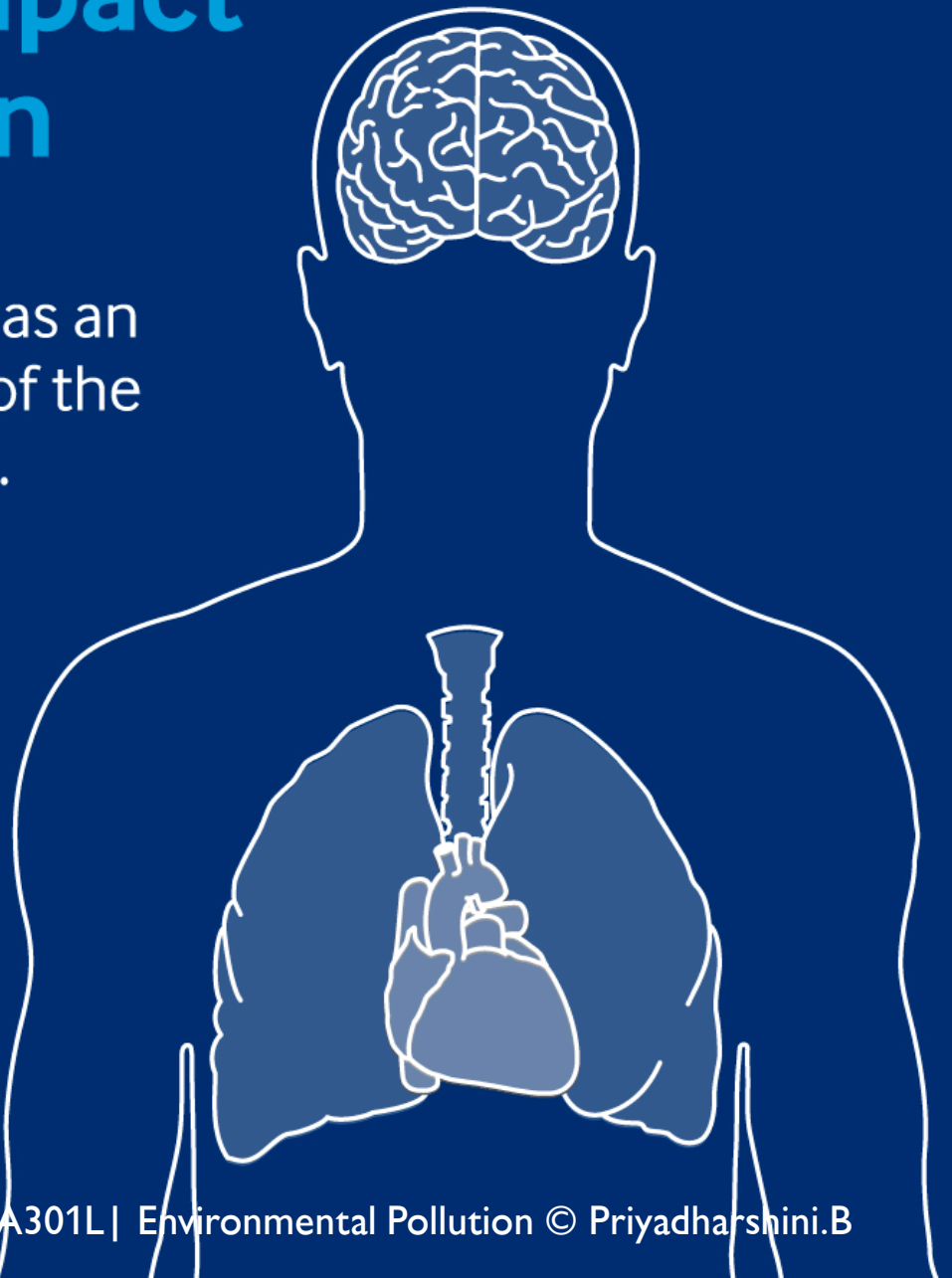
AQI Category	Associated Health Impact
Good (0 to 50)	Minimal impact
Satisfactory (51 to 100)	May cause minor breathing discomfort to sensitive people
Moderately Polluted (101 to 200)	May cause breathing discomfort to the people with lung disease such as asthma and discomfort to people with heart disease, children and older adults
Poor (201 to 300)	May cause breathing discomfort to people on prolonged exposure and discomfort to people with heart disease
Very Poor (301 to 400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases
Severe (401 to 500)	May cause respiratory effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

8 pollutants – NH_4, Pb (apart from the one's in the box)

Minimum 3 pollutant concentration is must to calculate AQI

The health impact of air pollution

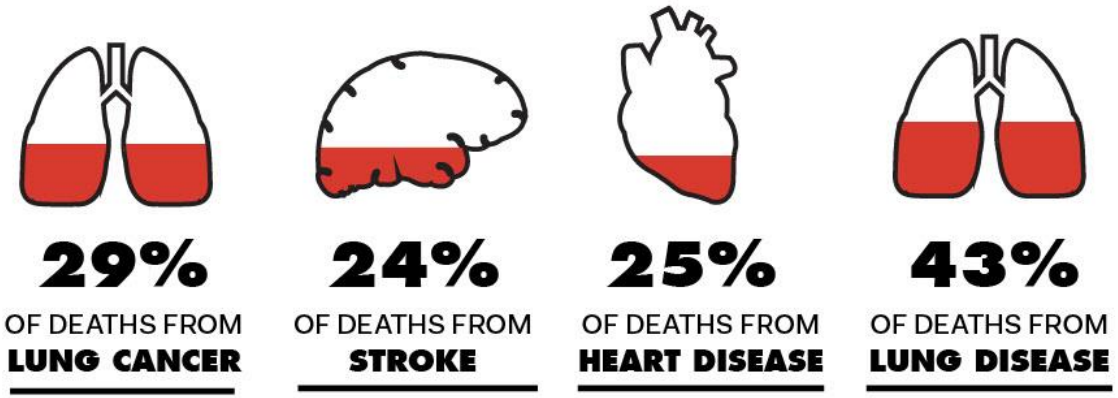
Exposure to air pollution has an impact on different parts of the body, at every stage of life.



Source: https://www.bma.org.uk/collective-voice/policy-and-research/public-and-population-health/climate-change

BMA

07-12-2022



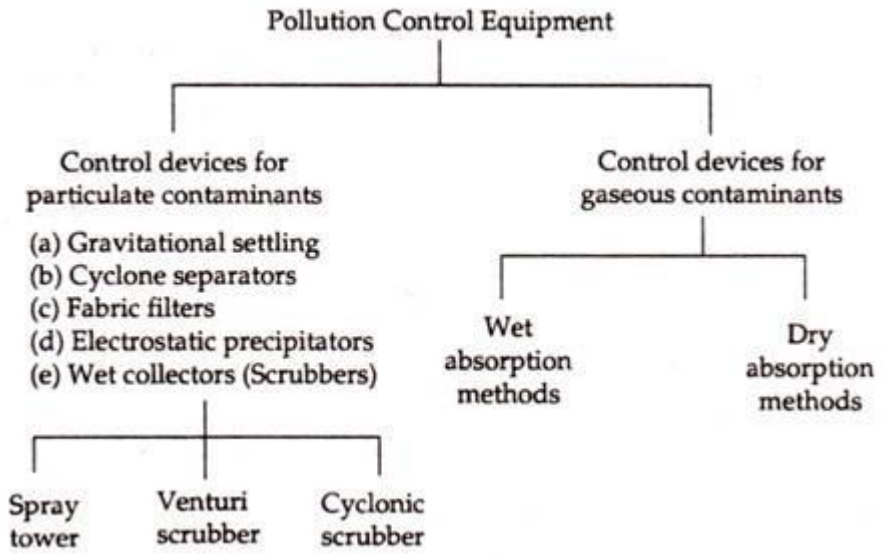
Air pollution increases the risk

Control measures for air pollution

Some of the effective methods to Control Air Pollution are as follows:

(a) Source Correction Methods (b) Pollution Control equipment (c) Diffusion of pollutant in air

(d) Vegetation (e) Zoning.

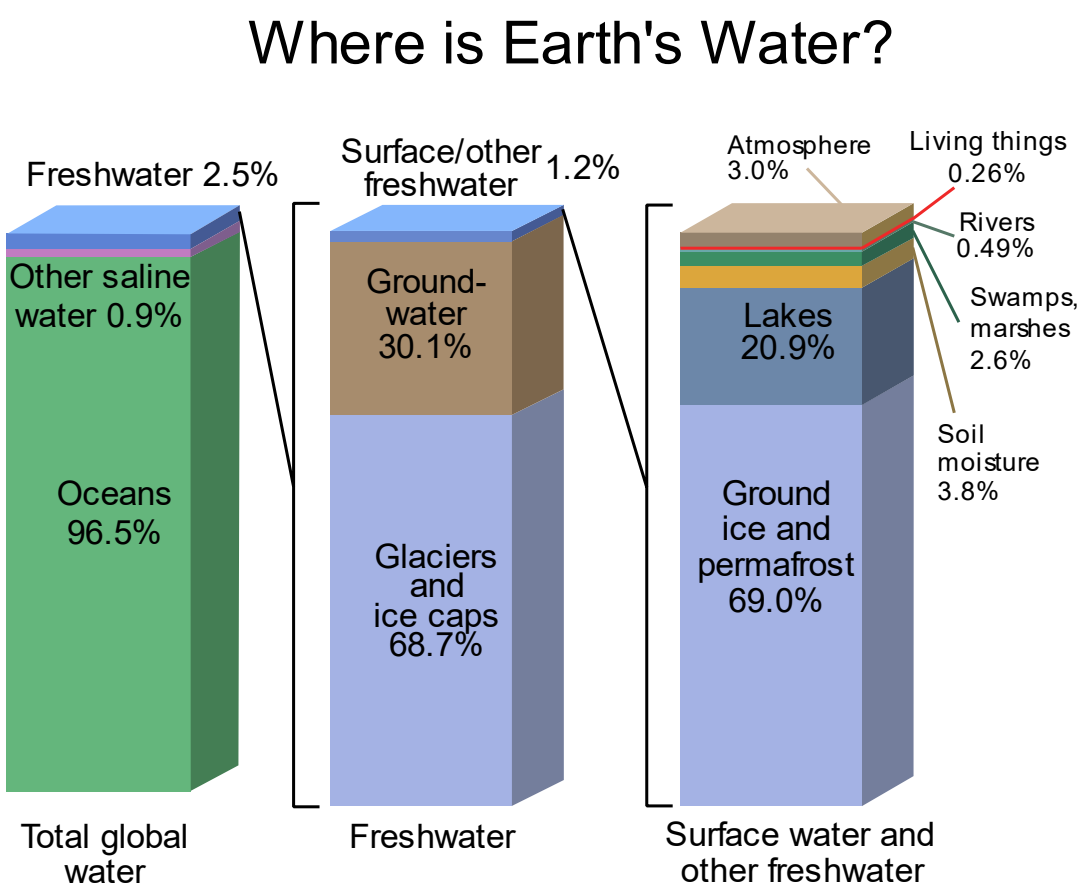


Legal aspects of air pollution control in India

- The Air (Prevention and Control of Pollution) Act was legislated in 1981.
- The Act provided for prevention, control and abatement of air pollution. In areas notified under this Act no industrial pollution causing activity could come up without the permission of the concerned State Pollution Control Board. But this Act was not strong enough to play a precautionary or a corrective role.
- After the Bhopal disaster, a more comprehensive Environment Protection Act (EPA) was passed in 1986. This Act for the first time conferred enforcement agencies with necessary punitive powers to restrict any activity that can harm the environment.

WATER POLLUTION

Water availability on the planet



Water found in streams, rivers, lakes, wetlands and artificial reservoirs is called Surface water.

Water that percolates into the grounds and fills the pores in soil and rock is called Ground water.

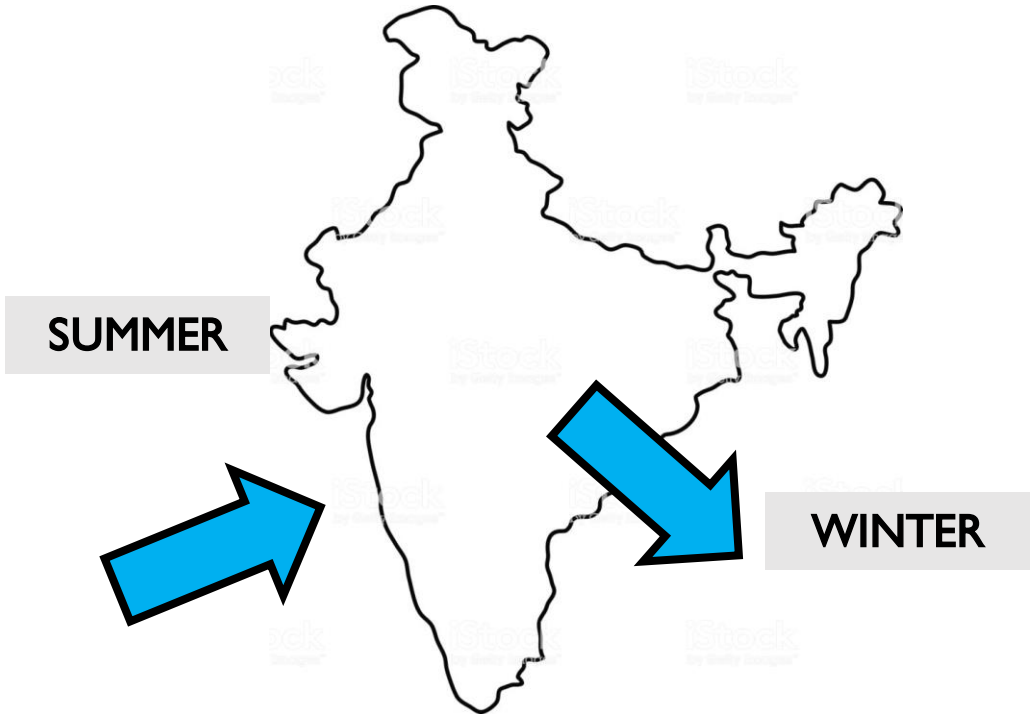
Porous water-saturated layers of sand, gravel or bed rock through ground water flows are called Aquifers.

Most Aquifers are replenished by Rainfall – Natural recharge

Water availability in India

India receives most of her rainfall during the months of June to September due to seasonal winds and temperature differences between the land and sea.

When the quality or composition of water changes directly or indirectly as a result of human activities such as that it becomes unfit for any purpose it is said to be **polluted**.



