EV20001: ENVIRONMENTAL SCIENCE

Lecture #8

Water Resources & Water Pollution

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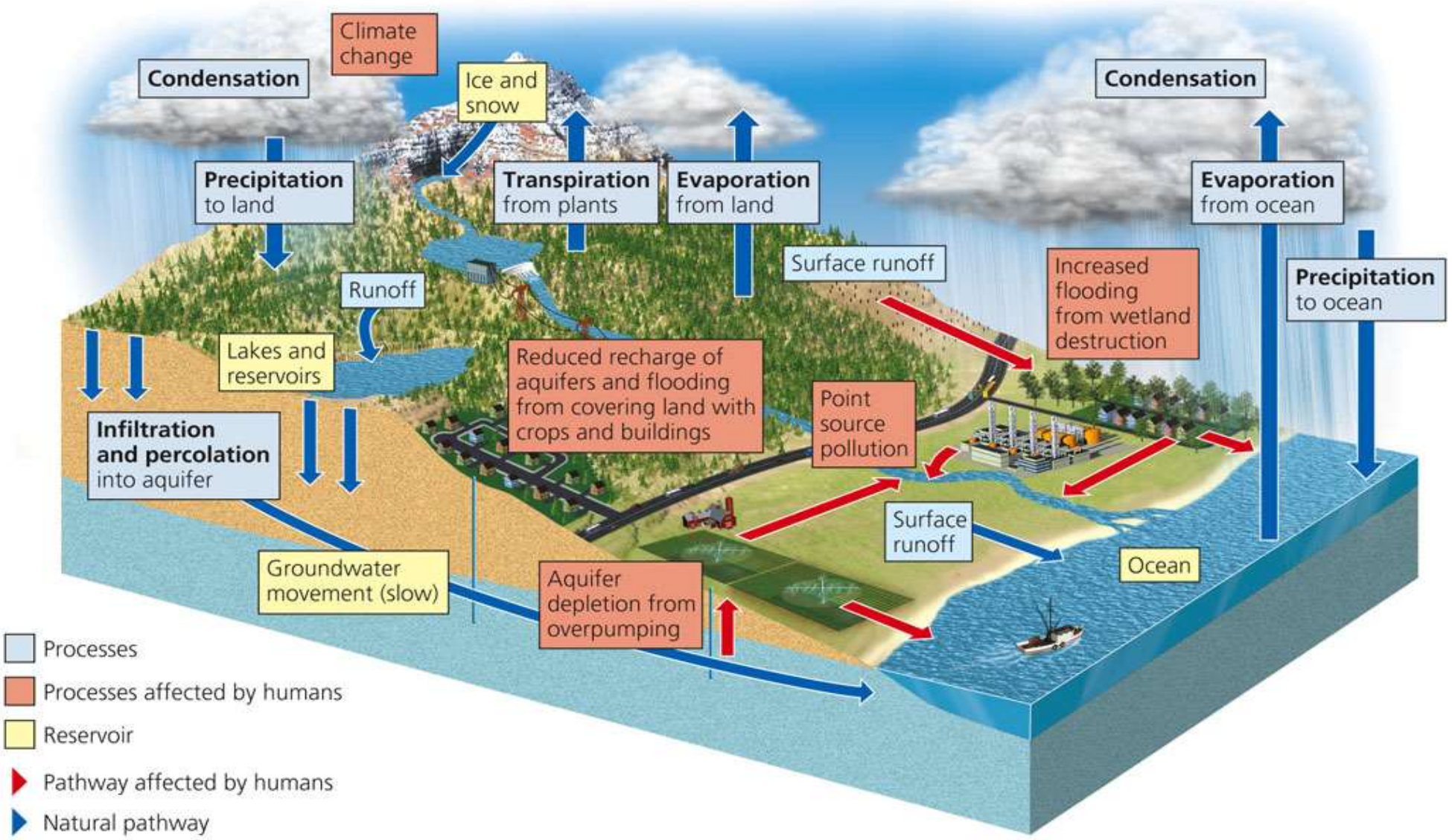
Importance and availability of water

- Water is crucial for all aspects of life, the defining feature of our planet.
- About 71% of the Earth’s surface is covered with water, and the oceans hold about 96.5% of all the Earth's water.
- Only 3% of the total water in the world is freshwater and less than 1% is readily available in rivers, lakes, and streams.
- The world’s freshwater supply is continually collected, purified, recycled, and distributed in the Earth’s water cycle.

