Water Pollution

Water:

- Fresh water is required in day-to-day life for various purposes like domestic, agricultural, power generation, industrial, forestry, fisheries, navigation and recreational activities.
- We require pure potable water free from unwanted and undesirable impurities.

Water Resources

Type of water source	Percentage of total water
Oceans and Salt Lakes	97.41
Fresh water	
• Ice Caps and Glaciars	1.984
• Ground water	0.592
• Lakes	0.007
• Rivers	0.0001

Qualities of Potable Water

Potable Water should be

- Colourless and odourless .
- Free from suspended particulate matter and turbidity.
- Must not contain disease causing bacteria etc.
- Free from toxic materials.
- Low hardness.
- Cool and fresh.

Water Pollution

- Water becomes polluted after utilization for different purposes.
- Water pollution may be defined as presence of unwanted and undesirable impurities which may be organic, inorganic or biological, resulting in the deterioration of the quality of water by change in physical, chemical and biological characteristics of water and making it unfit for use.

Indications of Water Pollution

- Bad taste and/or presence of odour and colour.
- Excessive growth of aquatic weeds in ponds/ rivers.
- Presence of pathogens due to contamination from sewer.
- Turbidity in water.
- Dead animals floating on water in river, lake, etc.
- Oil and grease floating on water.

Water Pollution due to Domestic Garbage

Water Pollution due to Sewage disposal

Water Pollution due to Industrial Effluents

Water Pollution due to Garbage

https://givingcompass.org/article/whos-to-blame-for-ocean-pollution/

Water Pollution due to Garbage

https://www.needpix.com/photo/1083944/water-polluted-plastic-garbage-bottle-environment-texture

Major Global Issues Related To Water Pollution

- Lack of pathogen free potable water
- Disposal of domestic or industrial effluents in water bodies
- Sewage, disease-causing agents, sediment pollution, inorganic plant and algal nutrients, organic compounds, inorganic chemicals, radioactive substances, and thermal pollution

Type of Water Pollutants

1.Disease-causing agents

- Bacteria, viruses, protozoa and parasitic worms that usually enter into water from domestic sewage and animal wastes.

2.Oxygen depleting wastes

- Organic wastes, which require a large quantity of oxygen for their bacterial decomposition. Large amount of bacteria consume these wastes resulting in the depletion of dissolved oxygen gas in water.

3.Inorganic nutrients

- Water soluble nitrate and phosphate cause too much growth of algae and other aquatic plants. The dead plants require a large quantity of oxygen for their decomposition, reducing the amount of dissolved oxygen in water, and thereby killing fish and other aquatic animals.

4.Water-soluble inorganic chemicals

- Presence of acids, salts, and compounds of toxic metals such as lead and mercury can make water unfit for drinking, harm fish and other aquatic life, decrease crop yields.

5. Organic chemicals

- Presence of detergents, cleaning solvents, plastics, pesticides, oil, gasoline etc. in water affect human health and harm aquatic animals.

6. Suspended matter or sediment

- Fine particles of soil and other solid inorganic and organic materials which remain suspended in water are the largest source of water pollution. Suspended particulate matter reduces the visibility in water, suppresses photosynthesis by aquatic plants, and disturbs aquatic ecosystem.

7. Radioactive substances

- Presence of radioactive substances in water makes it harmful for consumption by human beings and other living organisms.

8. Waste Heat

- Thermal or nuclear power plants discharge a large quantity of heated water into the nearby water bodies, which results in an increase in its temperature. This increase in water temperature results in the reduction in the dissolved oxygen content and severely affects the aquatic ecosystem as many species cannot survive in such water.

Sources of Water Pollution

The major sources of surface and ground water pollution in India are:

- Industrial effluents
- Domestic sewage
- Fertilizer and pesticide run-offs from agricultural fields
- Leaching from mining or waste disposal sites

Point and Non-point Sources

Point Sources:

- Point sources release pollutants at definite locations through pipes, channels, or sewers into water bodies.
- Industrial units, sewage treatment plants off-shore oil wells are some examples.

Non-point Sources:

- Non-point sources are big land areas that discharge pollutants into surface and underground water over a large area.
- Agricultural-runoffs and seepage into the ground from fields, construction areas, mining runoff , roadways and acid rain are some examples.

Industrial Wastes in Water

Different industries generate different pollutants

Food processing plants generate effluents with high BOD

Paper mills generate effluents with high BOD and toxic compounds

Biochemical oxygen demand (BOD):

It is the amount of dissolved oxygen (DO) needed (i.e. demanded) by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per litre of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water.

Chemical Oxygen Demand (COD):

It is a test that measures the amount of oxygen required to chemically oxidize the organic material and inorganic nutrients, such as Ammonia or Nitrate, present in water. The strong oxidizing agent potassium permanganate($KMnO_4$) was used for measuring chemical oxygen demand.

Difference between BOD and COD:

Biological Oxygen Demand

- It is the amount of oxygen required by the microbes to decompose the organic matter under aerobic conditions.
- It can be determined by putting a sealed water sample under specific temperature and conditions for five days.

- **Chemical Oxygen Demand**
- It is the total amount of oxygen required to break down the organic matter by chemical oxidation.
- It can be determined by putting a water sample with a strong oxidizing agent under specific temperature and conditions, for a short period of time.

Inorganic Plant and Algal Nutrients

Water soluble compounds containing nitrate, Phosphate and Ammonium ions.

Human sources: Sewage, manure and runoff of agricultural and urban fertilizers.

Effects

Cause excessive growth of algae and other aquatic plants, which die, decay, and deplete dissolved oxygen in water thereby killing fish

Presence of nitrates in drinking water lower the oxygen carrying capacity of the blood and can kill children and infants.

Eutrophication

- Sewage and agricultural run-off provide plant nutrients in water giving rise to the biological process know as eutrophication. Large input of fertilizer and nutrients from these sources leads to enormous growth of aquatic weeds which gradually cover the entire water-body.
- This aquatic ecosystem gets destroyed as the water body loses its D.O. and the fish cannot survive under such conditions.

Eutrophication

Eutrophication of Lakes

https://www.flickr.com/photos/48722974@N07/4464986156

Eutrophication

https://www.flickr.com/photos/33406492@N06/5052332517

Disease-causing Agents

Bacteria, Viruses, Protozoa, and parasitic worms.

Sources

Human and animal wastes

Effects: Variety of diseases like Typhoid, Jaundice, Dysentery, Amoebiasis, Polio (Infantile Paralysis), Trachoma (Eye Infection), Cholera etc.

Garbage

The urban wastes consisting of garbage and rubbish materials like plastics, glasses, metallic cans, fibres, paper, rubbers, street sweepings, fuel residues, leaves, containers, abandoned vehicles and other discarded manufactured products.

Urban domestic wastes though disposed off separately from industrial wastes, can still be dangerous. This happens because they are not easily degraded.

Organic Compounds

Oil, Gasoline, Plastics, Pesticides, Cleaning solvents and Detergents.

Human Sources: Industrial effluents, household cleansers and surface runoff from farms.

Effects

Can threaten human health by causing nervous system damage and some cancers.

Harm fish and wildlife.

Inorganic Chemicals

Contaminants that contain elements other than carbon

Examples: acids, salts, and heavy metals

Do not degrade easily

Lead: Found in old paint, industrial pollutants, leaded gasoline

Mercury: Mercury bioaccumulates in the muscles of top predators of the open ocean

Radioactive Compounds

Contain atoms of unstable isotopes that spontaneously emit radiation

- Mining,
- Processing radioactive materials
- Nuclear power plants
- Natural sources

Radioactive isotopes of Iodine, Radon, Uranium, Cesium and Thorium

Effects: Genetic mutations, birth defects and certain cancers.

Ground water pollution

- About 0.6% of the total water available on earth is ground water. Its total amount much higher than surface water.
- Ground water is less susceptible to pollution as various contaminants get removed during its passage through soil. However, there are a number of sources of ground water pollution.
- Septic tanks, industrial effluents (textile, chemical, tanneries), and mining etc. are main source of ground water pollution.
- Contaminated ground water is also found naturally in some regions where it contains arsenic and fluoride etc.