Sources of pollution

- **Point Source** – when a pollution source can be readily identified because it has a definite source and place where it enters the water it is said to come from a point source; example municipal discharge and industrial discharge pipes.

- **Non-point source** – When a source of a pollution cannot be readily identified, such as agricultural run-off or acid rain, they are said to be non-point sources or diffused sources of pollution.

Causes of water pollution

- Disease causing agents (Pathogens)
- Oxygen depleting waste
- Inorganic plant nutrients
- Water-soluble inorganic chemicals
- Organic chemicals
- Sediment of suspended matter
- Water-soluble radioactive isotopes, and
- Hot water released by power plants and industries

Ground water pollution

Or

Surface water pollution

Disease causing agents (Pathogens)

Untreated human and animal wastes → domestic sewage (un-treated) - mix with water source

↓

Bacteria, viruses, protozoa and parasitic worms

↓

Escherichia coli and Streptococcus faecalis } large intestine of humans

↓

↓ Not harmful

↑ Harmful } Water – borne diseases

Oxygen depleting waste

Organic wastes →  → Decomposed by aerobic (oxygen requiring) bacteria.

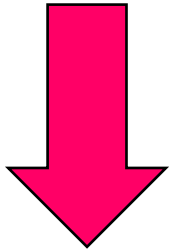
Water source

Aerobic bacteria consumes oxygen to degrade → Organic wastes  ↓ Oxygen consumed in this process from water source

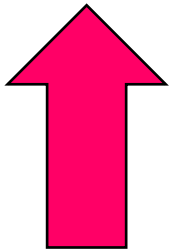
↓

Amount required = biological oxygen demand (BOD)

Indicator of pollution

Less or more pollution

No foul smell and aquatic organisms thrives

Foul smell and aquatic organisms dies

Observe the colour of the water

Inorganic plant nutrients

Water soluble nitrates and phosphates → excessive growth of algae and other aquatic plants

↓

Eutrophication

They may interfere with the use of the water by clogging water intake pipes, changing the taste and odour of water and cause a buildup of organic matter.

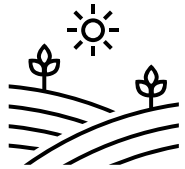
As the organic matter decays, oxygen levels decrease, and fish and other aquatic species die.

Water-soluble Inorganic chemicals

These are acids, salts and compounds of toxic metals such as mercury and lead.

High levels of these chemicals can make the water unfit to drink, harm fish and other aquatic life, reduce crop yields and accelerate corrosion of equipment that use this water.

Sediment of suspended matter



Soil erosion → Insoluble particles of soil and other solids → Reaches water source

Suspended particles in water – suspended particles

High levels of soil particles suspended in water, interferes with the penetration of sunlight.

This reduces the photosynthetic activity of aquatic plants and algae disrupting the ecological balance of the aquatic bodies.

When the velocity of water in streams and rivers decreases the suspended particles settle down at the bottom as sediments. Excessive sediments that settle down destroys feeding and spawning grounds of fish, clogs and fills lakes, artificial reservoirs etc.

Water-soluble radioactive isotopes

Radioactive material – Industry, medical and scientific purpose - nuclear waste

These can be concentrated in various tissues and organs as they pass through food chains and food webs.

Ionizing radiation emitted by such isotopes can cause birth defects, cancer and genetic damage.

Hot water released by power plants and industries

Hot water let out by power plants and industries that use large volumes of water to cool the plant result in rise in temperature of the local water bodies.

Thermal pollution occurs when industry returns the heated water to a water source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity.

For efficient functioning of the steam turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to absorb the heat.

This heated water, which is at least 15°C higher than the normal is discharged back into the water body.

The warm water not only decreases the solubility of oxygen but changes the breeding cycles of various aquatic organisms.

Organic chemicals

Another cause of water pollution is a variety of organic chemicals, which include oil, gasoline, plastics, pesticides, cleaning solvents, detergent and many other chemicals.

These are harmful to aquatic life and human health.

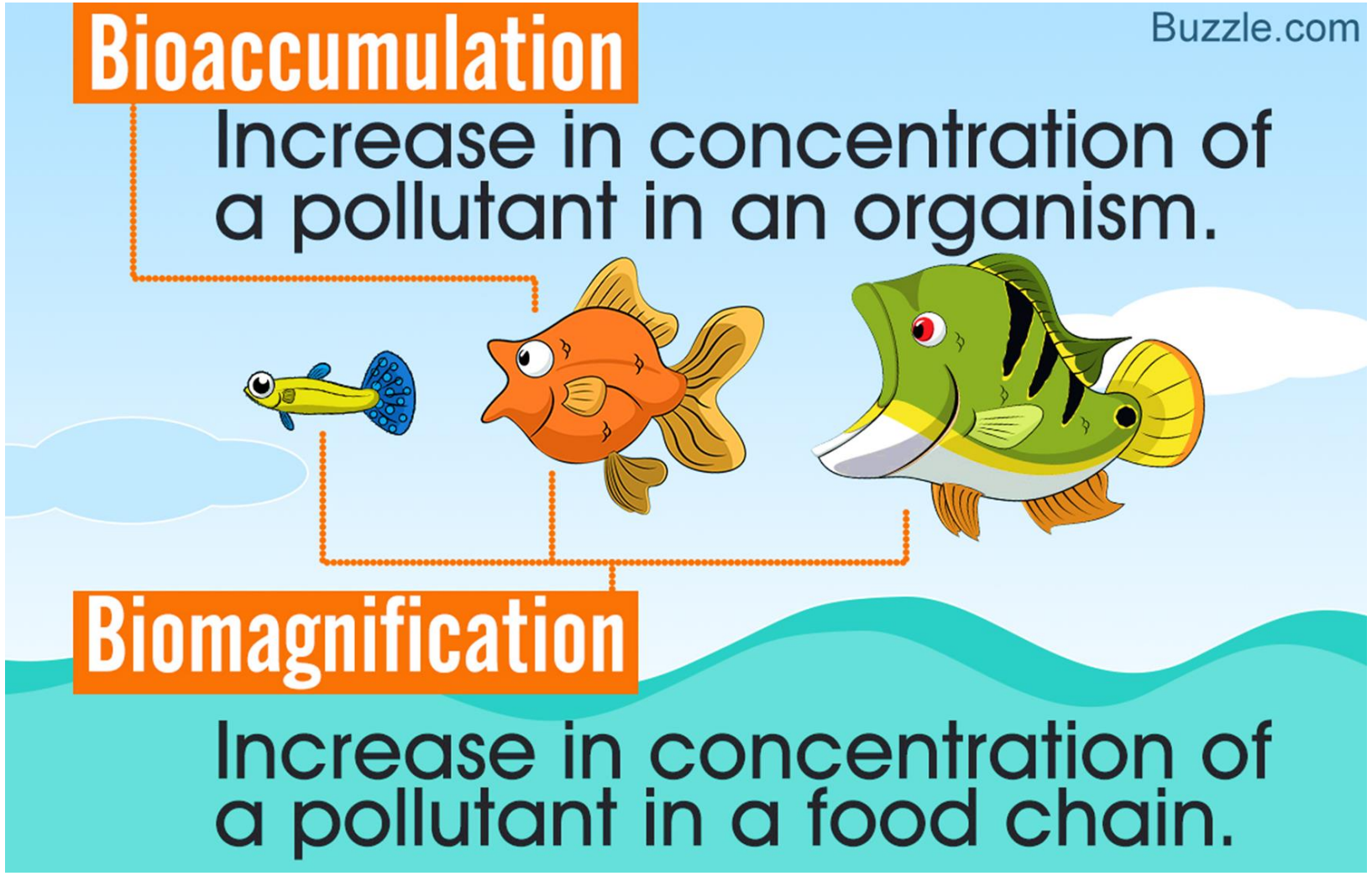
They get into the water directly from industrial activity either from improper handling of the chemicals in industries and more often from improper and illegal disposal of chemical wastes.

Examples: pesticides

Effects of DDT

Birds lay eggs with much thinner shells. This results in premature breaking of these eggs, killing the immature chicks inside.

DDT - Banned in India



Source: Buzzle.com

Groundwater pollution

Urban run-off of untreated or poorly treated waste-water and garbage

Industrial waste storage located above or near aquifers

Agricultural practices such as the application of large amounts of fertilizers and pesticides, animal feeding operations, etc. in the rural sector

Leakage from underground storage tanks containing gasoline and other hazardous substances

Leachate from landfills

Poorly designed and inadequately maintained septic tanks

Mining wastes

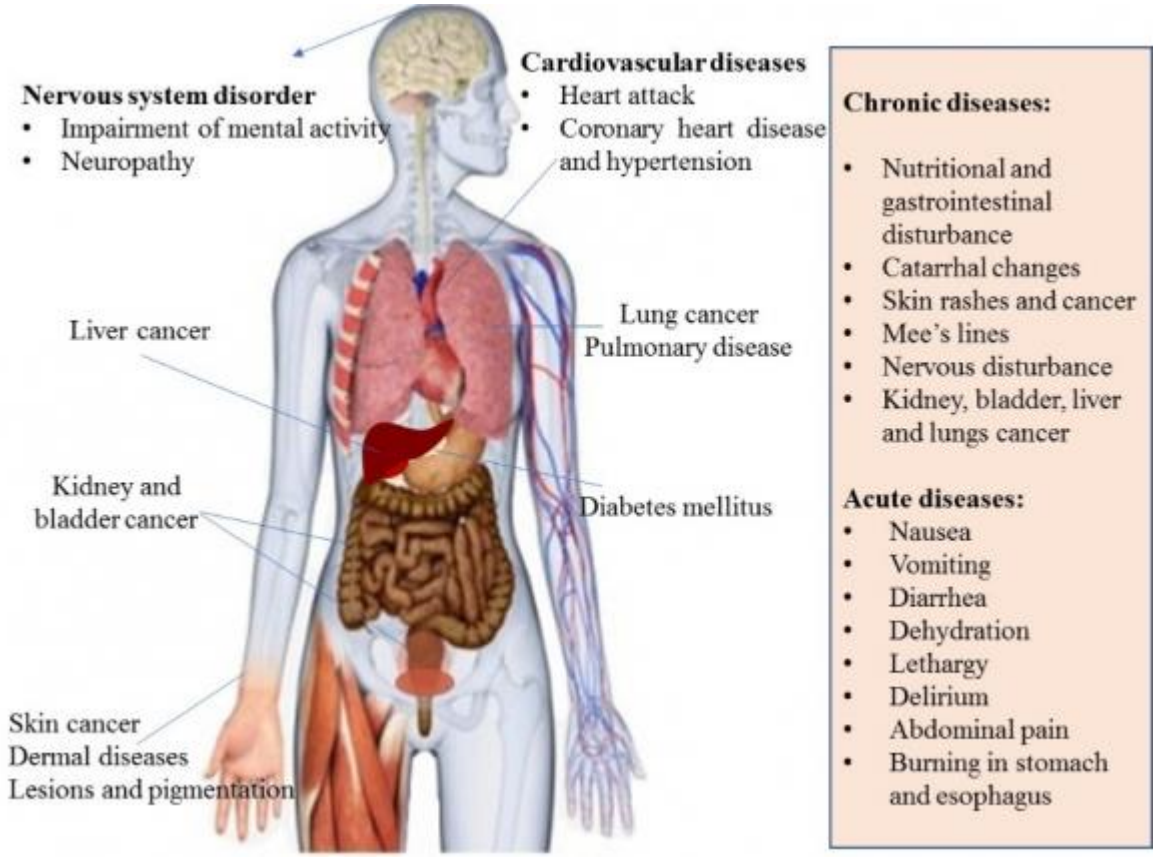
Case study

Arsenic poisoning – West Bengal

Arsenicosis or Arsenic toxicity – 2 to 5 years of drinking Arsenic contaminated water.

Natural

High rate of ground water extraction



The state of India's river

1985 – Ganga Action Plan (GAP)

Phase II – 1991 – Cleaning operations of tributaries of Ganga, Yamuna, Gomti, and Damodar

Yamuna Action Plan (YAP), Gomti Action Plan and Damodar Action Plan (DAP)

1995 – National River Conservation Plan (NRCP) – Cleaning up of Rivers – Tap drains – Divert sewage to treatment plants.

772.08 Crores – 18 rivers in 10 States and 46 towns – MOEF bore this cost.

National Ganga River Basin Authority (NGRBA) – 2009 – Making Ganga pollution free by 2020 – 15000 Crores

Control measures of water pollution?

Control of pollution at source

Water/wastewater treatment

Wastewater treatment

What is marine pollution?

Marine pollution can be defined as the introduction of substances to the marine environment directly or indirectly by man resulting in adverse effects such as hazards to human health, obstruction of marine activities and lowering the quality of sea water

Causes for marine water pollution

1. Discharge through pipes – domestic sewage
2. Pesticides and fertilizers from agriculture
3. Petroleum and oils washed off from the roads

Sewage → Treated

4. Ship accidents and accidental spillages
5. Offshore oil exploration and extraction also pollute – BP oil spill

Image source: https://interviewtimes.net/oil-spill-all-you-need-to-know/
http://blogs.nature.com/news/2011/03/counting_corpses_underestimate.html

Oil mixed sewage → (sewer) → Sewage treatment plant

Process?