Importance and availability of water

- Freshwater is an irreplaceable resource that is most poorly managed. We waste it and pollute it. We also charge too little for making it available.
- Water is an economic issue because it is vital for reducing poverty and producing food and energy.
- Water is a national and global security issue because of increasing tensions within and between nations over access to limited waster resources that they share.
- Water is an environmental issue because excessive withdrawal of water from rivers and aquifers results in dropping water tables, shrinking lakes, and loss of wetlands.

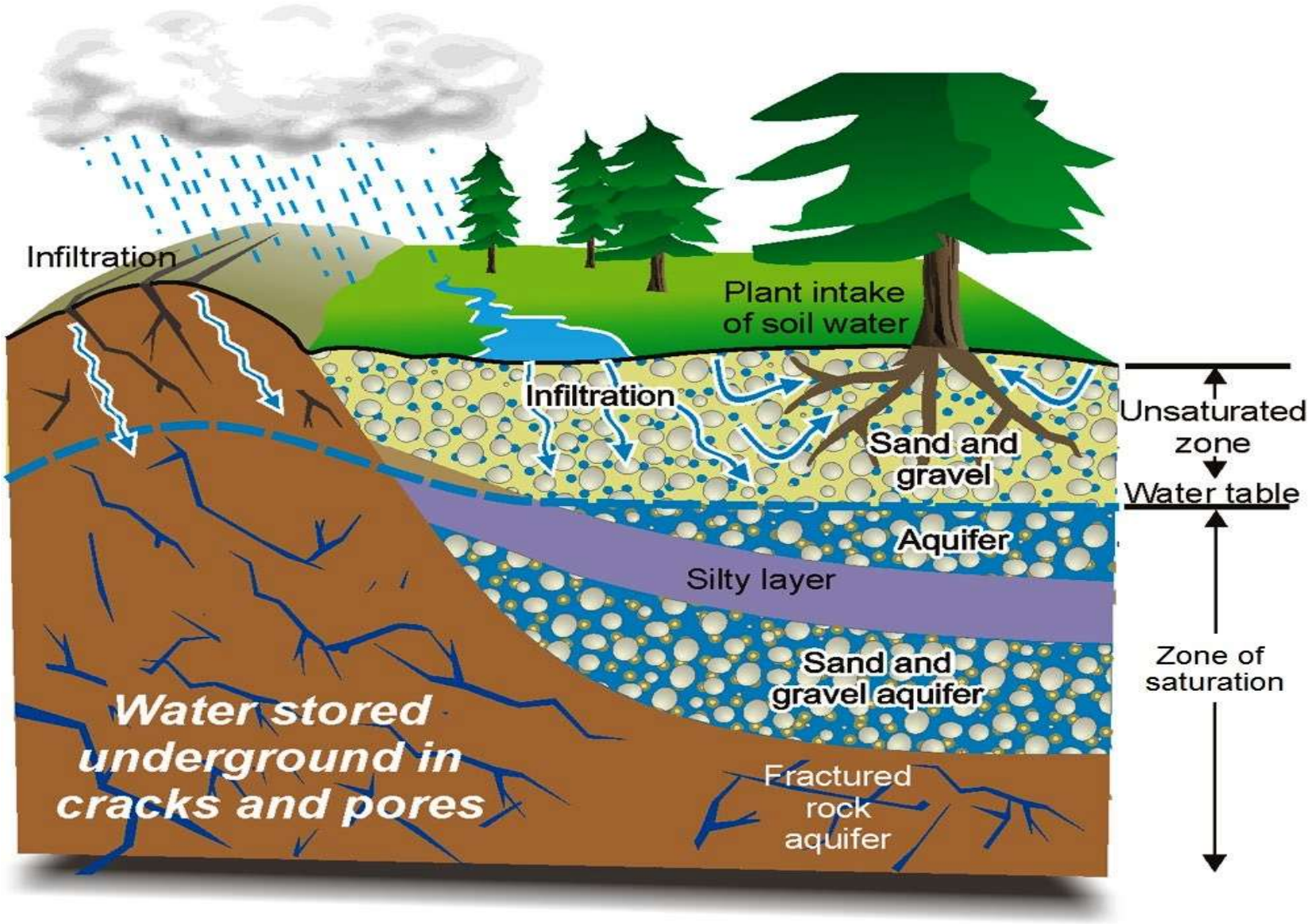
- Some of our actions purposefully affect the water cycle and other human activities have unintentional consequences on the water cycle.