- Groundwater is one of our most important sources of water for irrigation. Groundwater contamination is a serious problem. Water scarcity puts lives at risk. In addition, many industries rely on water as a resource, which means water contamination threatens their supply chains. Governments, business and communities should all take necessary action to protect this valuable resource.

Groundwater Pollution

- Any addition of undesirable substances to groundwater caused by human activities is considered to be contamination. It has often been assumed that contaminants left on or under the ground will stay there. This has been shown to be wishful thinking. Groundwater often spreads the effects of dumps and spills far beyond the site of the original contamination. Groundwater contamination is extremely difficult, and sometimes impossible, to clean up.

- Groundwater contaminants come from two categories of sources: point sources and distributed, or non-point sources. Landfills, leaking gasoline storage tanks, leaking septic tanks, and accidental spills are examples of point sources. Infiltration from farm land treated with pesticides and fertilizers is an example of a non-point source.

Sources of ground water pollution:

- Most concern over groundwater contamination has centred on pollution associated with human activities.

- Human groundwater contamination can be related to waste disposal (private sewage disposal systems, land disposal of solid waste, municipal wastewater, wastewater impoundments, land spreading of sludge, brine disposal from the petroleum industry, mine wastes, deep-well disposal of liquid wastes, animal feedlot wastes,
- Pesticides, fertilizers, herbicides and animal waste are agricultural sources of groundwater contamination
- Manufacturing and service industries have high demands for cooling water, processing water and water for cleaning purposes.
- Groundwater pollution occurs when used water is returned to the hydrological cycle.
- Residential wastewater systems can be a source of many categories of contaminants, including bacteria, viruses, nitrates from human waste, and organic compounds.

- ***Other sources of ground water pollution:***
- 1. Storage Tanks
- May contain gasoline, oil, chemicals, or other types of liquids and they can either be above or below ground.
- 2. Septic Systems
- Onsite wastewater disposal systems used by homes, offices or other buildings that are not connected to a city sewer system.
- 3. Uncontrolled Hazardous Waste
- Hazardous waste sites can lead to groundwater contamination if there are barrels or other containers lying around that are full of hazardous materials.
- 4. Landfills
- Landfills are the places that our garbage is taken to be buried. Landfills are supposed to have a protective bottom layer to prevent contaminants from getting into the water.

5. Chemicals and Road Salts

- The widespread use of chemicals and road salts is another source of potential groundwater contamination. Chemicals include products used on lawns and farm fields to kill weeds and insects and to fertilize plants, and other products used in homes and businesses.

6. Atmospheric Contaminants

- Since groundwater is part of the hydrologic cycle, contaminants in other parts of the cycle, such as the atmosphere or bodies of surface water, can eventually be transferred into our groundwater supplies.

Effect of polluted ground water on Health:

- Drinking contaminated groundwater can have serious health effects.
- Diseases such as hepatitis and dysentery may be caused by contamination from septic tank waste.
- Poisoning may be caused by toxins that have leached into well water supplies.
- Wildlife can also be harmed by contaminated groundwater.
- Other long term effects such as certain types of cancer may also result from exposure to polluted water.

Purification of Drinking Water

- Chlorination

Chlorine kills disease causing organisms

Chlorine byproducts are linked to numerous cancers, miscarriages and birth defects

- Fluoridation

Prevents tooth decay

Linked to cancer, kidney disease

Control measures of water pollution

- Scientific techniques should be adopted for environmental regulation of rivers, ponds or streams.
- Recycling operations must be encouraged as it helps prevent disposal of wastes into natural waters.
- Planting of more trees as they are capable of reducing sulphur dioxide and nitric oxide.

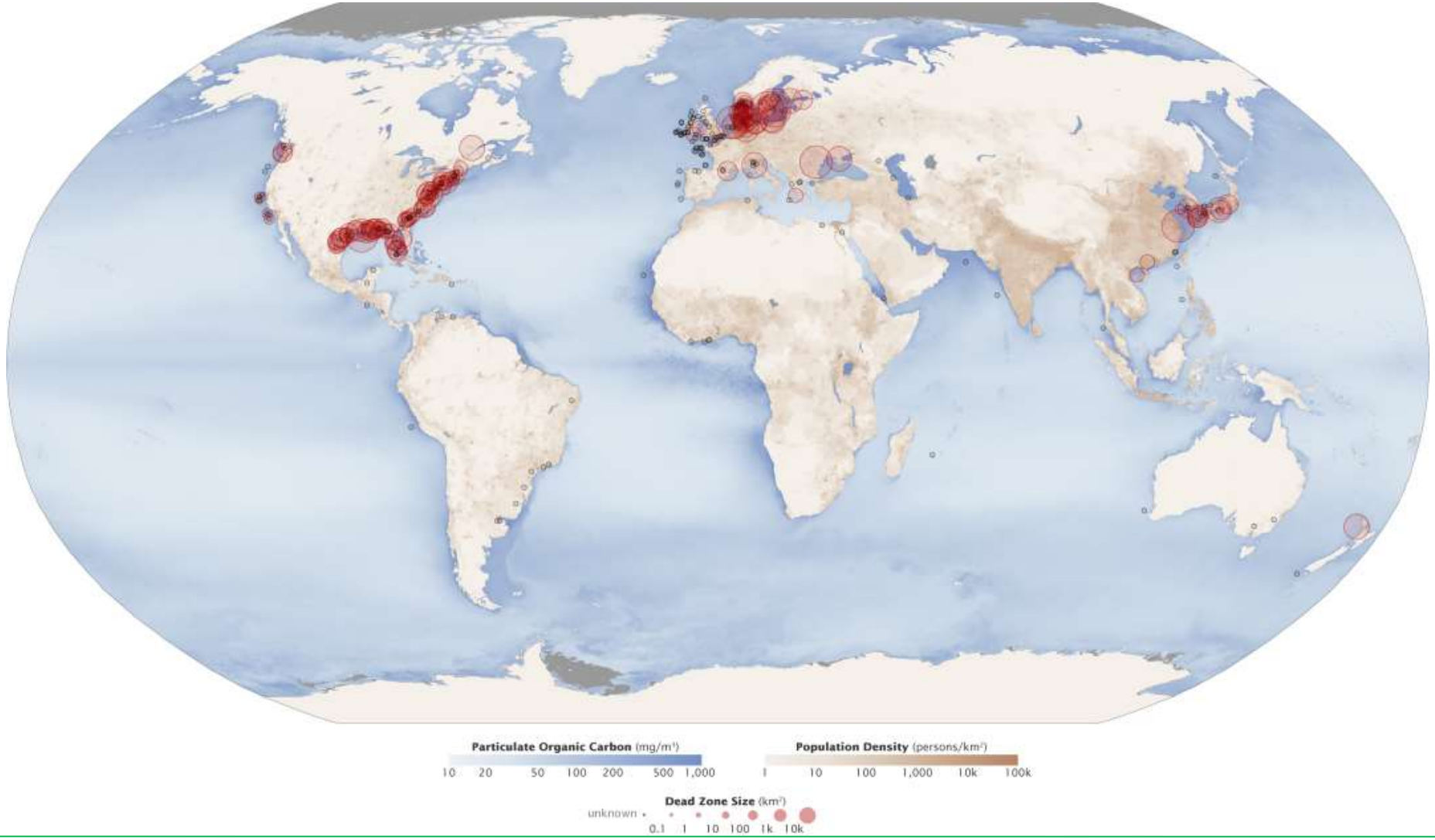
Strict laws should be enacted by state or central government

- No waste (treated, partially treated or untreated) should be discharged into any natural water body. Industries should develop closed loop water supply schemes and domestic sewage should be treated by organic methods.
- Public awareness must be created regarding adverse effects of water pollution.
- Laws, standards and practices should be established to prevent water pollution based on current requirements and technological advancements.