1. Discharge through pipes – domestic sewage
2. Pesticides and fertilizers from agriculture
3. Petroleum and oils washed off from the roads
4. Others

Wastewater treatment process

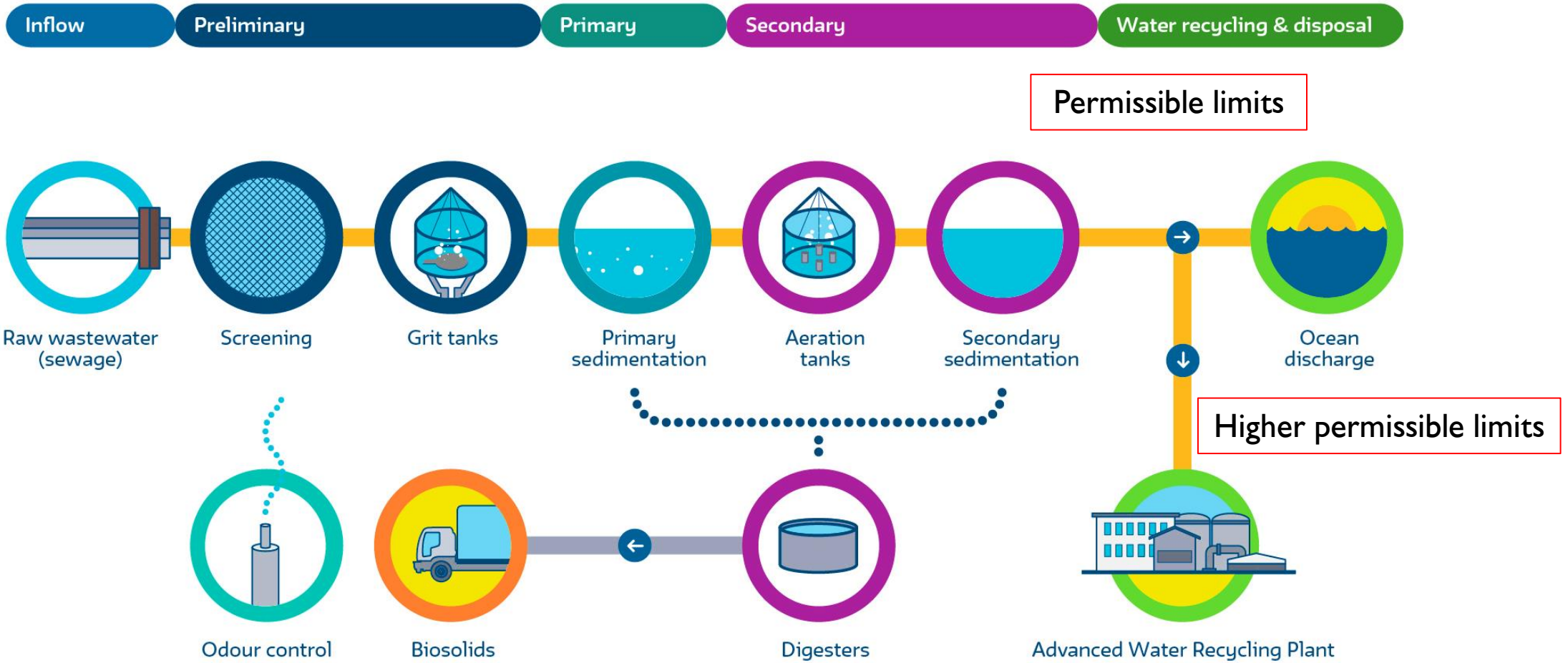
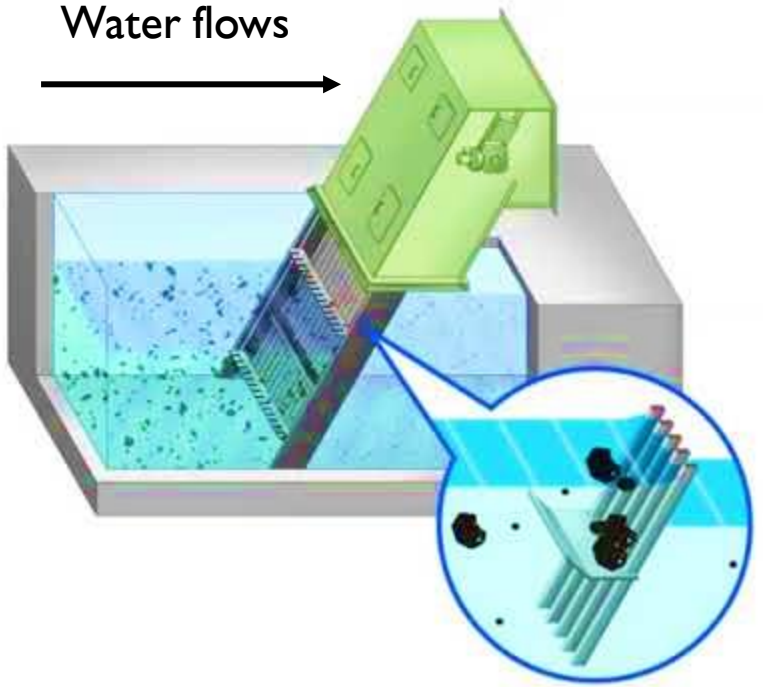


Image source: https://www.watercorporation.com.au/Our-water/Wastewater/How-wastewater-is-treated

Screening

Primary treatment – These treatment plants use physical processes such as screening and sedimentation to remove pollutants that will settle, float or, that are too large to pass through simple screening devices.

A screen consists of parallel bars spaced 2 to 7cms apart followed by a wire mesh with smaller openings.



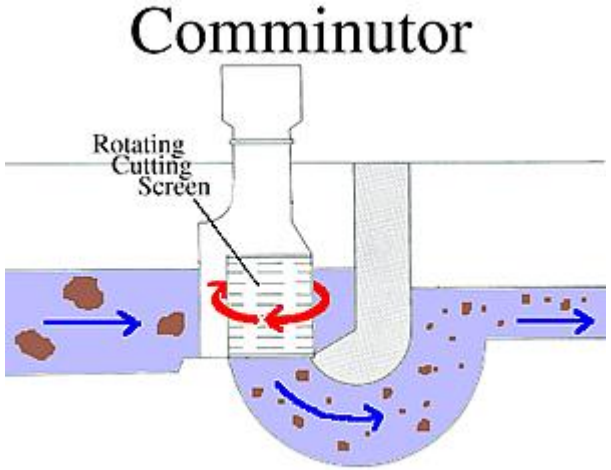
Source: https://www.youtube.com/watch?v=luQ2-A5NOMA

Screen size can vary depending on the particle size to be filtered out from coarse to fine screen

Comminutor

Disposal problem can be overcome by comminutor.

Grinds the coarse material into small pieces that can then be left in the wastewater



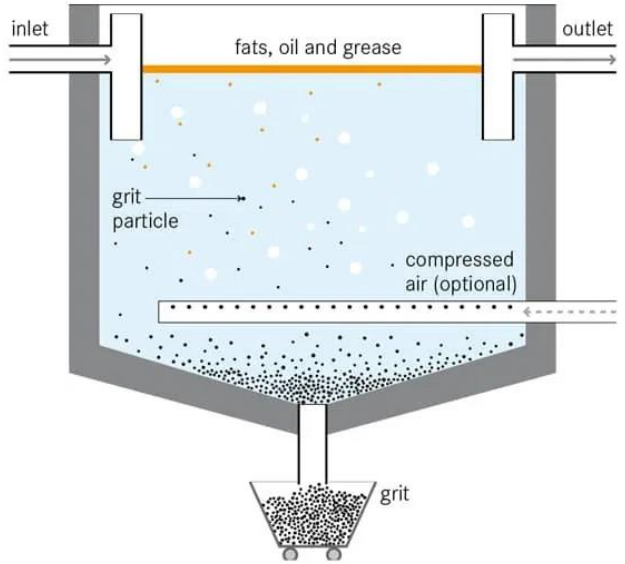
Source: https://water.mecc.edu/courses/ENV295WWII/lesson2.htm

Optional in the treatment process

Grit chamber

After screening the wastewater passes into a grit chamber.

The detention time is chosen to be long enough to allow inorganic material to settle.



Source: https://theconstructor.org/water-resources/grit-chamber-type-working-advantages/36098/

Protection of mechanical equipment, prevent from clogging of pipe lines

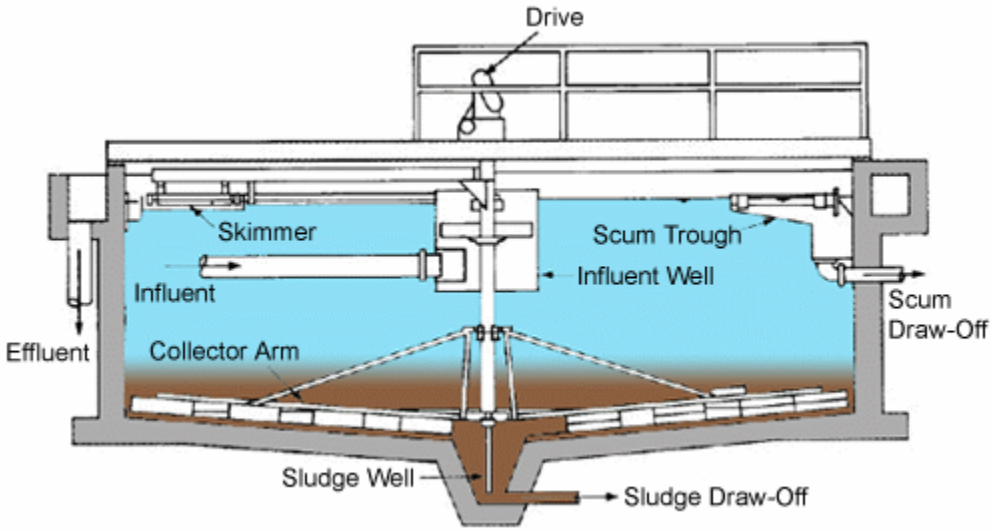
Primary sedimentation tank

From the grit chamber the sewage passes into a primary settling tank (also called as sedimentation tank)

The flow speed is reduced sufficiently to allow most of the suspended solids to settle out by gravity.

Only primary treatment - chlorinated to destroy bacteria and control odours after which the effluent is released.

Primary treatment normally removes about 35 percent of the BOD and 60 percent of the suspended solids.



Source: https://testmyprep.com/subject/commodity-studies/the-basic-technological-schemes-of-sewage

Secondary treatment

The main objective of secondary treatment is to remove most of the BOD.

There are three commonly used approaches:

- Trickling filters
- Activated sludge process and
- Oxidation ponds.

Secondary treatment can remove at least 85 percent of the BOD

Trickling filters

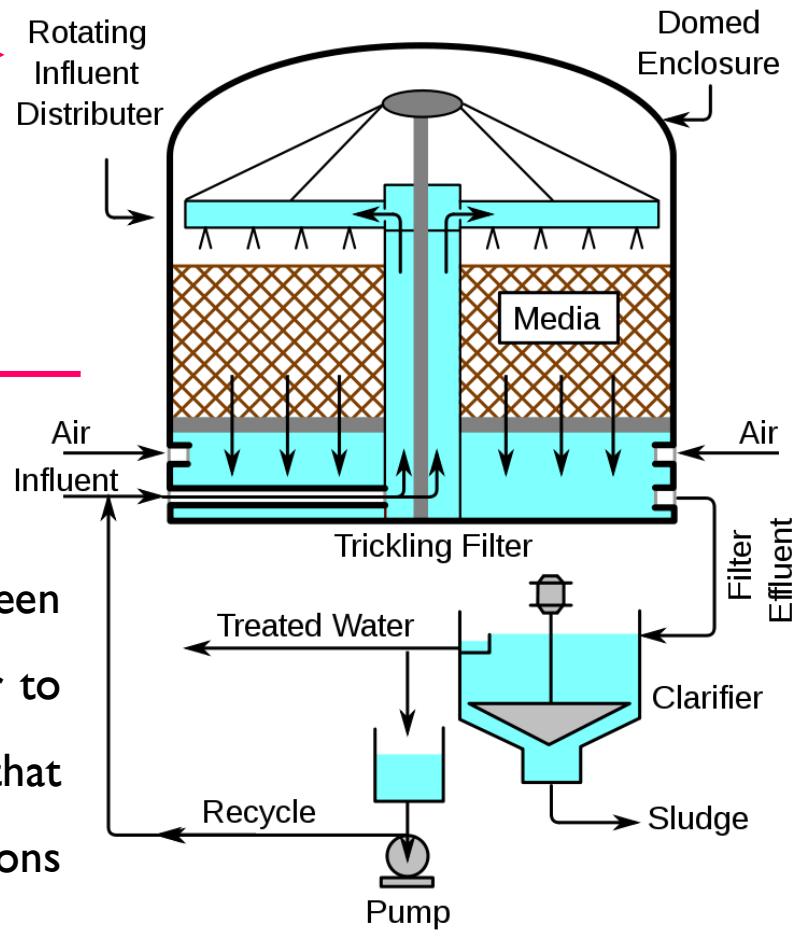
The spaces between the rocks allow air to circulate easily so that aerobic conditions can be maintained.

The **individual rocks** in the bed are covered **with a layer of slime**, which consists of bacteria, fungi, algae, etc. which degrade the waste trickling through the bed.

This slime periodically slides off individual rocks and is collected at the bottom of the filter along with the treated wastewater and is then passed on to the secondary settling tank where it is removed.

Trickling filters

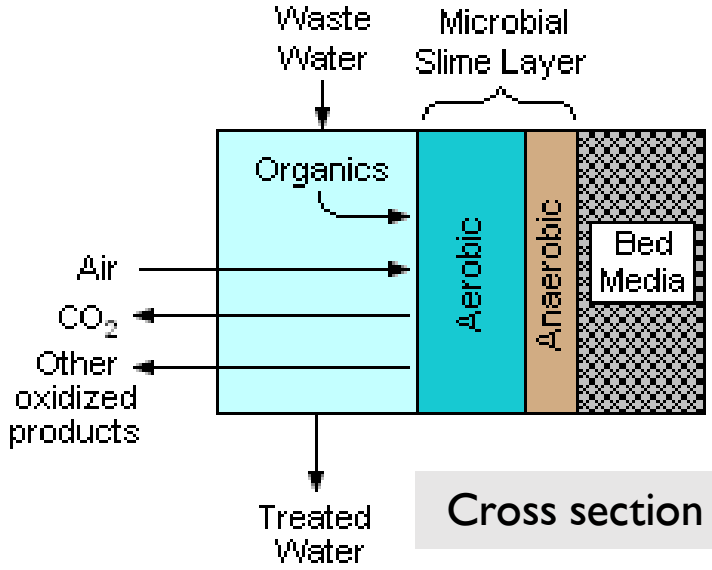
Rotating distribution arm that sprays liquid wastewater over a circular bed of 'fist size' rocks or other coarse materials.



The spaces between the rocks allow air to circulate easily so that aerobic conditions can be maintained.

Source: https://en.wikipedia.org/wiki/Trickling_filter

Bacteria, fungi, algae, etc. which degrade the waste trickling through the bed.



Cross section view of TF

This slime periodically slides off individual rocks and is collected at the bottom of the filter along with the treated wastewater and is then passed on to the secondary settling tank where it is removed.

Activated sludge process

The sewage is pumped into a large tank and mixed for several hours with bacteria rich sludge and air bubbles to facilitate degradation by micro-organisms.

The water then goes into a sedimentation tank where most of the microorganisms settle out as sludge.

This sludge is then broken down in an anaerobic digester where methane-forming bacteria slowly convert the organic matter into carbon dioxide, methane and other stable end products.