Groundwater

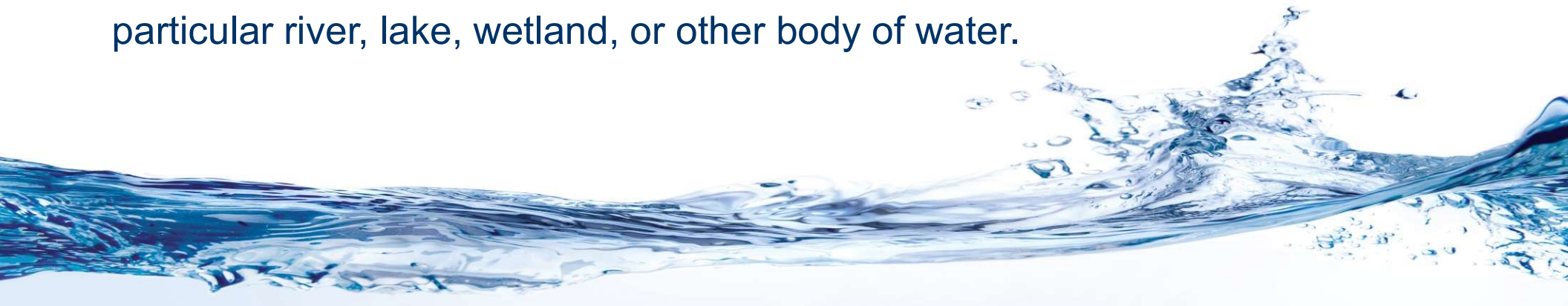
- Water located beneath Earth's surface in soil pore spaces and in the fractures of rock formations.
- Water table is the level beneath the Earth's surface below which all pore spaces are filled with water, and above which the pore spaces are filled with air.
- Zone of saturation is the area beneath the water table where all pore spaces are completely filled with water.
- Aquifers are underground caverns and porous layers of sand, gravel, or bedrock through which groundwater flows.
- Most aquifers are replenished by natural recharge. Others are recharged by lateral recharge.

- Groundwater can become polluted with nutrients or chemicals when surface water carrying these substances drains into the groundwater environment.