Suffocated Aquatic Zones

https://www.downtoearth.org.in/coverage/environment/dying-oceans-50679

Aquatic Dead Zones



https://earthobservatory.nasa.gov/images/44677/aquatic-dead-zones

Marine Pollution

- Marine pollution can be defined as release of harmful substances into marine waters that cause damage to the marine ecosystem.
- The pollutants may include sewage, farm waste, and industrial waste or toxic chemicals.
- This pollution results in damage to the environment, and harms the health of all living organisms present in marine ecosystem.

Sources of Marine Pollution

- Hotels, industry, agricultural practices in coastline areas release large amount of pollutants.
- Enormous amount of sewage, garbage, plastic and agricultural discharge is dumped into river waters which ultimately goes to the seas.
- Oil well drilling and shipment causes release of oil & other pollutants in the marine environment
- Radioactive wastes & toxic substances etc. are stored in large containers and usually dumped in deep sea. Leaking of toxic waste may take place from these containers.

- Petroleum refinery, and off-shore oil production units cause marine pollution.
- Tankers transporting oil cause significant marine pollution.
- Shipping industries and ship-accidents also cause marine pollution

Effects of Marine Pollution

- The marine plants and animals like phytoplankton, zooplankton, coral reefs, algal species, fishes, birds and mammals are severely affected by marine pollution.
- Several pollutants get bio-magnified in the food chain which makes fish and other aquatic animals unsuitable for human consumption.
- The toxic compounds present in polluted water such as DDT, can destroy the eggs of fishes and other aquatic animals and cause diseases in fish and other organisms.

- Oil in the sea water affects sensitive plants and animals.
- Phytoplankton, zooplankton, algal species, many species of invertebrates, coral reefs, fish, birds and mammals are affected by oil pollution.
- Oil sticks to the feathers of marine birds and results in death of birds.
- The dissolution of oxygen gets reduced due to the formation of a thick blanket of oil, spilled over the sea water.
- Microplastic particles are getting embedded into fishes and other marine animals.

Control of Marine Pollution

- Toxic effluents from industries and sewage treatment plants should not be discharged in coastal waters.
- Developmental activities along coastal areas should be strictly controlled.
- Oil and grease from service stations should be recycled.
- Oil ballast should not be dumped into sea.
- Ecologically vulnerable coastal areas should be protected from oil well drilling.

- Proper treatment of industrial effluents should be done before the discharge and dumping of radioactive substances.
- Dumping of toxic waste, sewage and sludge in marine waters should be banned.
- Strict environmental regulations should be implemented for offshore oil wells.
- Public awareness programs should be organized.
- Enforcement of Marine Acts and Coastal Acts.

Marine Pollution

https://www.wallpaperflare.com/indonesia-kuta-beach-litter-sea-bali-playing-football-wallpaper-erktd

Marine Pollution

https://www.wallpaperflare.com/waste-floating-on-water-trash-river-pines-rubble-pollution-wallpaper-wjyqe

Marine Pollution – Littered Beach

https://www.flickr.com/photos/plasticpollution/4349792311

Marine Pollution – Littered Beach

https://www.flickr.com/photos/gridarendal/31710726256

Marine Pollution - Oil Spills

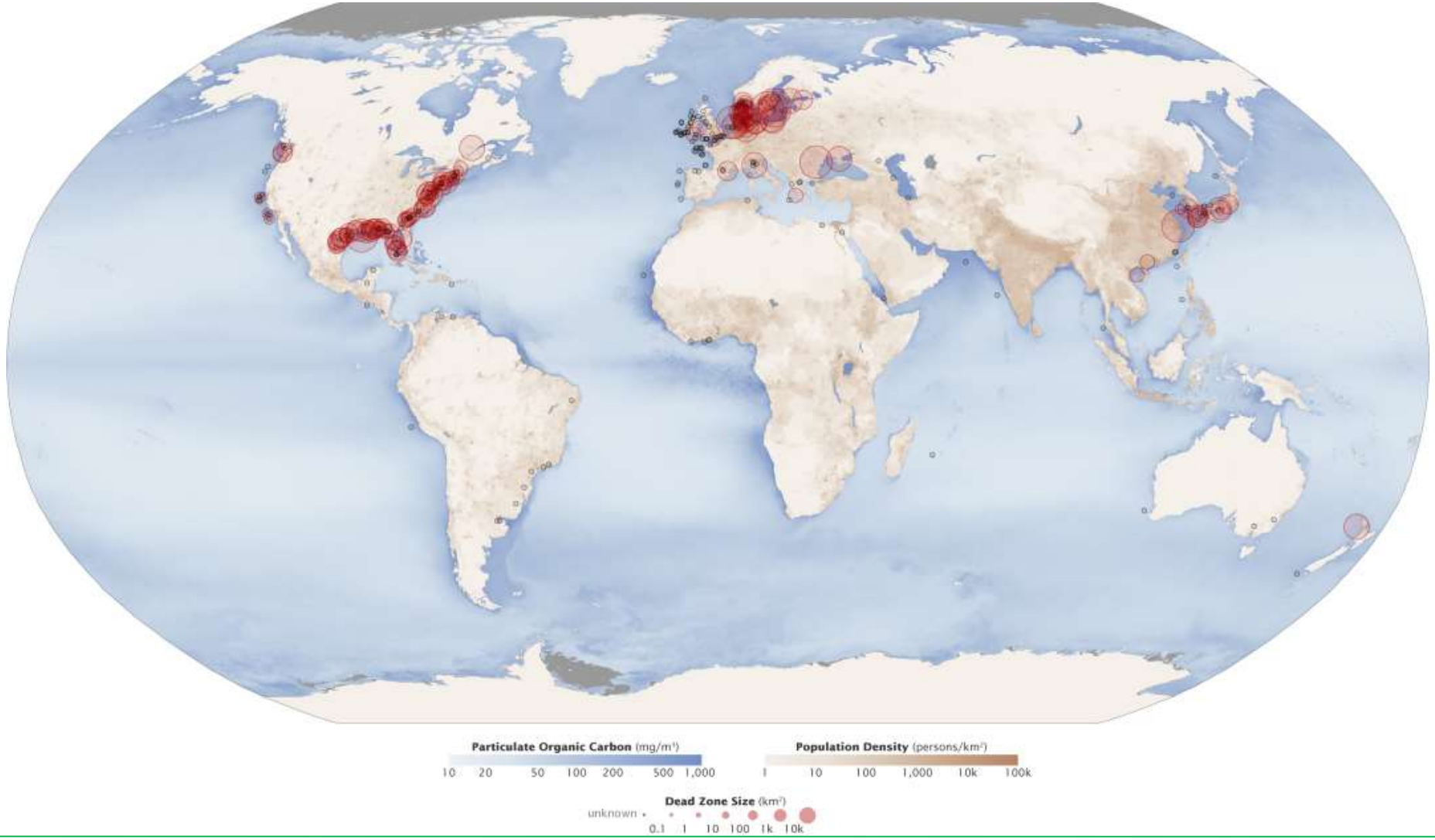
https://www.flickr.com/photos/19378856@N04/2037098785

Marine Pollution - Oil Spills

Suffocated Aquatic Zones

https://www.downtoearth.org.in/coverage/environment/dying-oceans-50679

Aquatic Dead Zones



https://earthobservatory.nasa.gov/images/44677/aquatic-dead-zones

Chemical Degradation of wastes and Chemicals

• Chemical degradation is defined as **a full depolymerization of polymer to the monomers, or partial depolymerization to oligomers and other chemical substances**.