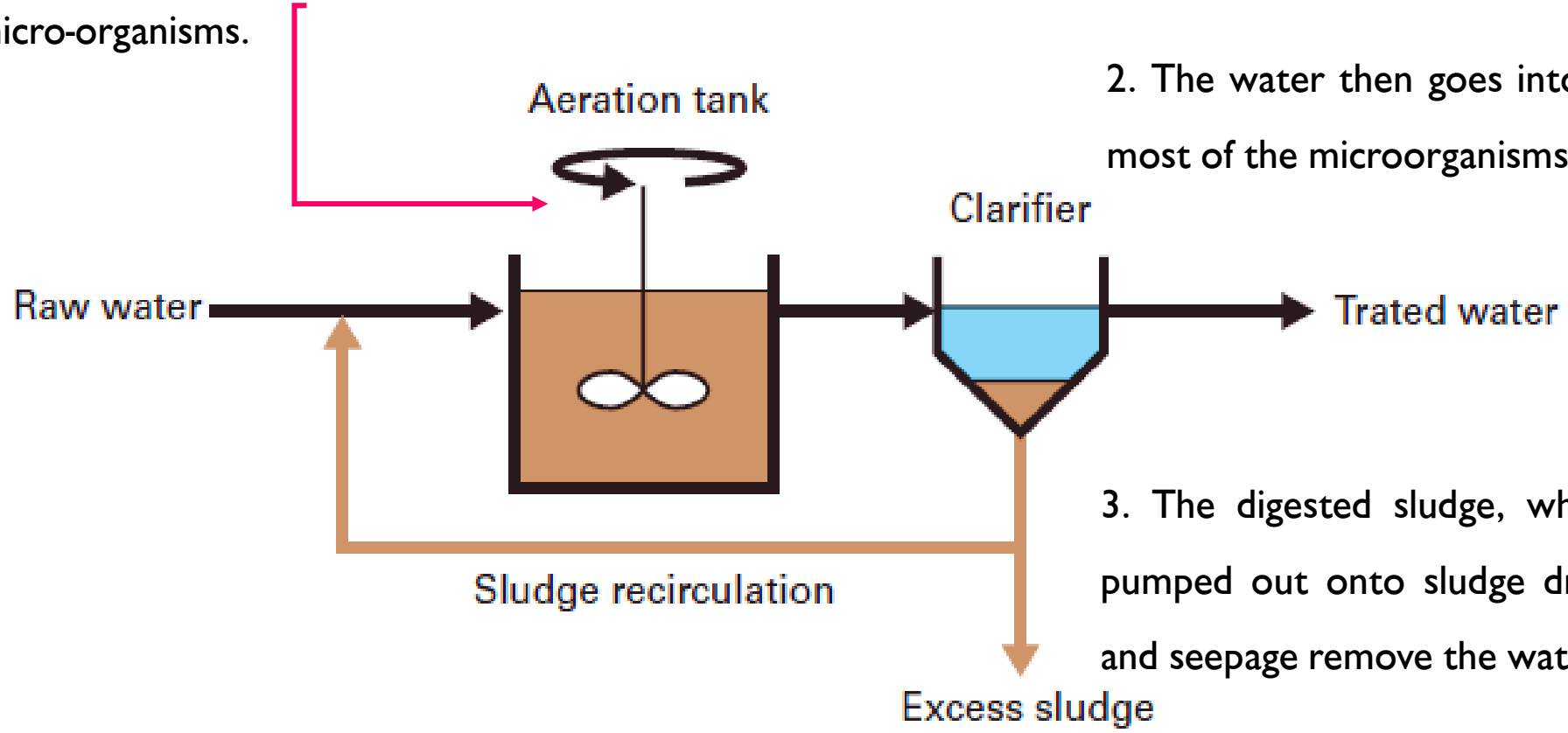
The gas produced in the digester is 60 percent methane, which is a valuable fuel

and can be put to many uses within the treatment plant itself.

The digested sludge, which is still liquid, is normally pumped out onto sludge drying beds where evaporation and seepage remove the water.

Activated sludge process

1. The sewage is pumped into a large tank and mixed for several hours with bacteria rich sludge and air bubbles to facilitate degradation by micro-organisms.



2. The water then goes into a sedimentation tank where most of the microorganisms settle out as sludge.

3. The digested sludge, which is still liquid, is normally pumped out onto sludge drying beds where evaporation and seepage remove the water.

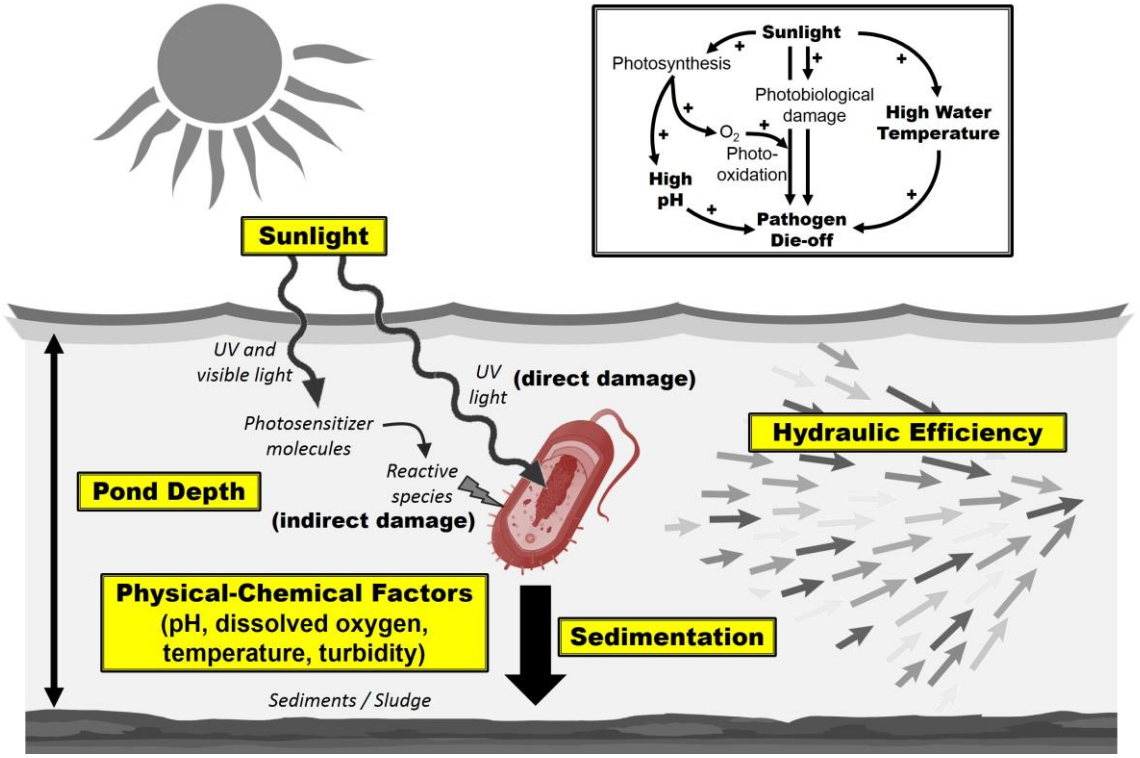
Source: https://www.suezwaterhandbook.com/processes-and-technologies/

Oxidation ponds

Large shallow ponds approximately 1 to 2 metres deep where raw or partially treated sewage is decomposed by microorganisms.

They are easy to build and manage and accommodate large fluctuations in flow and can provide treatment at a much lower cost.

They however require a large amount of land and hence can be used where land is not a limitation.



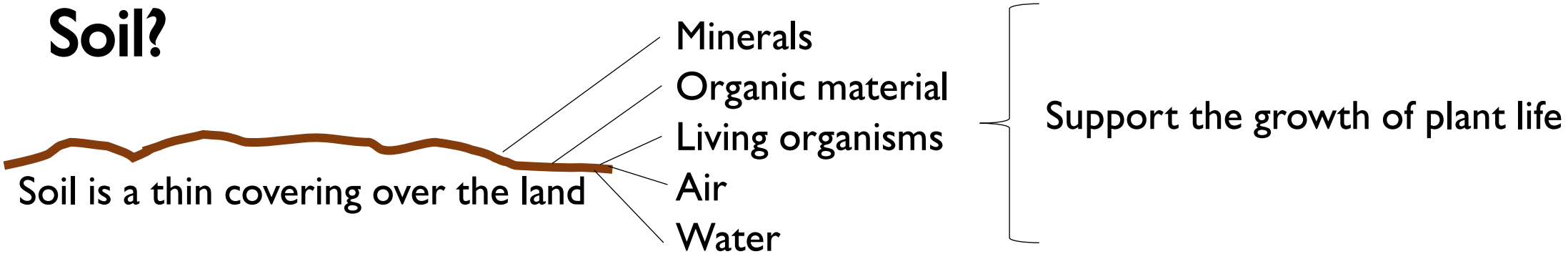
Source: https://www.waterpathogens.org/book/waste-stabilization-ponds

Advanced sewage treatment - This involves a series of chemical and physical process that removes specific pollutants left in the water after primary and secondary treatment.

Level of treatment depends of degree of water pollution

Soil Pollution

Soil?



Several factors contribute to the formation of soil from the parent material.

This includes mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichens. Climate and time are also important in the development of soils.

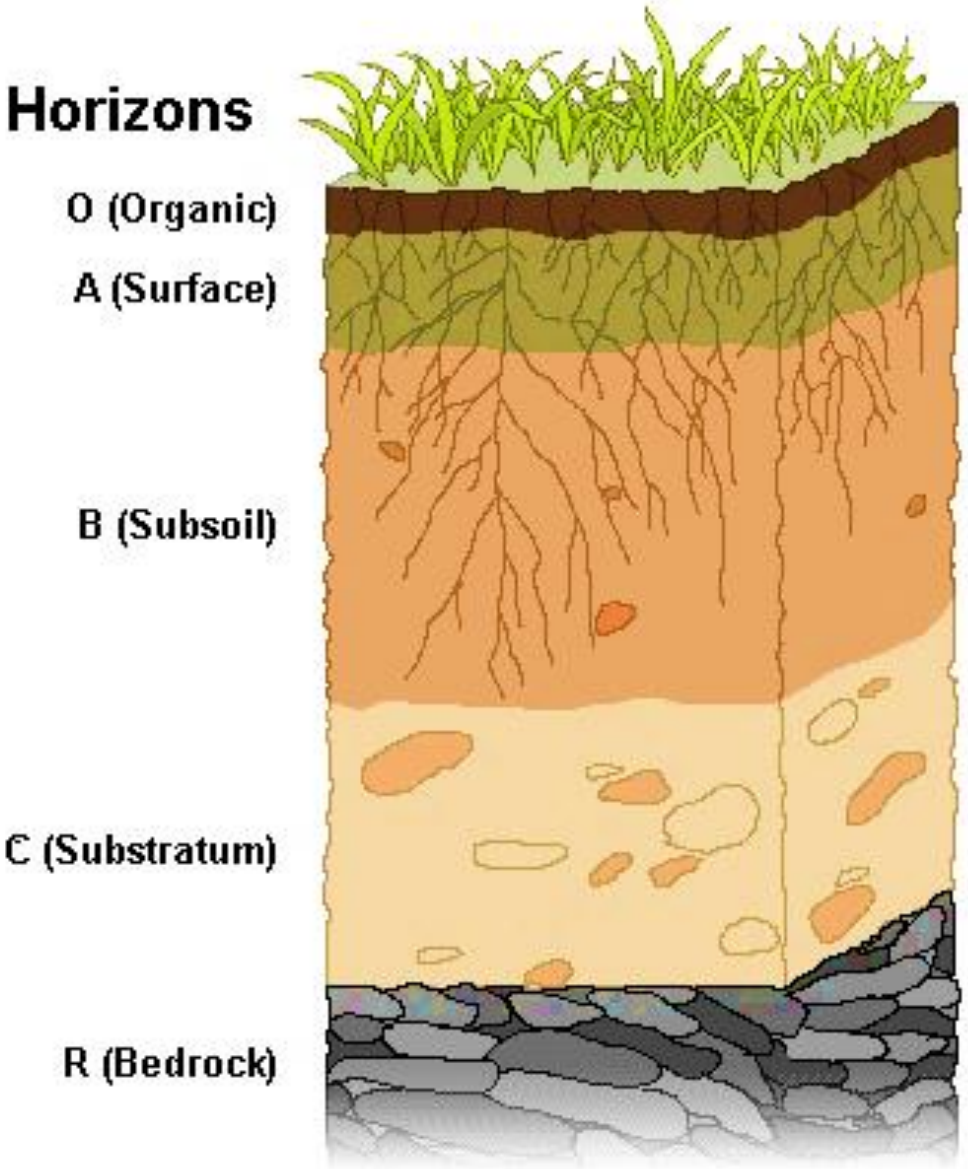
Extremely dry or cold climates **develop soils very slowly**

Humid and warm climates **develop them more rapidly**

Under ideal climatic conditions soft parent material may develop into a centimeter of soil within 15 years. Under poor climatic conditions a hard parent material may require hundreds of years to develop into soil.

Mature soils are arranged in a series of zones called soil horizons. Each horizon has a distinct texture and composition that varies with different types of soils.

A cross sectional view of the horizons in a soil is called a soil profile.



Source: https://en.wikipedia.org/wiki/Soil_horizon

O horizon consists mostly of freshly fallen and partially decomposed leaves, twigs, animal waste, fungi and other organic materials. Normally it is brown or black.

The uppermost layer of the soil called the A horizon consists of partially decomposed organic matter (humus) and some inorganic mineral particles. It is usually darker and looser than the deeper layers.

The B horizon often called the subsoil contains less organic material and fewer organisms than the A horizon.

The area below the subsoil is called the C horizon and consists of weathered parent material. This parent material does not contain any organic materials. The chemical composition of the C-horizon helps to determine the pH of the soil and also influences the soil's rate of water absorption and retention.

Soils vary in their content of clay (very fine particles), silt (fine particles), sand (medium size particles) and gravel (coarse to very coarse particles).

The relative amounts of the different sizes and types of mineral particles determine soil texture.

Soils with approximately equal mixtures of clay, sand, silt and humus are called loams.

Image source: https://www.corfestone.com/grit-sand/

Causes of soil pollution

1. Soil degradation
2. Excess use of fertilizers
3. Excess salts and water

Reasons and treatment methods

Causes of soil degradation

Erosion

Soil erosion can be defined as the movement of surface litter and topsoil from one place to another. While erosion is a natural process often caused by wind and flowing water it is greatly accelerated by human activities such as farming, construction, overgrazing by livestock, burning of grass cover and deforestation.