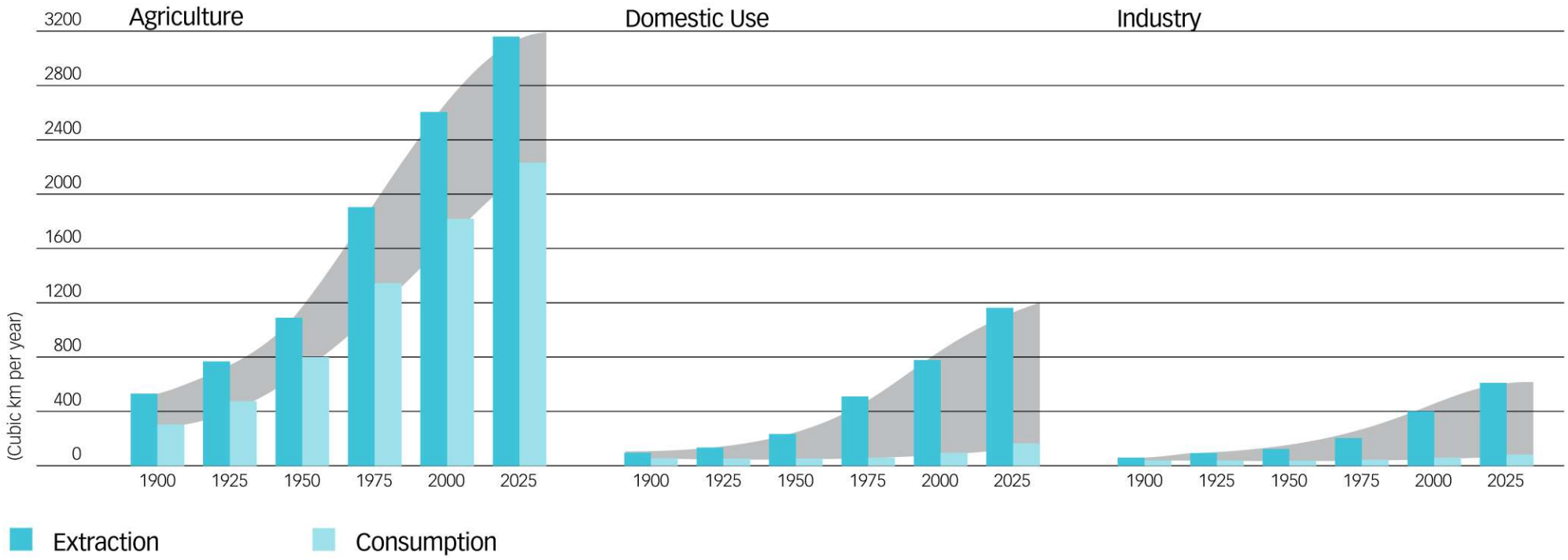
Surface water

- Water from precipitation and snowmelt that flows across the Earth's land surface and into lakes, wetlands, streams, rivers, estuaries, and ultimately to the oceans.
- Surface runoff – precipitation that does not infiltrate the ground or return to the atmosphere by evaporation.
- Two third of the annual surface runoff in rivers and streams is lost by seasonal floods and is not available for human use.
- Remaining one third is reliable surface runoff – source of freshwater from year to year.
- Watershed/Drainage basin is the land from which surface water drains into a particular river, lake, wetland, or other body of water.



Global water use

- Water may be extracted, used, recycled (or returned to rivers or aquifers) and reused several times over. Consumption is the final use of water, after which it can no longer be reused.
- That extraction has increased at a much faster rate, is an indication of how much more intensively we now exploit water. Only a fraction of water extracted is lost through evaporation.



Global water crisis

- Main factors causing water scarcity: (i) dry climate, (ii) drought, (iii) too many people using a water supply, and (iv) wasteful use of water.
- Currently, about 1 billion people – one of every seven – in the world lack regular access to clean water.
- There will be a 40% gap between water demand and water available by 2030.
- 1.8 billion people now use water as drinking source that is contaminated by faeces.
- 80% or more of wastewater returns to the environment without adequate treatment.
- 30% of global water abstraction is lost due to leakage.
- Water scarcity currently affects 40% of the global population.
- 70% more food will be needed to feed the world's population by 2050, and therefore 70-90% of all water globally will be used for agriculture.

Common effects of water scarcity

- The effects of water stress and water scarcity can be felt in many ways, both immediate and long-term.