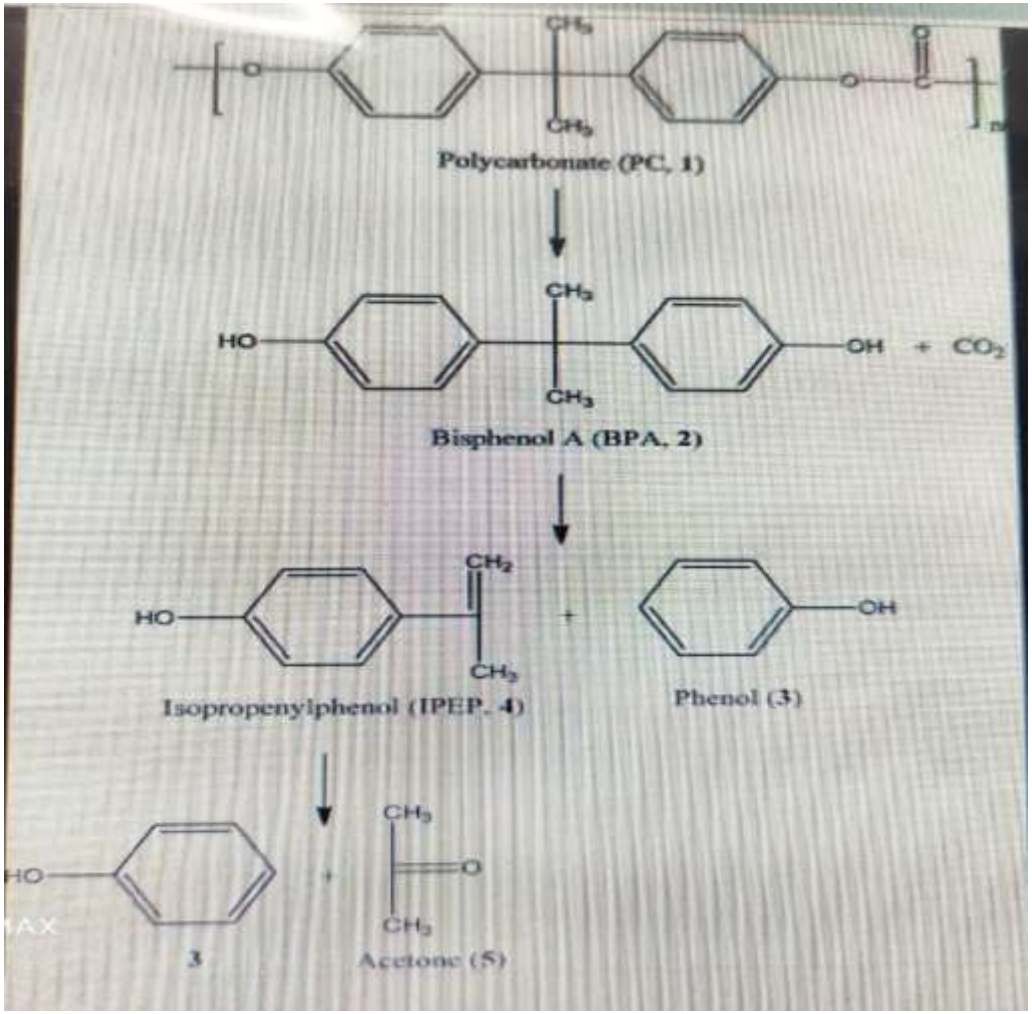
• Chemical Degradation Methods for Wastes and Pollutants focuses on established and emerging chemical procedures for the management of pollutants in industrial wastewater and the environment.

• Some of the most utilized **chemical degradation** methods are alcoholysis, **hydrolysis** and aminolysis etc.

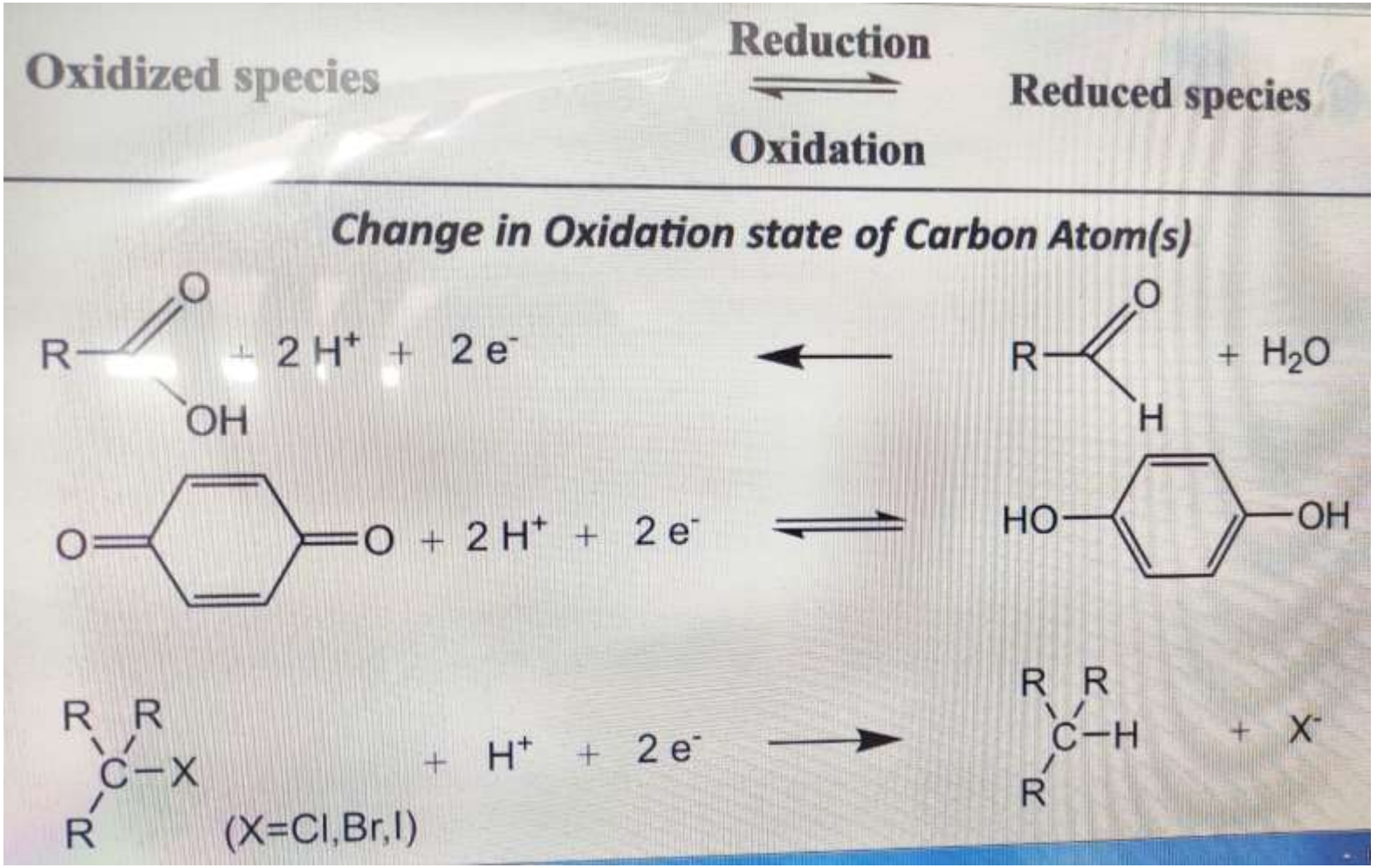
• Hydrolytic reactions are important chemical reactions removing organic contaminants and are particularly important for chemicals containing acid derivatives as functional groups. Common examples of such chemicals are pesticides of the organophosphate and carbamate classes such as parathion, diazinon, aldicarb and carbaryl.

- As the name suggests, hydrolysis reactions involve using water (*hydro-*) to break (*-lysis*) a bond. Hydrolyses are reactions with water to produce an acid and either an alcohol or amine as products. Hydrolyses can be catalysed by either OH^- or H^+ ions and their rates are therefore pH dependent.
- Halogenated organic molecules may also be hydrolysed to form alcohols (releasing the halogen as a halide ion).
- Redox (reduction and oxidation) reactions are another important reaction class involved in the degradation of organic chemicals.
- Reduction reactions are important redox reactions for environmental contaminants in anaerobic environments such as sediment and groundwater aquifers. Under these conditions, organic chemicals containing reducible functional groups such as carboxylic acids and nitro groups undergo reduction reactions.