Loss of the topsoil makes a soil less fertile and reduces its water holding capacity. The topsoil, which is washed away, also contributes to water pollution clogging lakes, increasing turbidity of the water and also leads to loss of aquatic life. For one inch of topsoil to be formed it normally requires 200-1000 years depending upon the climate and soil type.

Thus if the topsoil erodes faster than it is formed the soil becomes a non-renewable resource.

Treatment methods

There are several techniques that can protect soil from erosion. Today both water and soil are conserved through integrated treatment methods. Some of the most commonly employed methods include the two types of treatment that are generally used.

- Area treatment which involves treating the land
- Drainage line treatment which involves treating the natural water courses (nalas)

Area Treatment

Purpose	Treatment Measure	Effect
Reduces the impact of rain drops on the soil	Develop vegetative cover on the non arable land	Minimum disturbance and displacement of soil particles
Infiltration of water where it falls	Apply water infiltration measures on the area	In situ soil and moisture conservation
Minimum surface run off	Store surplus rain water by constructing bunds, ponds in the area	Increased soil moisture in the area, facilitate ground water recharge
Ridge to valley sequencing	Treat the upper catchment first and then proceed towards the outlet	Economically viable, less risk of damage and longer life of structures of the lower catchments

Drainage line treatment

Purpose	Treatment measure	Effect
Stop further deepening of gullies and retain sediment run-off	Plug the gullies at formation	Stops erosion, recharges groundwater at the upper level.
Reduce run-off velocity, pass cleaner water to the downstream side	Crate temporary barriers in nalas	Delayed flow and increased groundwater recharge
Minimum sedimentation in the storage basins	Use various methods to treat the catchments	
Low construction cost	Use local material and skills for constructing the structures	Structures are locally maintained

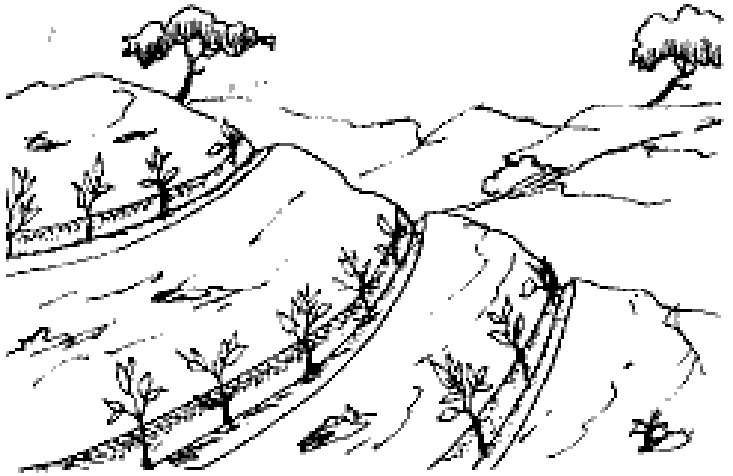
Continuous contour trenches can be used to enhance infiltration of water reduce the runoff and check soil erosion.

These are actually shallow trenches dug across the slope of the land and along the contour lines basically for the purpose of soil and water conservation.

They are most effective on gentle slopes and in areas of low to medium rainfall.

These bunds are stabilized by fast growing tree species and grasses.

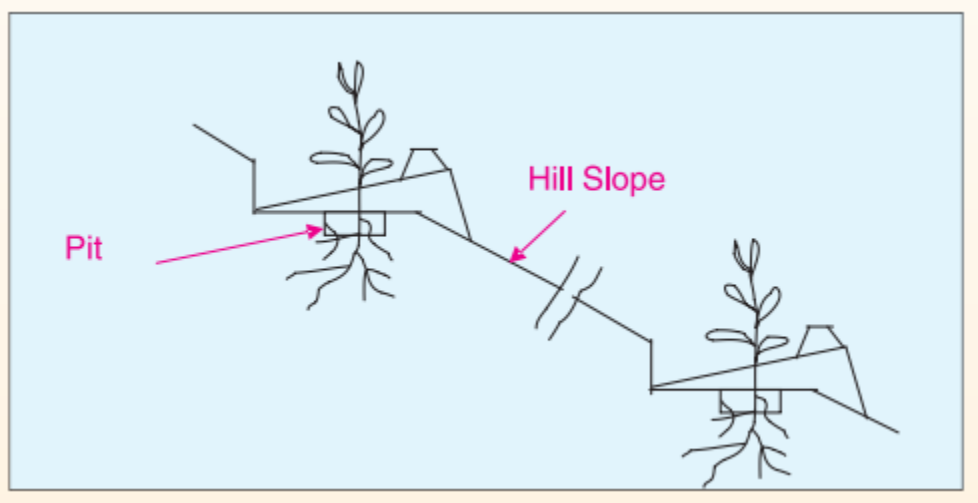
In areas of steep slopes where the bunds are not possible, continuous contour benches (CCBs) made of stones are used for the same purpose.



Continuous Trenches

Gradonies can also be used to convert wastelands into agricultural lands.

In this narrow trenches with bunds on the downstream side are built along contours in the upper reaches of the catchment to collect run-off and to conserve moisture from the trees or tree crops.



The area between the two bunds is use for cultivation of crops after development of fertile soil cover.

Live check dams which barriers created by planting grass, shrubs and trees across the gullies can be used for this purpose.

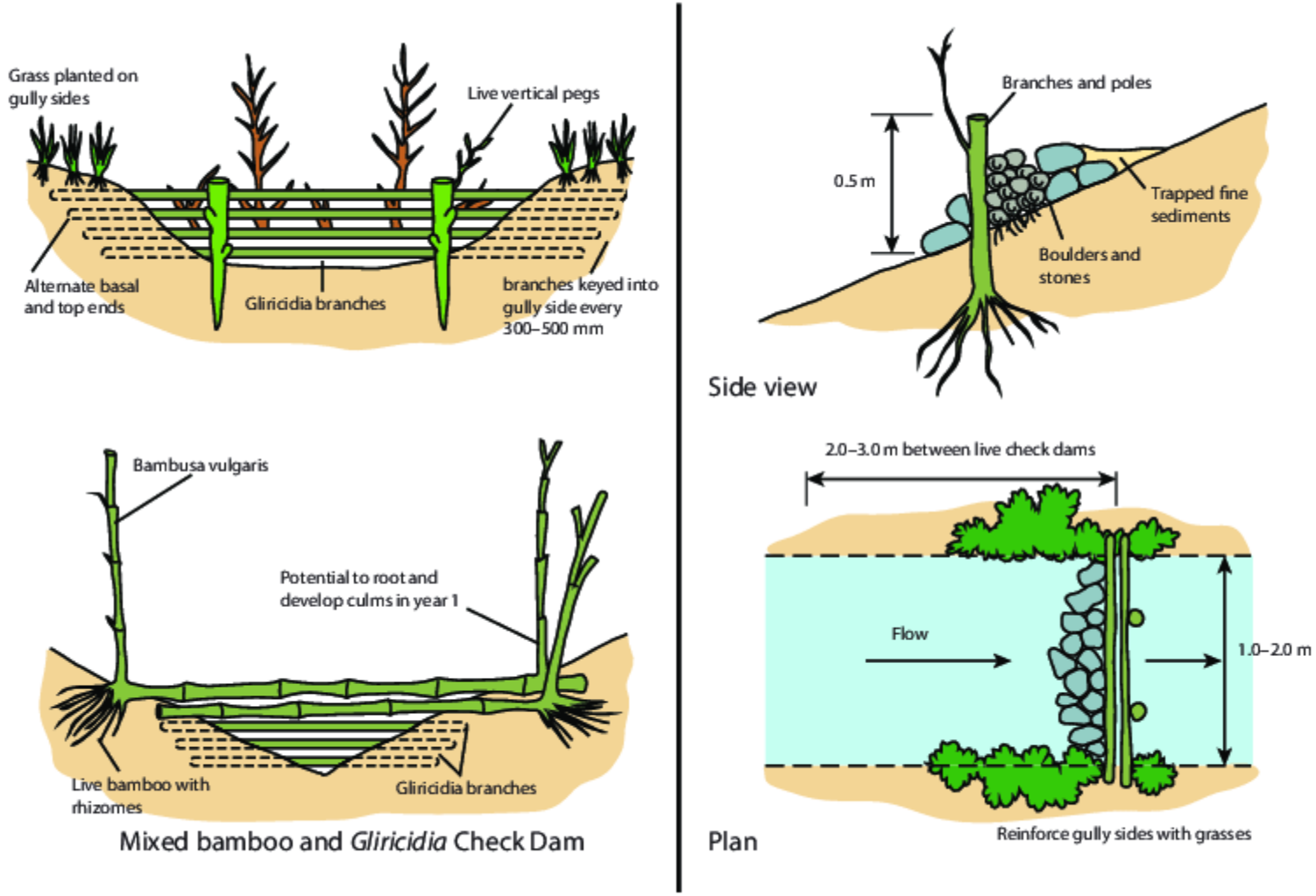


Image source: Live mini check dam (Clark and Hellin,1996).

A **bund constructed out of stones** across the stream can also be used for conserving soil and water.

An Earthen check bund is constructed out of local soil across the stream to check soil erosion and flow of water.

A **Gabion structure** is a bund constructed of stone and wrapped in galvanized chain link.


Gabion structure

A Gabion structure with ferrocement impervious barrier has a one inch thick impervious wall of ferrocement at the center of the structure which goes below the ground level upto the hard strata. This ferrocement partition supported by the gabion portion is able to retain the water and withstand the force of the runoff water.

An Underground bandhara is an underground structure across a nalla bed to function as a barrier to check the ground water movement.

Excess use of fertilizers

Approximately 25 percent of the world's crop yield is estimated to be directly attributed to the use of chemical fertilizers.

- Insecticides are used to control insect populations
- Fungicides are used to control unwanted fungal growth
- Mice and rats are killed by rodenticides
- Plant pests are controlled by herbicides

Problems with pesticide use

Persistent or non-persistent.

Persistent pesticides once applied are effective for a long time. However as they do not break down easily they tend to accumulate in the soil and in the bodies of animals in the food chain.

DDT - Dichlorodiphenyltrichloroethane

The half-life of DDT varies according to the soil type, temperature, kind of soil organisms present and other factors.

Persistent pesticides may also accumulate in the bodies of animals, and over a period of time increase in concentration if the animal is unable to flush them out of its system thus leading to the phenomenon called bioaccumulation.

When an affected animal is eaten by another carnivore these pesticides are further concentrated in the body of the carnivore. This phenomenon of acquiring increasing levels of a substance in the bodies of higher trophic level organisms is known as biomagnification.

Reasons for the use of pesticides

Firstly the use of pesticides in the short term has increased the amount of food that can be grown in many parts of the world as the damage by pests is decreased.

The second reason for its extensive use is base on an economic consideration. The increased yields more than compensates the farmer for cost of pesticides.

Thirdly current health problems especially in developing countries due to mosquitoes are impossible to control without insecticides.

Sustainable agriculture

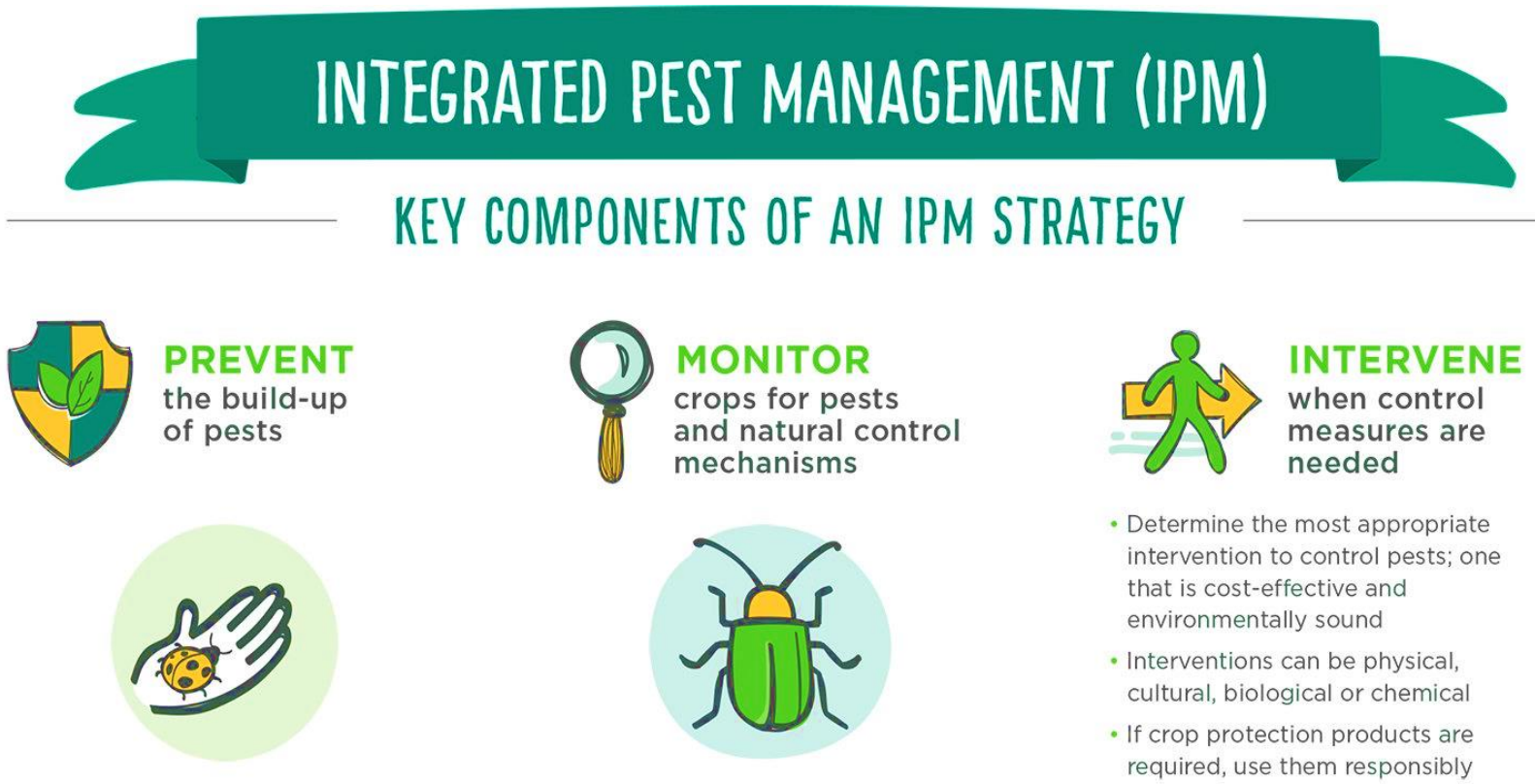


Image source: https://twitter.com/CropLifeIntl/status/986529597457039360/photo/1

Bio-pesticides

Bio-pesticides are derived from three sources,

- Microbial: Microorganisms such as bacteria, fungi, virus or protozoa that fights pests through variety of ways.
- Botanical
- Biochemical: Pesticides contain several chemicals that affect the reproductive and digestive mechanisms of pests.
- Mostly commonly used bio-pesticides are Bacillus thuringiensis (Bt), Neem (Azadirachta indica) and Trichogramma.