REDUCED OUTPUTS

HIGHER COSTS

POLITICAL STRESS

MIGRATION

FAMINE

Increasing freshwater supplies

Solutions

Reducing Water Waste

- Redesign manufacturing processes to use less water
- Recycle water in industry
- Landscape yards with plants that require little water
- Use drip irrigation
- Fix water leaks
- Use water meters
- Raise water prices
- Use waterless composting toilets
- Require water conservation in water-short cities
- Use water-saving toilets, showerheads, and front-loading clothes washers
- Collect and reuse household water to irrigate lawns and nonedible plants
- Purify and reuse water for houses, apartments, and office buildings

Increasing freshwater supplies

Trade-Offs

Withdrawing Groundwater

Advantages

Useful for drinking and irrigation

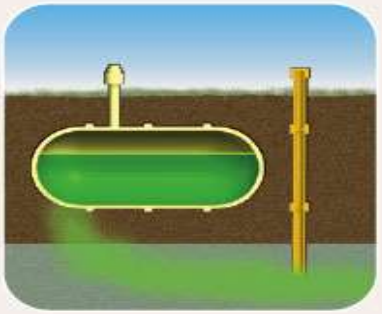
Available year-round

Exists almost everywhere

Renewable if not overpumped or contaminated

No evaporation losses

Cheaper to extract than most surface waters



Disadvantages

Aquifer depletion from overpumping

Sinking of land (subsidence) from overpumping

Aquifers polluted for decades or centuries

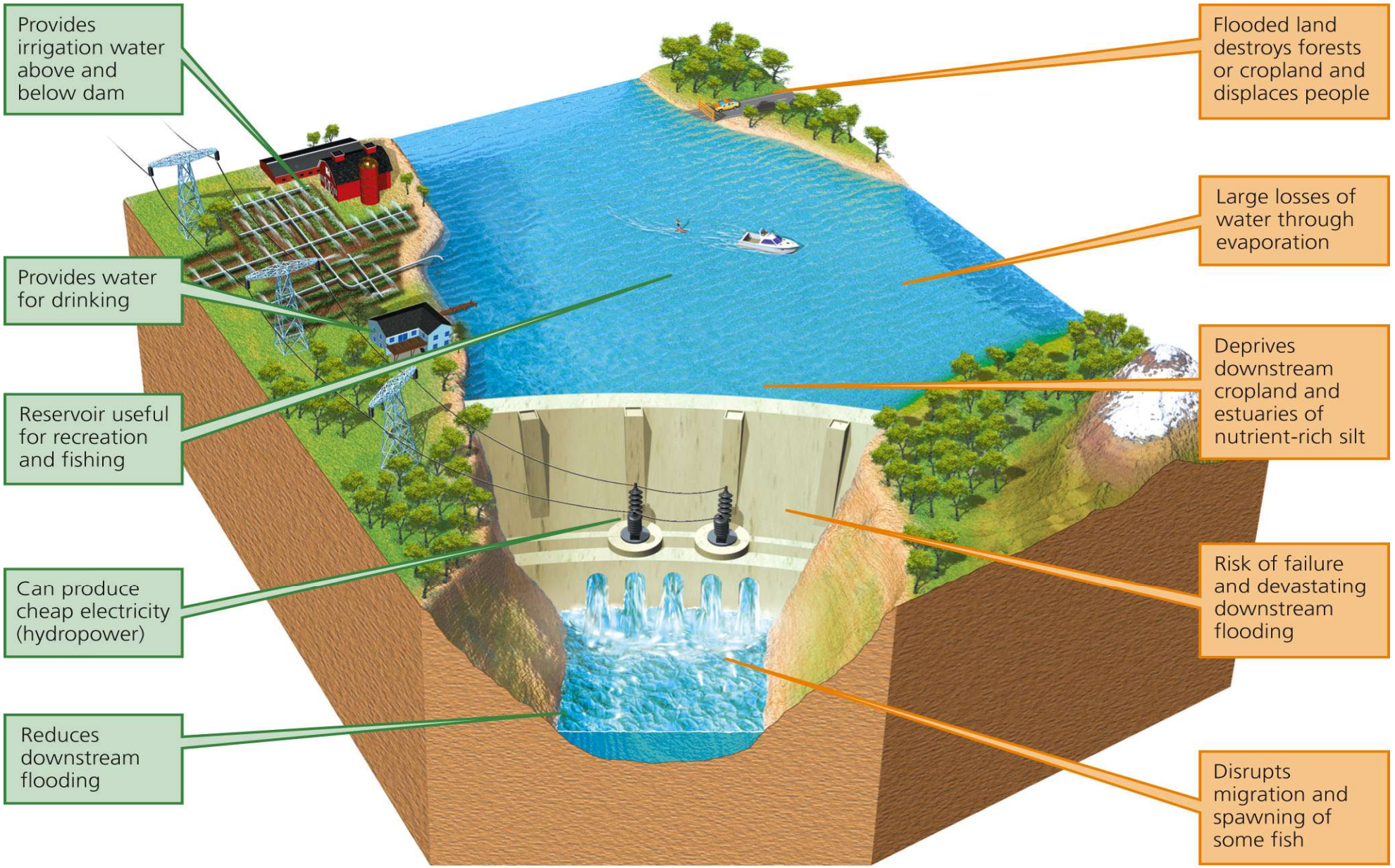
Saltwater intrusion into drinking water supplies near coastal areas