Chemical Degradation of Poly(bisphenol A carbonate) Waste Materials



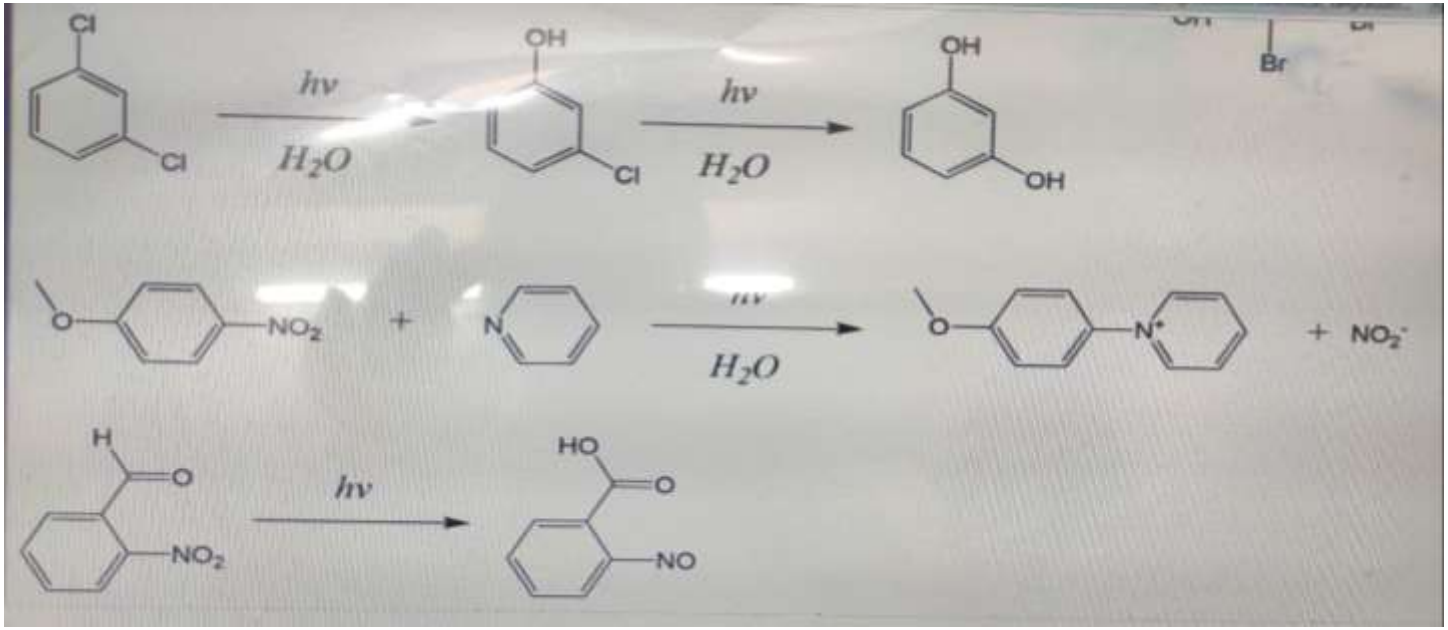
- Examples of chemical redox reactions that may occur in the environment



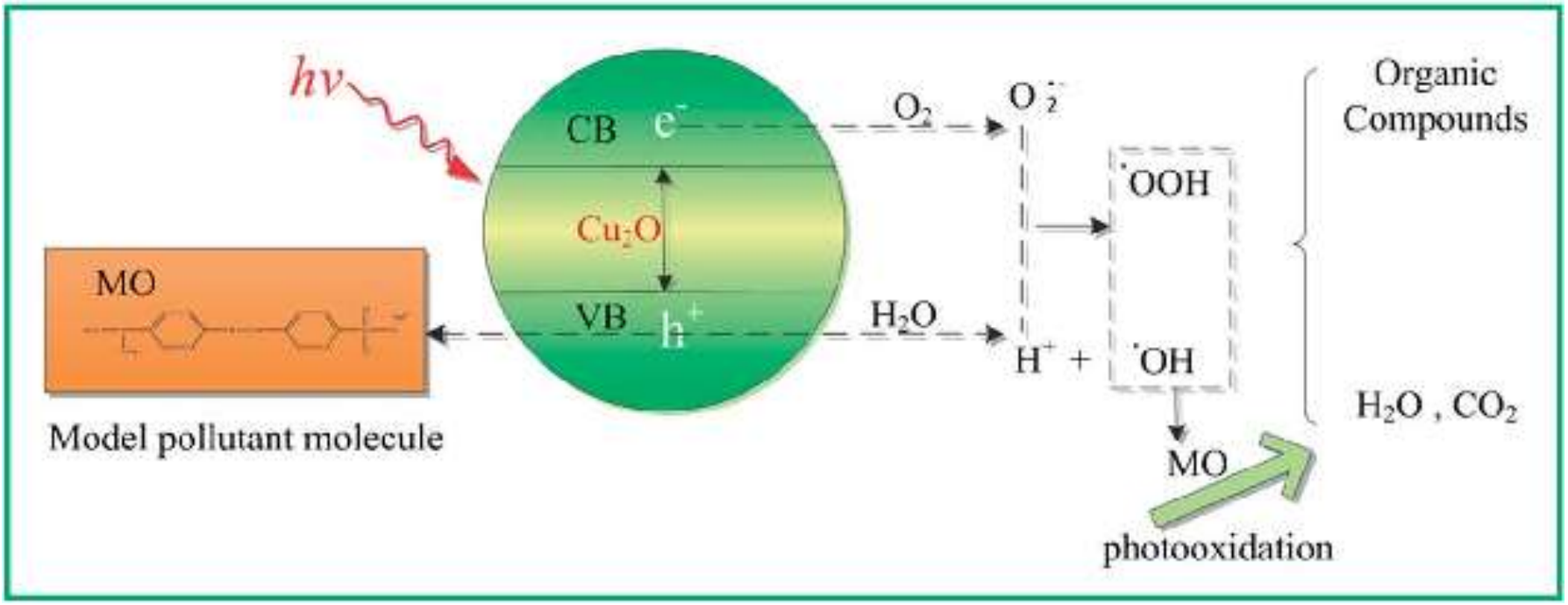
Photodegradation of pollutants

- Sunlight is an important source of energy to initiate chemical reactions and photochemical reactions are particularly important in the atmosphere.
- Aromatic compounds and other chemicals containing unsaturated bonds that are able to absorb light in the frequency range available in sunlight become exited (energized) and this can lead to chemical reactions. These reactions lead to cleavage of bonds between carbon atoms and other atoms such as halogens to produce radical species. These radicals are highly reactive and react further to remove hydrogen or OH radicals from water to produce C-H or C-OH bonds or may react with themselves to produce larger molecules. Well known examples of atmospheric photochemical stratospheric reactions of CFCs that have had a negative impact on the so-called ozone layer and photochemical oxidations of hydrocarbons that are involved in the generation of smog.

- In water, natural organic matter absorbs light and can participate in indirect photodegradation reactions. Other constituents in surface water, such as nitrogen oxides and iron complexes may also be involved in indirect photodegradation reactions.
- Some examples of photodegradation reactions:



- Mechanism of photodegradation of organic dye (methyl orange, MO) as pollutant:



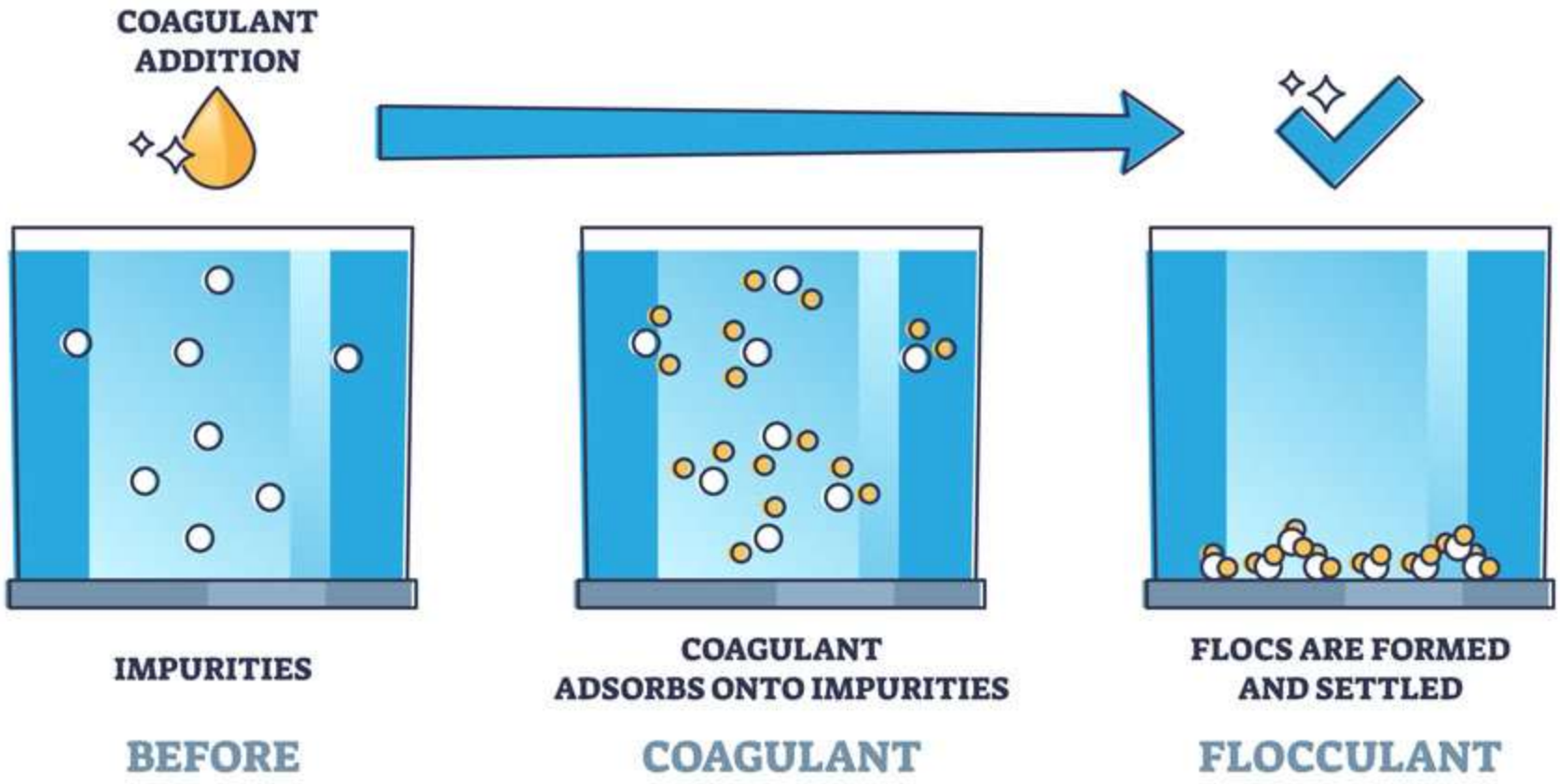
Coagulation and flocculation

- These are the chemical treatment process for the treatment of waste.
- Chemical treatment transforms waste into less hazardous substances These procedures involve the use of chemical reactions with the help of various chemicals to convert hazardous waste into less hazardous substances.
- The chemical treatment produces useful by- products and some-times residual effluent that are environmentally acceptable.
- Chemical reactions, either reduce the volume of the waste or convert the wastes to a less hazardous form.

Coagulation

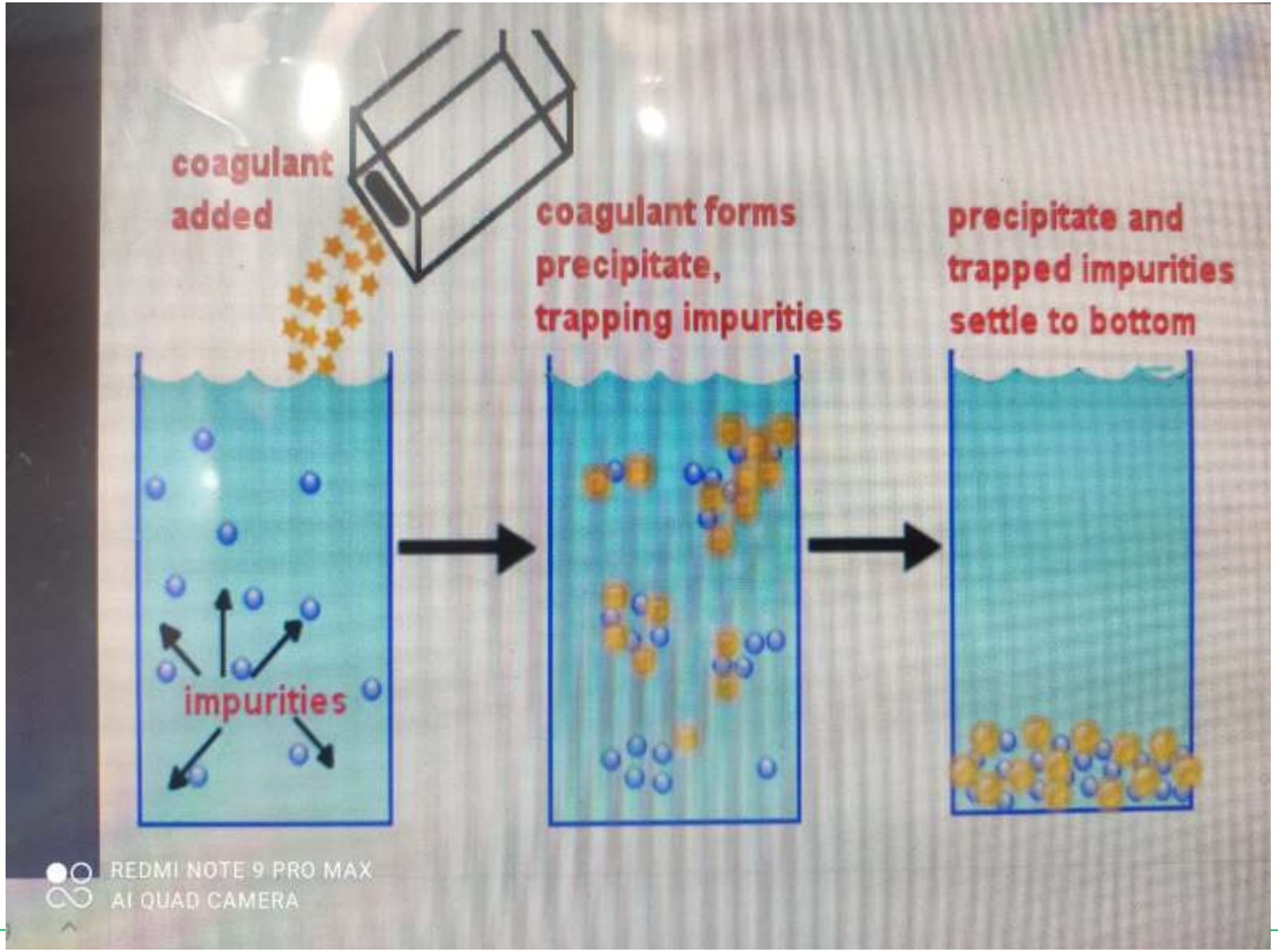
- Coagulation is the chemical water treatment process used to remove solids from water, by manipulating electrostatic charges of particles suspended in water. This process introduces small, highly charged molecules into water to destabilize the charges on particles, colloids, or oily materials in suspension. Selecting the right coagulant for a system will enhance overall system performance, and particularly improve solids removal efficiency by enhancing filter and clarifier performance.
- There are many wastewater treatment applications that require coagulation reactions, such as removing colloidal solids from water, demulsifying oil emulsions (“emulsion breaking”), and in paint detackification. There are also many types of coagulants available to meet specific needs of a treatment process. In general, coagulation precedes flocculation in a chemical water treatment process.