Excess salts and water

Irrigated lands produce higher crop yield > Rain water

Dissolved salts

Dry climate - Salinization – Stunt plant growth, lower crop yield, kill the crops

Flushing of salts – Costly – Down stream - saltier

NOISE POLLUTION

Noise may not seem as harmful as the contamination of air or water but it is a pollution problem that affects human health and can contribute to a general deterioration of environmental quality.

Source: https://www.dnaindia.com/analysis/editorial-dna-edit-sounds-of-silence-rules-protecting-mumbai-s-silent-zones-are-more-robust-now-2655611

Noise

Noise: Noise is generally referred to as **unwanted sound** that can negatively disrupt human or animal life.

Subjective and based on individuals

Example: Rock music – Some love it, while others hate it.

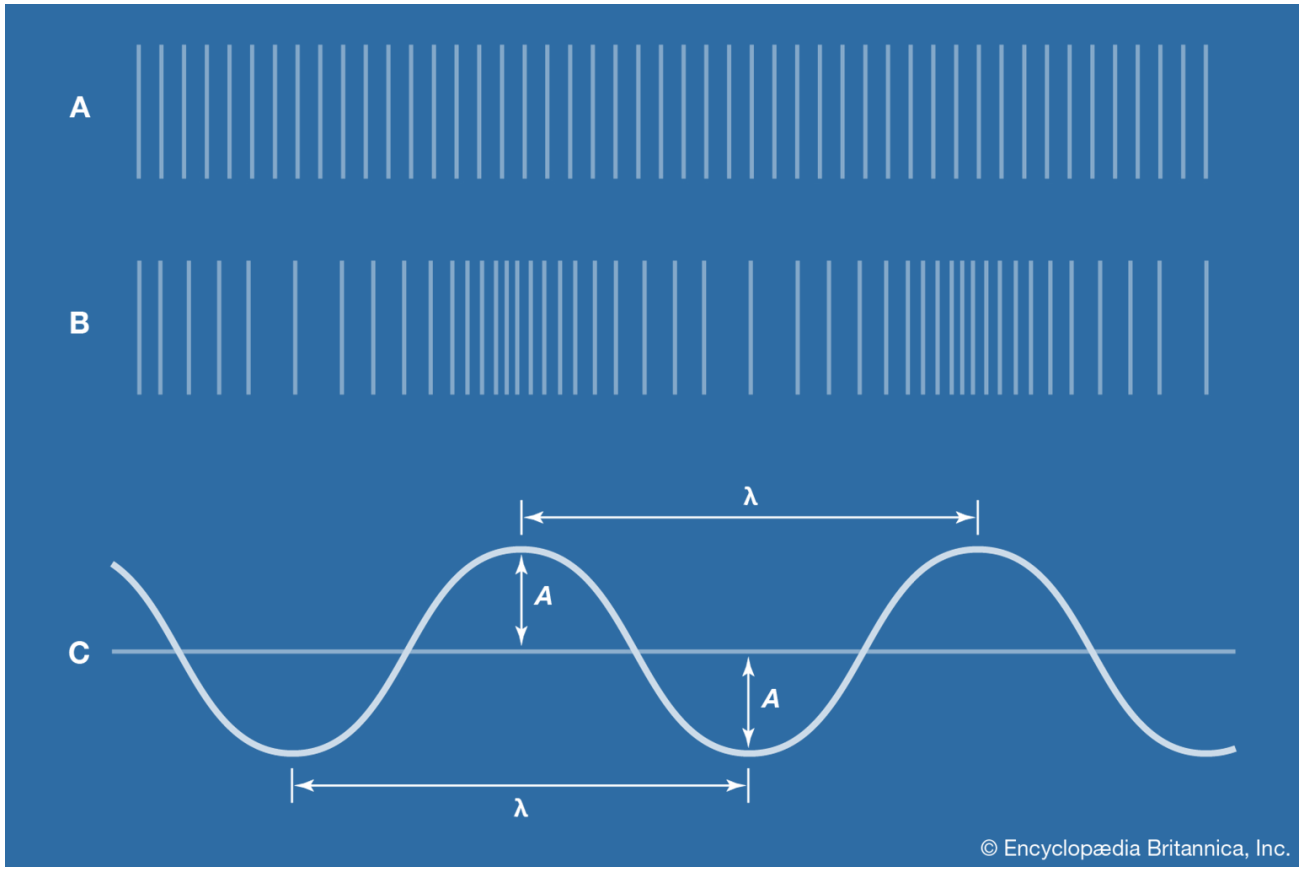
It is sound that is unwanted, inappropriate, interfering, distracting and irritating (Henry, 2013).

NOISE

SOUND

Sound?

Sound is the **result of pressure variations** in a medium – typically air. Pressure fluctuations above and below atmospheric pressure are detected by the human ear and this results in the sensation of hearing.



All sounds have three fundamental characteristics:

1. Frequency,
2. Amplitude and
3. Wavelength.

Decibel

Sound is commonly measured using decibel using the decibel (dB) scale. Decibel is the ratio of one pressure to another. It uses a logarithmic scale and thus reduces a large range of information down into something more manageable – it enables us to deal with very large and very small numbers with some ease.

In terms of environmental noise the sound pressure level, Lp, in decibels is calculated from:

$$Lp = 10 \log_{10} (p/p_0)^2 \text{ [dB]}$$

Where p is the sound pressure being measured and p_0 is the reference sound pressure; 2 $x10_5$ N/m^2 (or 20 μPa). The reference sound pressure corresponds to the lowest sound pressure a healthy human ear can detect at 1000 Hz.

Decibel levels of common sounds

dB	Environmental Condition
0	Threshold of hearing
10	Rustle of leaves
20	Broadcasting studio
30	Bedroom at night
40	Library
50	Quiet office
60	Conversational speech (at 1m)
70	Average radio
74	Light traffic noise
90	Subway train
100	Symphony orchestra
110	Rock band
120	Aircraft takeoff
146	Threshold of pain

Human ear can tolerate noise up to 120 decibels.

Types of noise pollution

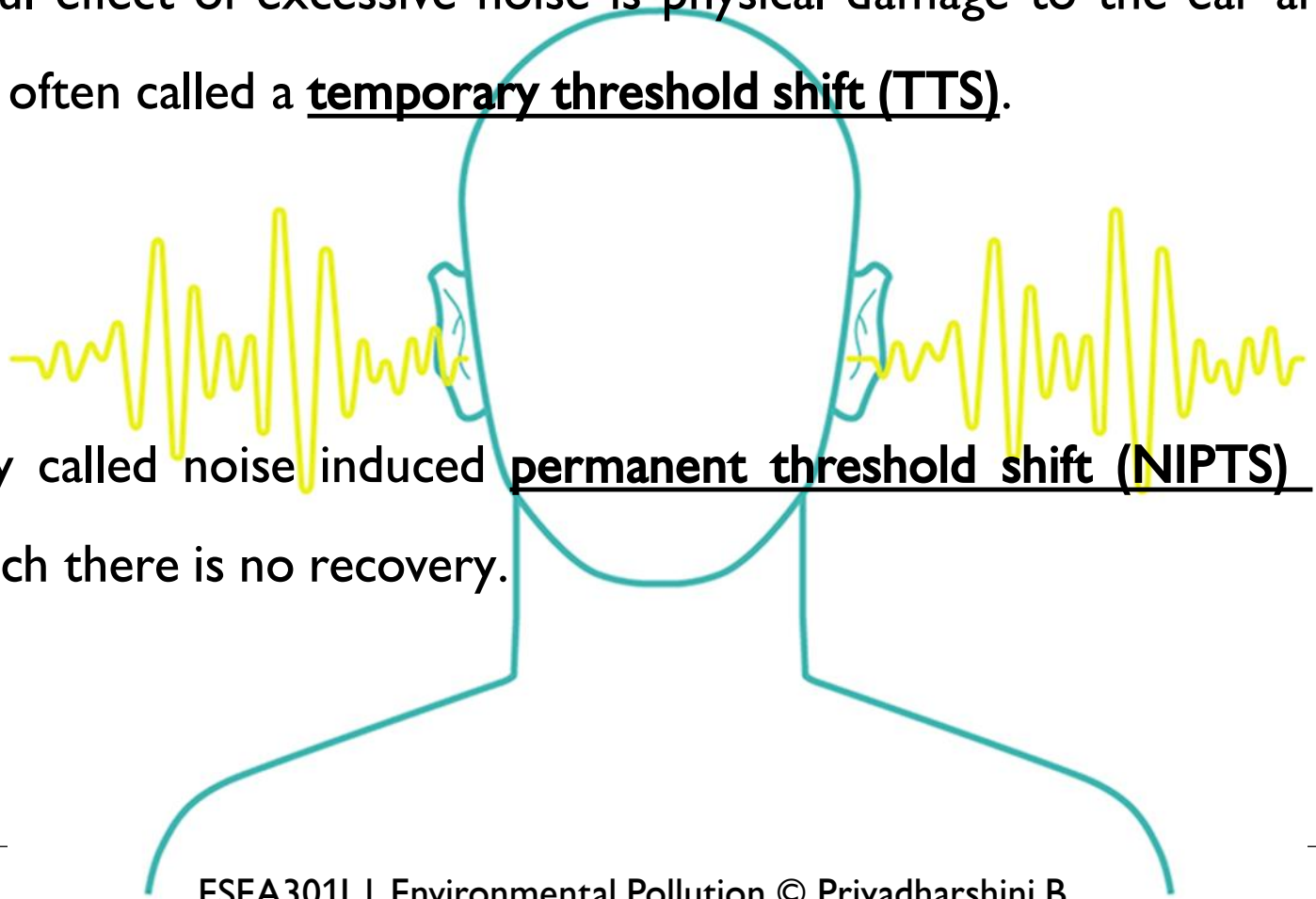
Indoor

Outdoor

Sources of noise pollution

Effects of noise pollution on physical health

The most direct harmful effect of excessive noise is physical damage to the ear and the temporary or permanent hearing loss often called a **temporary threshold shift (TTS)**.



Permanent loss, usually called noise induced **permanent threshold shift (NIPTS)** represents a loss of hearing ability from which there is no recovery.

- 80 dBA hearing loss does not occur at all.
- Temporary effects are noticed at sound levels between 80 and 130 dBA.
- A sound level of 150 dBA or more can physically rupture the human eardrum.
- The degree of hearing loss depends on the duration as well as the intensity of the noise.
- In addition to hearing losses excessive sound levels can cause harmful effects on the circulatory system by raising blood pressure and altering pulse rates.

Effects of noise pollution on mental health

Source: https://www.thedrum.com/news/2020/04/01/how-agencies-are-supporting-employee-mental-health-lockdown#&gid=1&pid=1

- Noise can also cause emotional or psychological effects such as irritability, anxiety and stress.
- Lack of concentration and mental fatigue are significant health effects of noise.

Permitted noise levels

Ambient Noise Levels dB

Zone	*Day-time*	*Night-time*
Silent Zone	50	40
Residential Zone	55	45
Commercial Zone	65	55
Industrial Zone	70	70

A standard safe time limit has been set for exposure to various noise levels. Beyond this 'safe' time continuing exposure over a period of a year will lead to hearing loss.

Duration	dBA
8 hours	90
4 hours	93
2 hours	96
1 hour	99
30 minutes	102
15 minutes	105
7 minutes	108
4 minutes	111
2 minutes	114
1 minute	117
30 seconds	120
Instantaneous rupture of membrane	150

Noise Control techniques

There are four fundamental ways in which noise can be controlled:

1. Reduce noise at the source,
2. Block the path of noise,
3. Increase the path length and
4. Protect the recipient.

In general, the best control method is to reduce noise levels at the source.

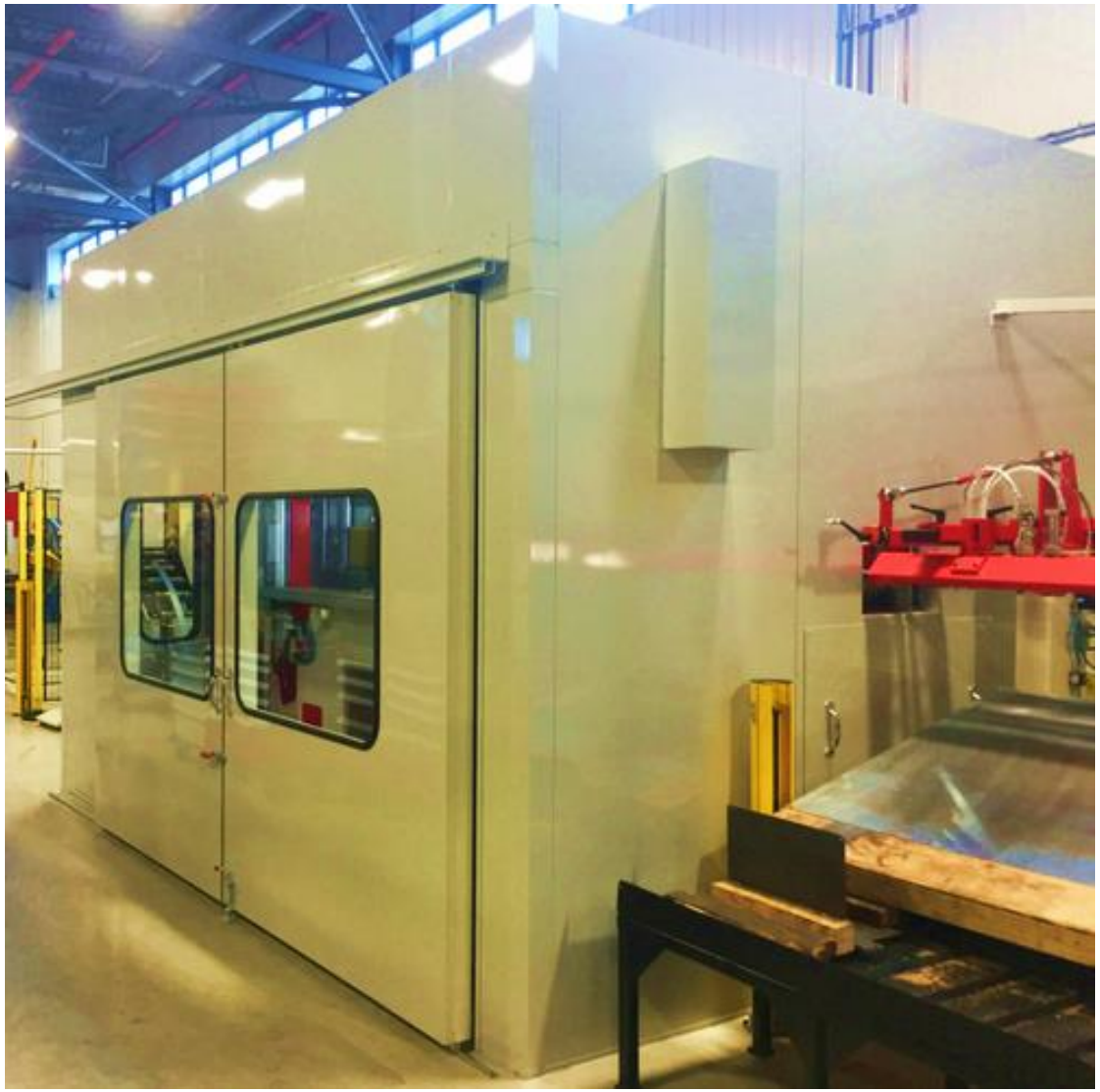
Reduce noise at the source

Source reduction can be done by effectively muffling vehicles and machinery to reduce the noise.

In industries noise reduction can be done by using rigid sealed enclosures around machinery lined with acoustic absorbing material.

Isolating machines and their enclosures from the floor using special spring mounts or absorbent mounts and pads and using flexible couplings for interior pipelines also contribute to reducing noise pollution at the source.

Muffler



Acoustic Sound Enclosures

Thermal pollution

What is Thermal Pollution?

Thermal pollution can be defined as “an accumulation of unusable heat from human activities that disrupts ecosystems in the natural environment”

Terrestrial or Aquatic

or

“as the degradation of water quality by any process that changes ambient water temperature.”

One major physical stressor on aquatic ecosystems is thermal pollution; it is not only problematic in itself, but can also exaggerate the impacts of chemical pollution

Sources: The discharge of warm water into a river is usually called a **thermal pollution.**

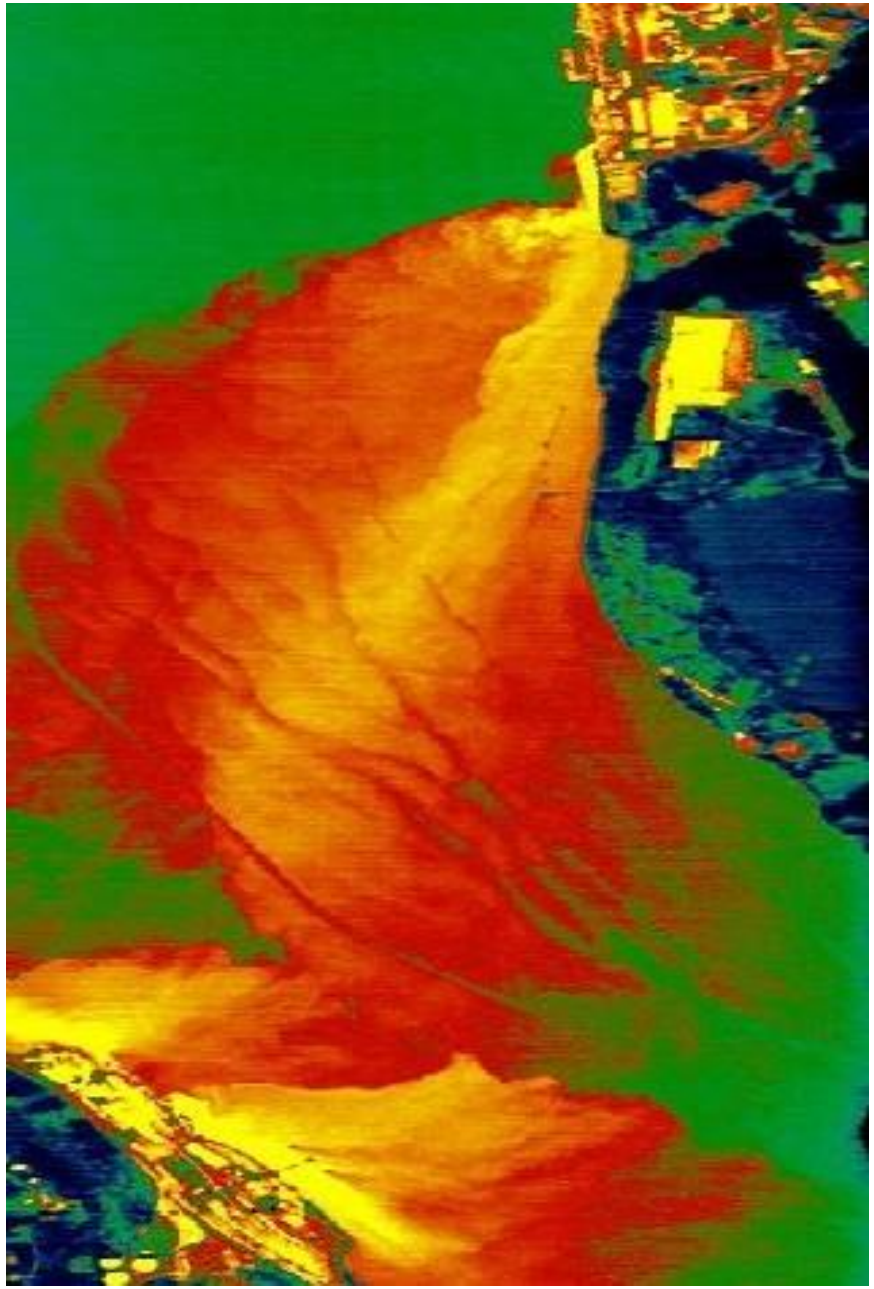
It occurs when an industry removes water from a source, uses the water for cooling purposes and then returns the heated water to its source.

Power plants heat water to convert it into steam, to drive the turbines that generate electricity.

For efficient functioning of the steam turbines, the steam is condensed into water after it leaves the turbines.

This condensation is done by taking water from a water body to absorb the heat.

This heated water, which is at least 15°C higher than the normal is discharged back into the water body



Hudson river

Indian Point nuclear plant

- Withdrew more than a billion gallons per day to keep its reactors cool, then dumps the heated water back into the river.
- Destroyed millions of fish, fish eggs and larvae, and causing what scientists call “thermal pollution”.

https://www.nytimes.com/2007/11/11/opinion/nyregionopinions/11WEreiss.html

Control measures – Thermal pollution

Method 1

Thermal pollution can be controlled by passing the heated water through

1. a cooling pond or
2. a cooling tower after it leaves the condenser.

The heat is dissipated into the air and the water can then be discharged into the river or pumped back to the plant for reuse as cooling water.

There are several ways in which thermal pollution can be reduced. One method is to construct a large shallow pond. Hot water is pumped into one end of the pond and cooler water is removed from the other end.

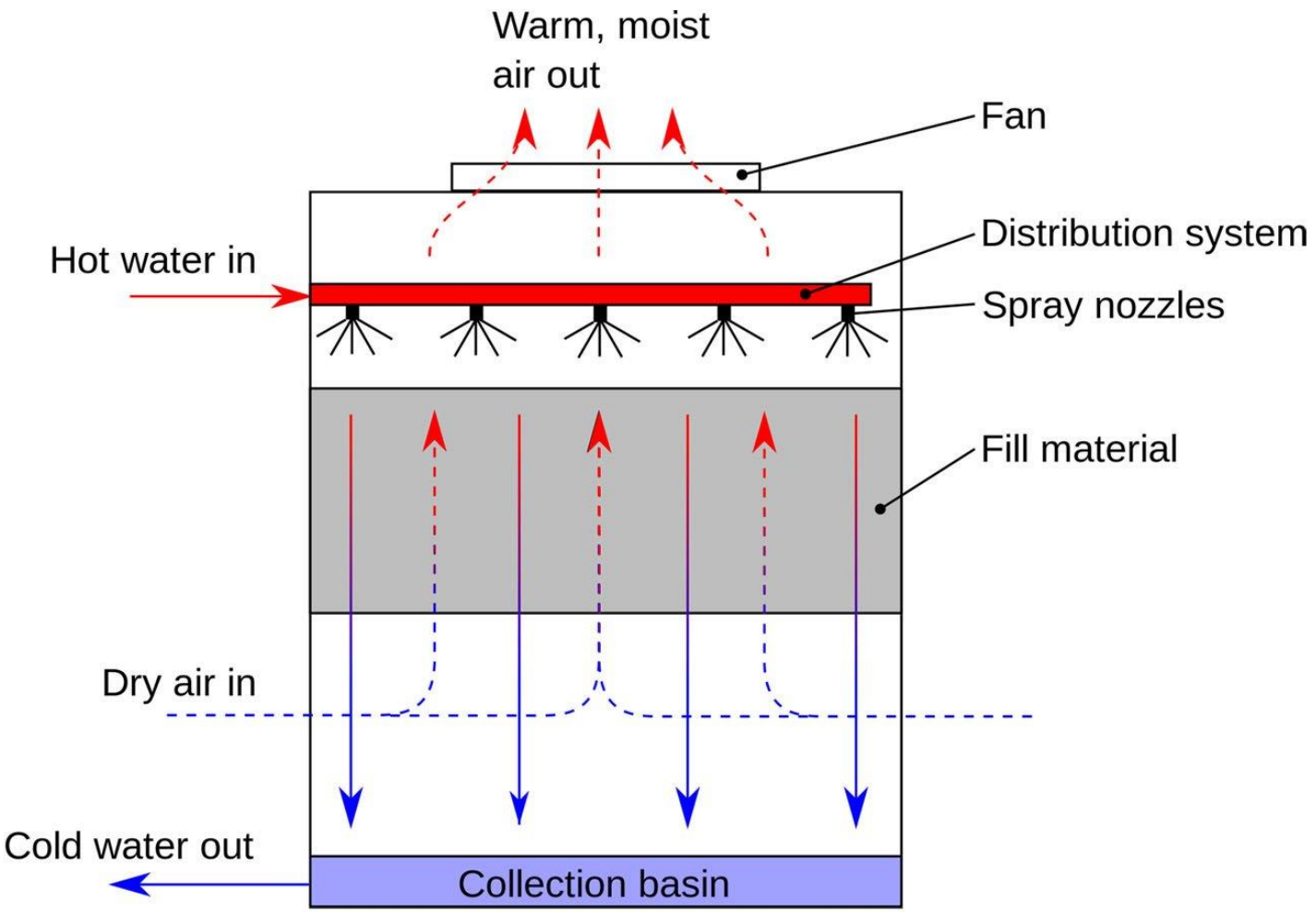
A second method is to use a cooling tower. These structures take up less land area than the ponds.

Here most of the heat transfer occurs through evaporation. Here warm waters coming from the condenser is sprayed downward over vertical sheets or baffles where the water flows in thin films.

Cool air enters the tower through the water inlet that encircles the base of the tower and rises upwards causing evaporative cooling.

A natural draft is maintained because of the density difference between the cool air outside and the warmer air inside the tower.

How Cooling Towers Work



Source: https://www.coolingtowerproducts.com/blog/how-cooling-towers-work-diagram-pictures-2015.htm

Continued

The waste heat is dissipated into the atmosphere about 100 m above the base of the tower.

The cooled water is collected at the floor of the tower and recycled back to the power plant condensers.

The disadvantage in both these methods is however that large amounts of water are lost by evaporation.

Cooling towers

Source: https://www.vox.com/2016/2/29/11132930/nuclear-power-costs-us-france-korea

SOLID WASTE MANAGEMENT

Overview

Due to rapid increase in the production and consumption processes, societies generate as well as reject solid materials regularly from various sectors – agricultural, commercial, domestic, industrial and institutional.

The considerable volume of wastes thus generated and rejected is called **solid wastes**.

In other words, solid wastes are the wastes arising from human and animal activities that are normally solid and are discarded as useless or unwanted.

This inevitably places an enormous strain on natural resources and seriously undermines efficient and sustainable development.

Effective solid waste management is necessary!

Classification of solid wastes

- Solid wastes are the organic and inorganic waste materials such as product packaging, grass clippings, furniture, clothing, bottles, kitchen refuse, paper, appliances, paint cans, batteries, etc., produced in a society, which do not generally carry any value to the first user(s).
- Solid wastes, thus, encompass both a heterogeneous mass of wastes from the urban community as well as a more homogeneous accumulation of agricultural, industrial and mineral wastes.
- While wastes have little or no value in one setting or to the one who wants to dispose them, the discharged wastes may gain significant value in another setting.

Management of solid wastes

Knowledge on the following is required,

1. Sources
2. Types of solid wastes
3. Information on composition and
4. Rate at which wastes are generated/ disposed

Essential for the design and operation of the functional elements

Solid wastes are classified on the basis of source of generation and type.

Source-based classification

Industrial: This mainly consists of process wastes, ashes, demolition and construction wastes, hazardous wastes, etc., due to industrial activities.

Agricultural: This mainly consists of spoiled food grains and vegetables, agricultural remains, litter, etc., generated from fields, orchards, vineyards, farms, etc.

Open areas: this includes wastes from areas such as Streets, alleys, parks, vacant lots, playgrounds, beaches, highways, recreational areas, etc.

Type-based classification

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes

Garbage - animal and vegetable wastes – Putrescible

Combustible and non-combustible wastes - paper, cardboard, textile and glass, crockery, tin etc.

Ashes and residues - Remains from the burning

Bulky wastes - household appliances

Street wastes - wastes collected from streets

Type-based classification

Biodegradable and non-biodegradable wastes - organic matter and inorganic materials.

Dead animals - dead animals are those that die naturally or are accidentally killed on the road.