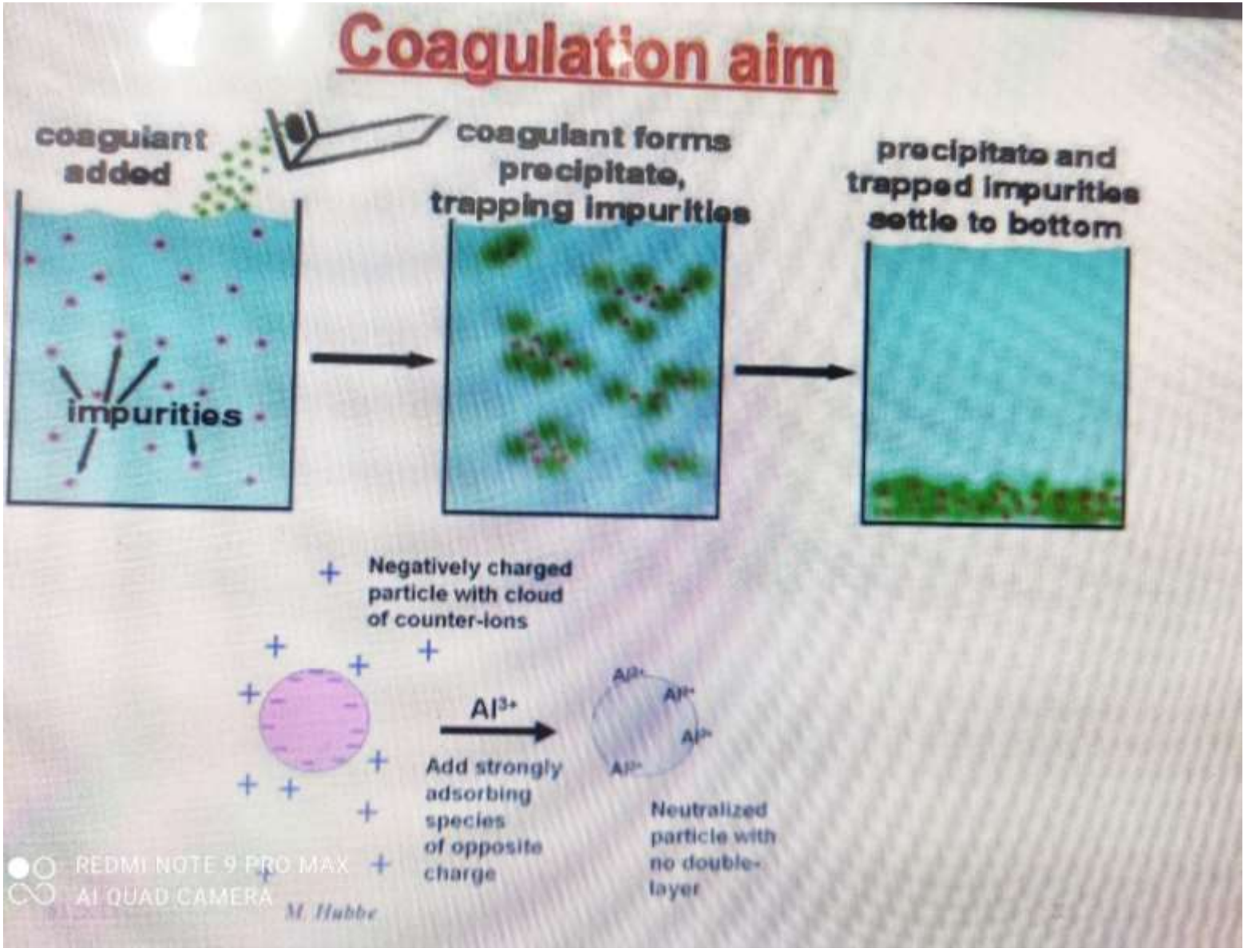
WATER COAGULATION



Theory of coagulation

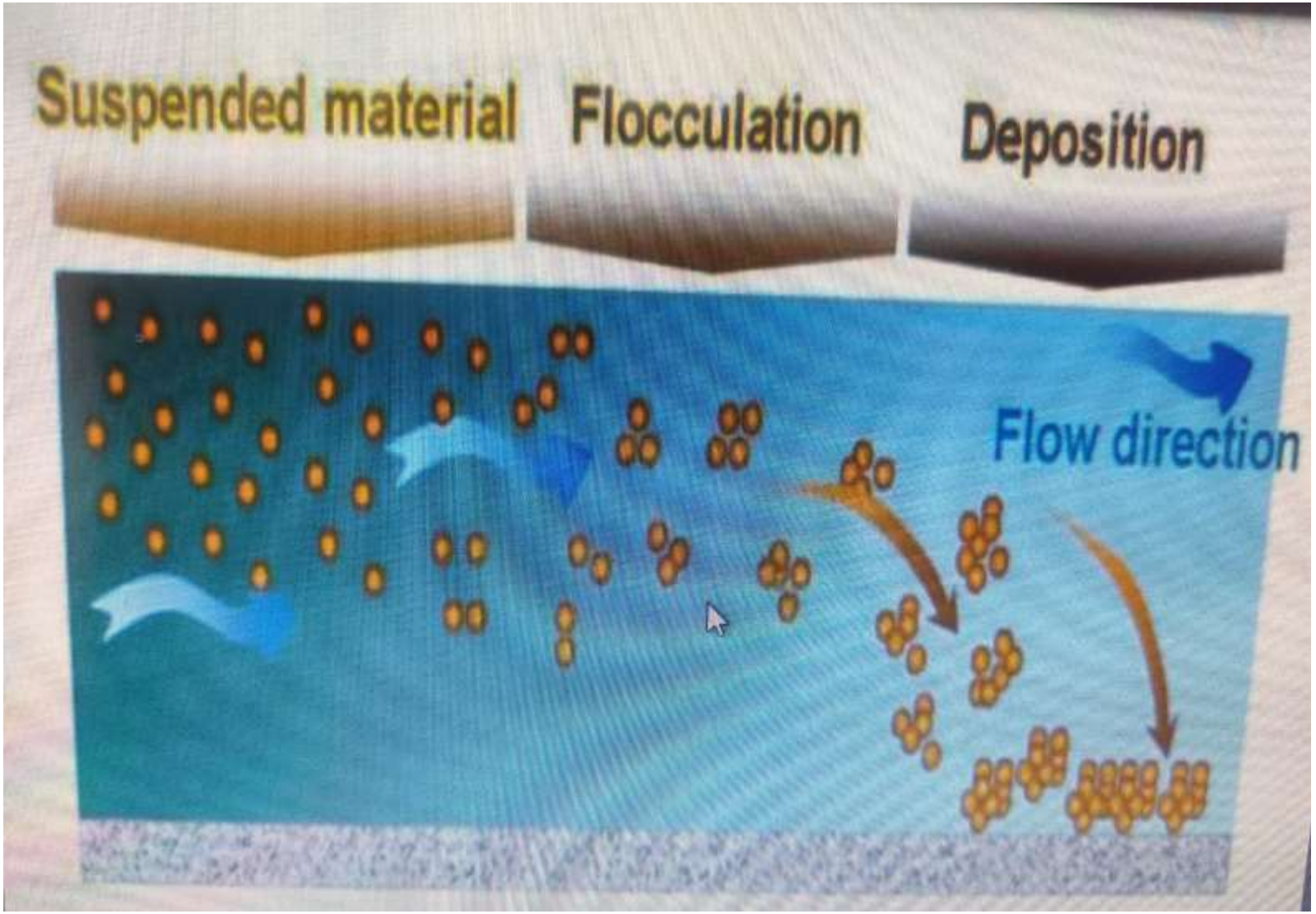
- Coagulation is the destabilization of colloids by addition of chemicals that neutralize the negative charges
- The chemicals are known as coagulants, usually higher valence
- cationic salts (Al^{3+}, Fe^{3+} etc.)
- Coagulation is essentially a chemical process
- Ionic layer compression
- Adsorption and charge neutralization
- Entrapment in a flocculent mass


coagulant added
coagulant forms precipitate, trapping impurities
precipitate and trapped impurities settle to bottom
impurities
REDMI NOTE 9 PRO MAX
AI QUAD CAMERA


Coagulation aim
coaguiant added
coaguiant forms precipitate, trapping impurities
precipitate and trapped impurities settle to bottom
impurities
Negatively charged particle with cloud of counter-ions
Al3+
Add strongly adsorbing species of opposite charge
Neutralized particle with no double-layer
M. Hubbe

Flocculation

- Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles. Microfloc particles collide, causing them to bond to produce larger, visible flocs called pinflocs.
- Chemicals used for flocculation include alum, lime, ferric chloride, ferrous sulphate and poly electrolytes. Poly electrolytes consist of long chain, water soluble polymers such as polyacrylamides.
- The inorganic flocculants such as alum, upon mixing with water, the slightly higher pH of water causes them to hydrolyse to form gelatinous precipitates of aluminium hydroxide.
- Flocculation is a water treatment process where solids form larger clusters, or flocs, to be removed from water. This process can happen spontaneously, or with the help of chemical agents. It is a common method of stormwater treatment, wastewater treatment, and in the purification of drinking water.
- One of the requirements for treated water leaving wastewater plants is the removal of suspended solids. Small solid particles affect the colour of the water and carry impurities into our natural water sources like rivers and the ocean.