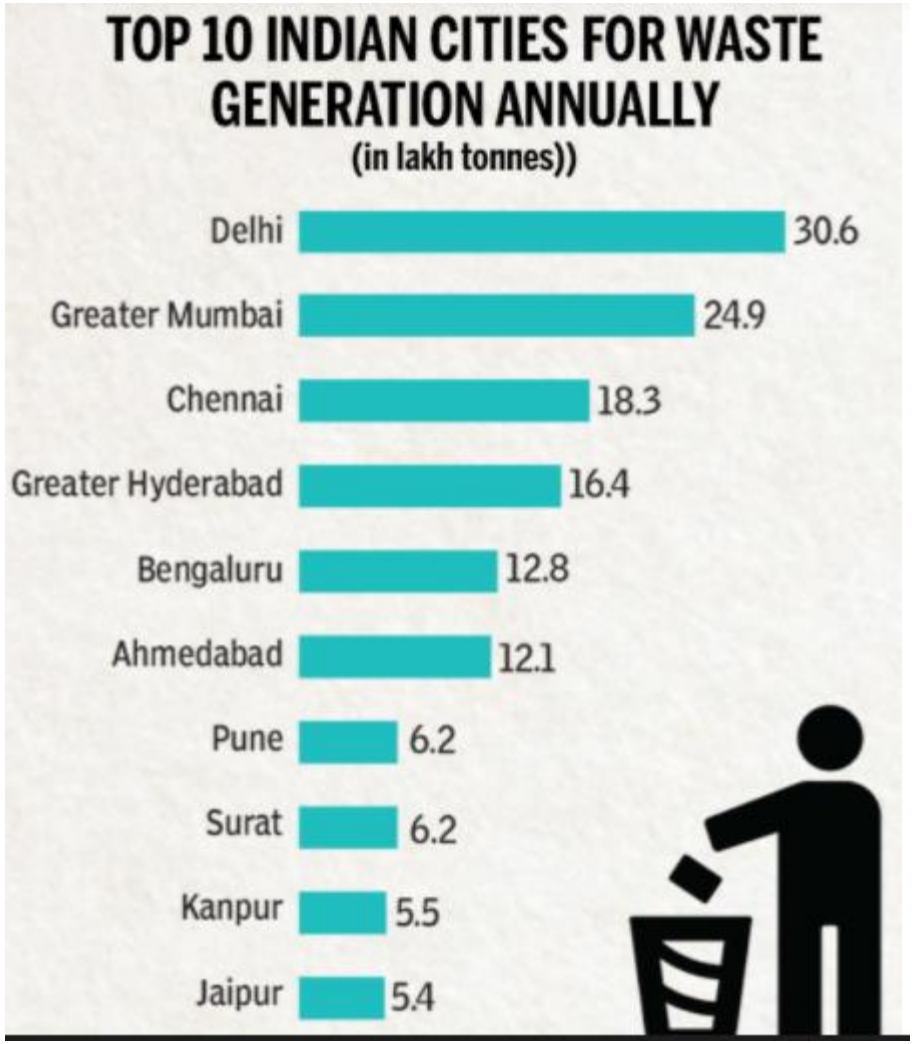
Abandoned vehicles - automobiles, trucks etc.

Construction and demolition wastes - construction, refurbishment, repair and demolition of houses, commercial buildings and other structures.

Farm wastes - diverse agricultural activities.

Hazardous wastes - potentially dangerous – ex. solvents, paints and pesticides etc.

Sewage wastes - solid by-products of sewage treatment.



Source: https://timesofindia.indiatimes.com/india/in-30-years-india-tipped-to-double-the-amount-of-waste-it-generates/articleshow/74454382.cms

Solid waste management?

Solid waste management (SWM) is associated with the **control of waste generation, its storage, collection, transfer and transport, processing and disposal** in a manner that is in accordance with the best principles of public health, economics, engineering, conservation, aesthetics, public attitude and other environmental considerations.

SWM processes: Factors

SWM processes differ depending on factors

1. Economic status (e.g., the ratio of wealth created by the production of primary products to that derived from manufactured goods, per capita income, etc.)
2. Degree of industrialization,
3. Social development (e.g., education, literacy, healthcare, etc.) and
4. Quality of life of a location.
5. In addition, regional, seasonal and economic differences influence the SWM processes

The functional elements that constitute the system are

Waste generation - The most important aspect of this part of the SWM system is the identification of waste. (based on sources).

Waste storage - key functional element – must be removed within 8 days – examples: plastic containers, conventional dustbins (of households), used oil drums, large storage bins.

Waste collection - gathering of wastes and hauling them to the location, where the collection vehicle is emptied, which may be a transfer station or a processing plant or a disposal site.

Transfer and transport - transfer station include the type of transfer operation, capacity, equipment, accessories and environmental requirements.

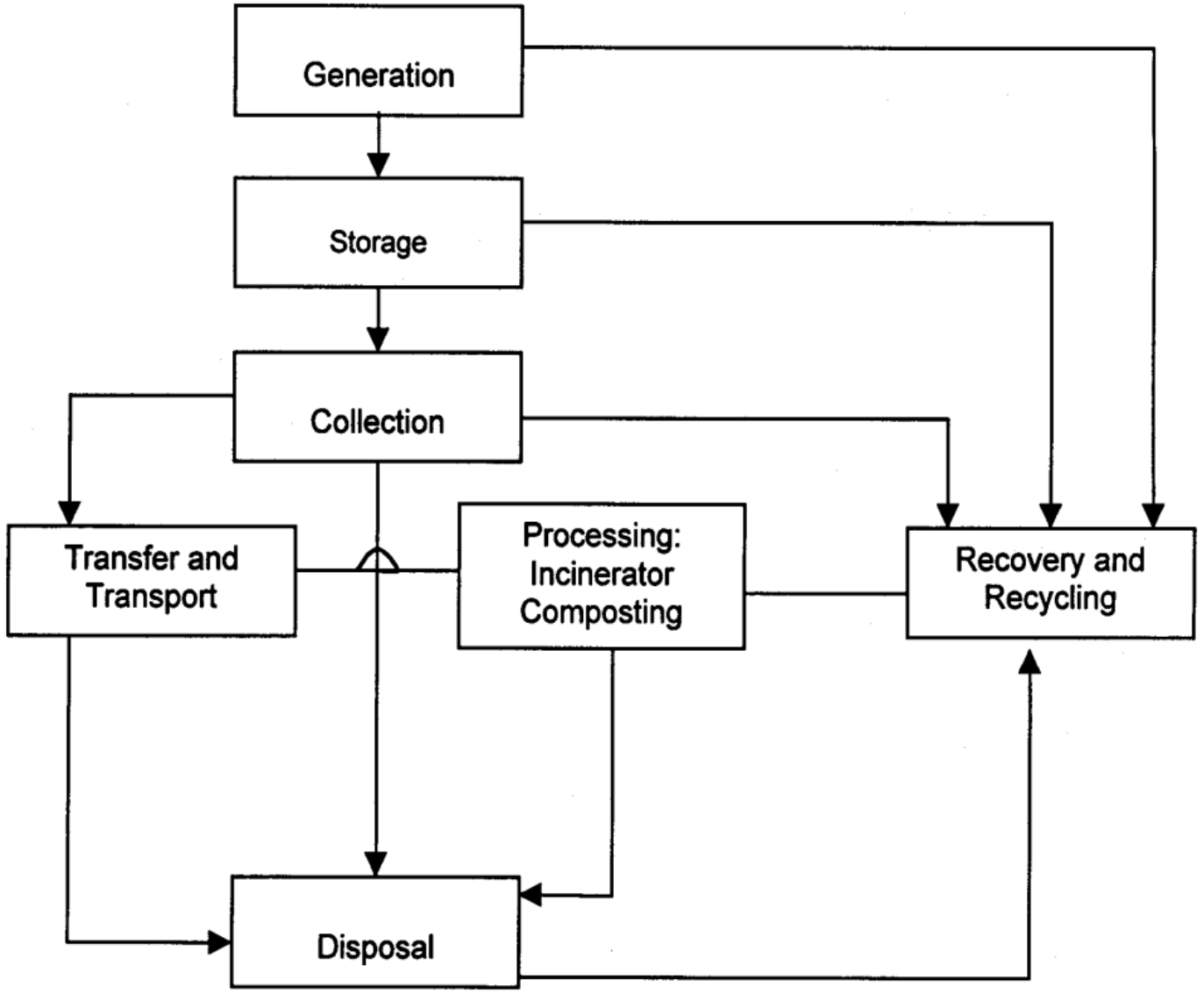
Processing - Processing is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling. Examples: Compost, volume reduction, incineration etc.

Recovery and recycling – improve both the efficiency of disposal system and recovery of usable material and energy.

Waste disposal - A modern sanitary landfill.

Typical SWM System:

Functional Elements



Purpose of processing

The processing of wastes helps in achieving the best possible benefit from every functional element of the solid waste management (SWM) system.

Improving efficiency of SWM system

Recovering material for reuse

Recovering conversion products and energy (incineration, pyrolysis, composting or bio-digestion)

Mechanical volume and size reduction

The main purpose is to reduce the volume (amount) and size of waste, as compared to its original form, and produce waste of uniform size.

Volume reduction or compaction - Compactors

Size reduction or shredding – Hammer mill, Hydropulper etc.

Chemical volume reduction – Pyrolysis

Component separation

Component separation is a necessary operation in which the waste components are identified and sorted either manually or mechanically to aid further processing

Recovery of valuable materials for recycling

Preparation of solid wastes by removing certain components prior to incineration, energy recovery, composting and biogas production.

The most effective way of separation is manual sorting in households prior to collection.

1. Air separation 2. Magnetic separators 3. Screening 4. Others (hand sorting)

Source reduction

Purpose of source reduction are as follows

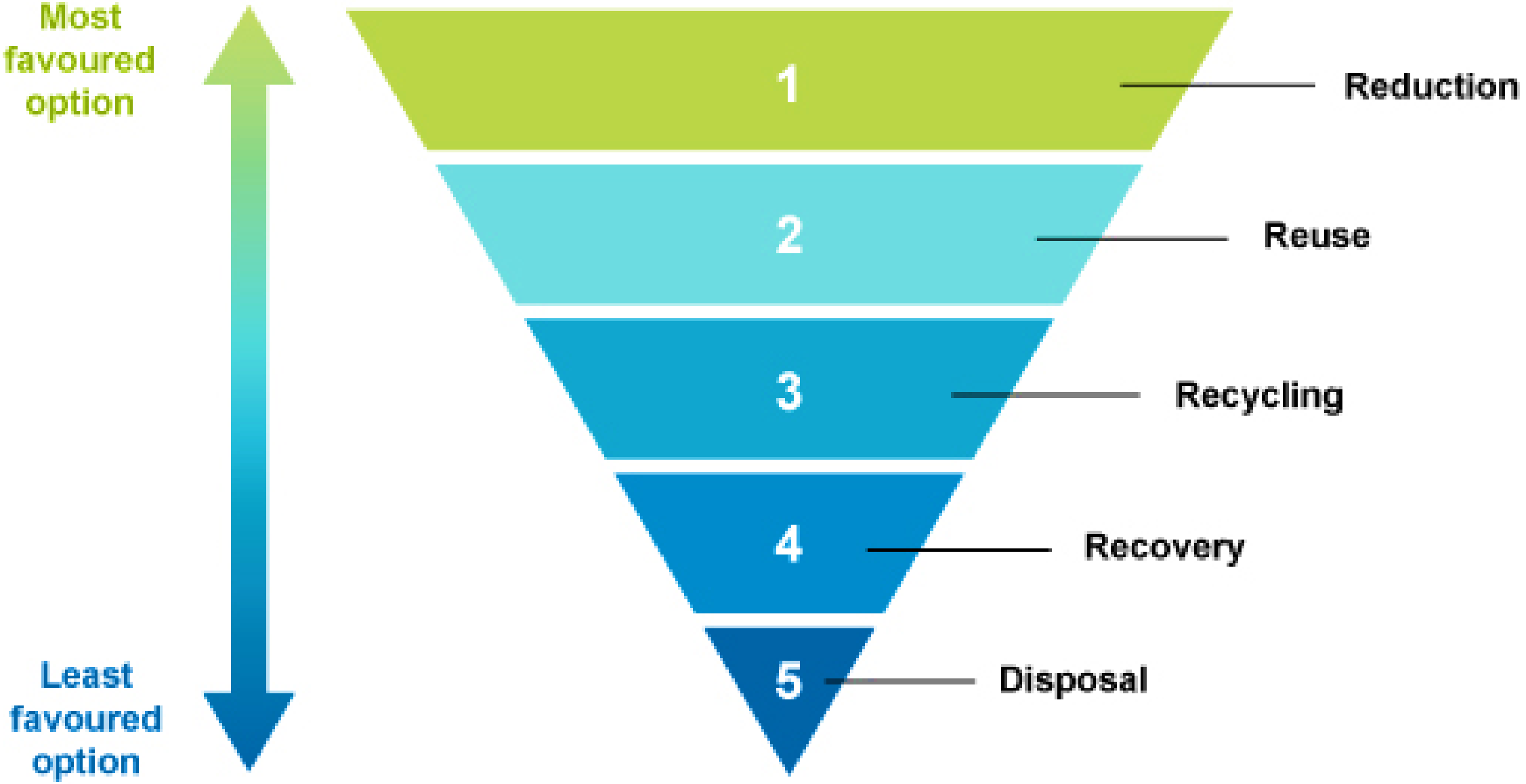
Product reuse

Material volume reduction

Toxicity reduction

Increased product lifetime

Decreased consumption


Most favoured option
1
Reduction
2
Reuse
3
Recycling
4
Recovery
5
Disposal
Least favoured option

Health impacts

Due to the absence of standards and norms for handling municipal wastes, municipal workers suffer occupational health hazards of waste handling.

Municipal workers and rag pickers who operate informally for long hours rummaging through waste also suffer from similar occupational health diseases ranging from respiratory illnesses (from ingesting particulates and bio-aerosols), infections (direct contact with contaminated material), puncture wounds (leading to tetanus, hepatitis and HIV infection) to headaches and nausea, etc.

Environmental impacts

Contaminated leachate and surface run-off from land disposal facilities affects ground and surface water quality.

Volatile organic compounds and dioxins in air-emissions are attributed to increasing cancer incidence and psychological stress for those living near incinerators or land disposal facilities.

Drain clogging due to uncollected wastes leading to stagnant waters and subsequent mosquito vector breeding.

Laws and regulations

E-waste (Management) Rules, 2016 was enacted on October 1, 2017

The rule has strengthened the Extended Producer Responsibility (EPR) - practice to ensure the take-back of the end-of-life products

Global E-Waste Monitor 2017, India generates about 2 million tonnes (MT) of e-waste annually and ranks fifth among e-waste producing countries, after the US, China, Japan and Germany.

The Ministry of Environment, Forest and Climate Change (MoEF & CC) on March 19, 2020, issues the Solid Waste Management (Amendment) Rules, 2020 to further amend the Solid Waste Management Rules, 2016.

Disclaimer!

The author has taken attention to acknowledge most of the sources referred to in the presentation. However, if some citations/references have been missed, it has only been referred solely for educational purposes.