Suspended material
Flocculation
Deposition
Flow direction

Waste water treatment by Flocculation:

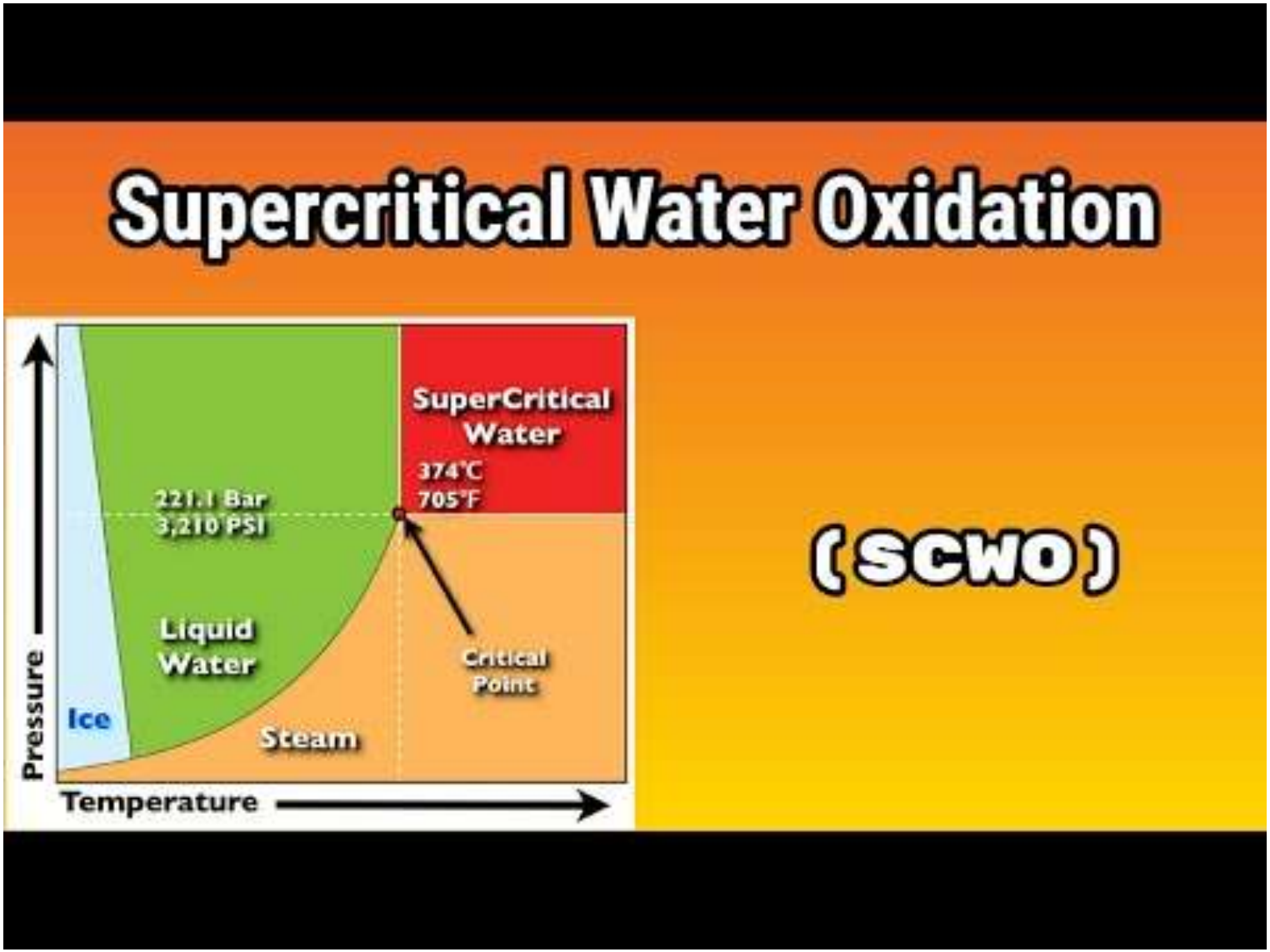
- Flocculation involves adding chemicals to the wastewater in sequence and allowing tiny solid particles to collect together in a larger mass called a floc. As a treatment of wastewater, flocculation is carried out in stages.
- **STAGE 1**
- **Suspended solid particles in wastewater are negatively charged.** In the first stage of flocculation, a coagulant like aluminium sulphate is added to the wastewater. The positively charged coagulant molecules neutralize the negatively charged solid particles suspended in the water. Neutralising these particles paves the way for them to flocculate together into a larger mass.
- **STAGE 2**
- **The wastewater must be agitated with mixers.** High energy mixing is required initially to ensure that the coagulant spreads throughout the water. When flocculation is in progress the mixing energy is reduced to prevent the mass of particles from separating again.

- **STAGE 3**
- **Once floc is beginning to form, a polymer chemical is added to the wastewater.** Polymers bridge the flocculant from micro to macro flocculant, meaning that the mass of particles collecting together gets bigger. This chemical also binds the collected mass together so that it does not easily disintegrate even when the water is slightly agitated.
- **STAGE 4**
- **After flocculation is complete, the large solid masses can be removed from the wastewater stream.** This is done either through settling where the floc drops to the bottom for removal or through the use of filters which capture the floc in the filter material. Care must be taken when cleaning the filters to ensure that the phosphorus rich floc is contained and treated.

Supercritical Water Oxidation (SCWO)

- Supercritical water oxidation (SCWO) is a single step wet oxidation process that transforms organic matter into water, carbon dioxide and, depending on the waste undergoing treatment, an inert mineral solid residue.
- The process is highly effective and can treat a variety of wet wastes without dewatering.
- The SCWO technology allows for the complete destruction of persistent and toxic organic contaminants such as perfluoroalkyl and polyfluoroalkyl substances (PFAS), 1,4-dioxane, and many more.

- Supercritical water oxidation (SCWO) is an advanced oxidation process that holds enormous potential for the treatment of a wide range of organic wastes, in particular concentrated wet wastes in slurries such as biosolids, sludges, agricultural wastes, chemical wastes with recalcitrant chemicals such as perfluoroalkyl and polyfluoroalkyl substances (PFAS), and many more.
- SCWO relies on the unique reactivity and transport properties that occur when an aqueous waste stream is brought above the critical point of water (374°C and 218 atm, or 704°F and 3200 psi, see phase diagram in Figure).
- Supercritical water is a dense single phase with transport properties similar to those of a gas, and solvent properties comparable to those of a non-polar solvent. Oxygen is fully soluble in supercritical water, resulting in extremely rapid and complete oxidation of all organics to carbon dioxide, clean water (that can be reused), and some non-leachable inorganic salts.


Supercritical Water Oxidation
SuperCritical Water
374°C
705°F
221.1 Bar
3,210 PSI
Liquid Water
Ice
Steam
Critical Point
Pressure
Temperature
(SCWO)

Supercritical water oxidation of waste fluid