Reduced water flows into surface waters

Increased cost and contamination from deeper wells

Increasing freshwater supplies

- Building dams and reservoirs to store runoff in rivers

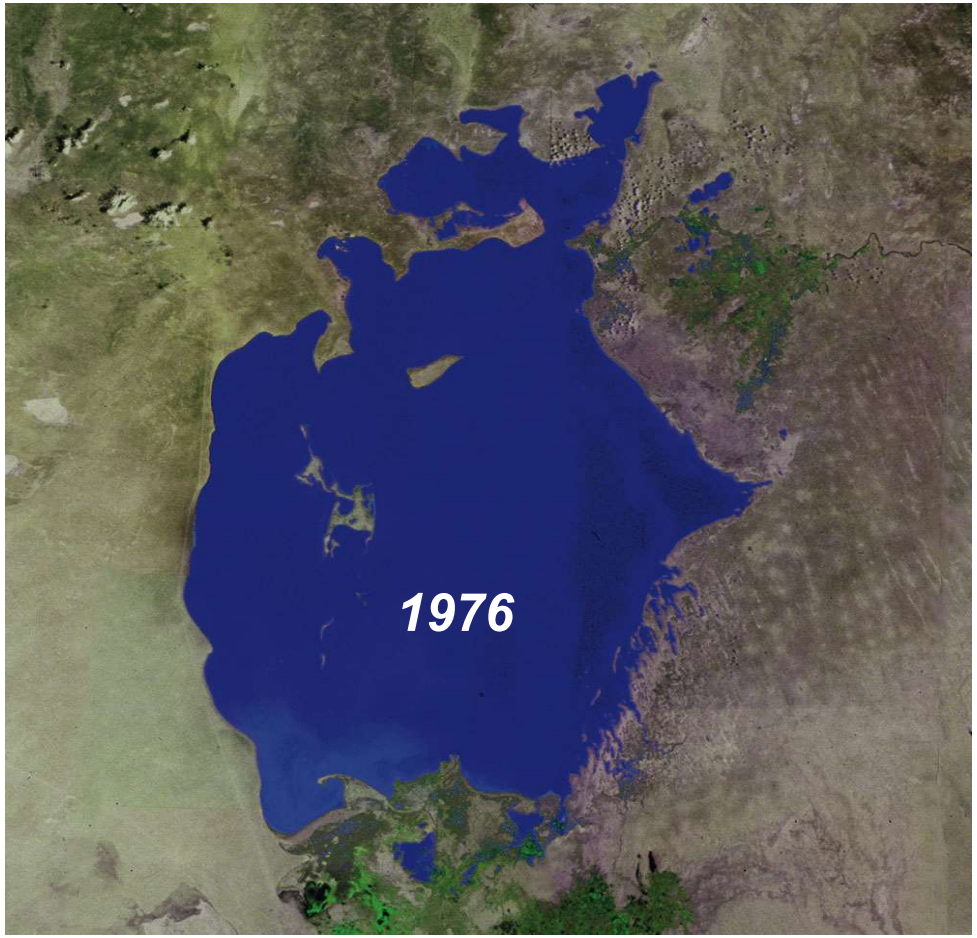


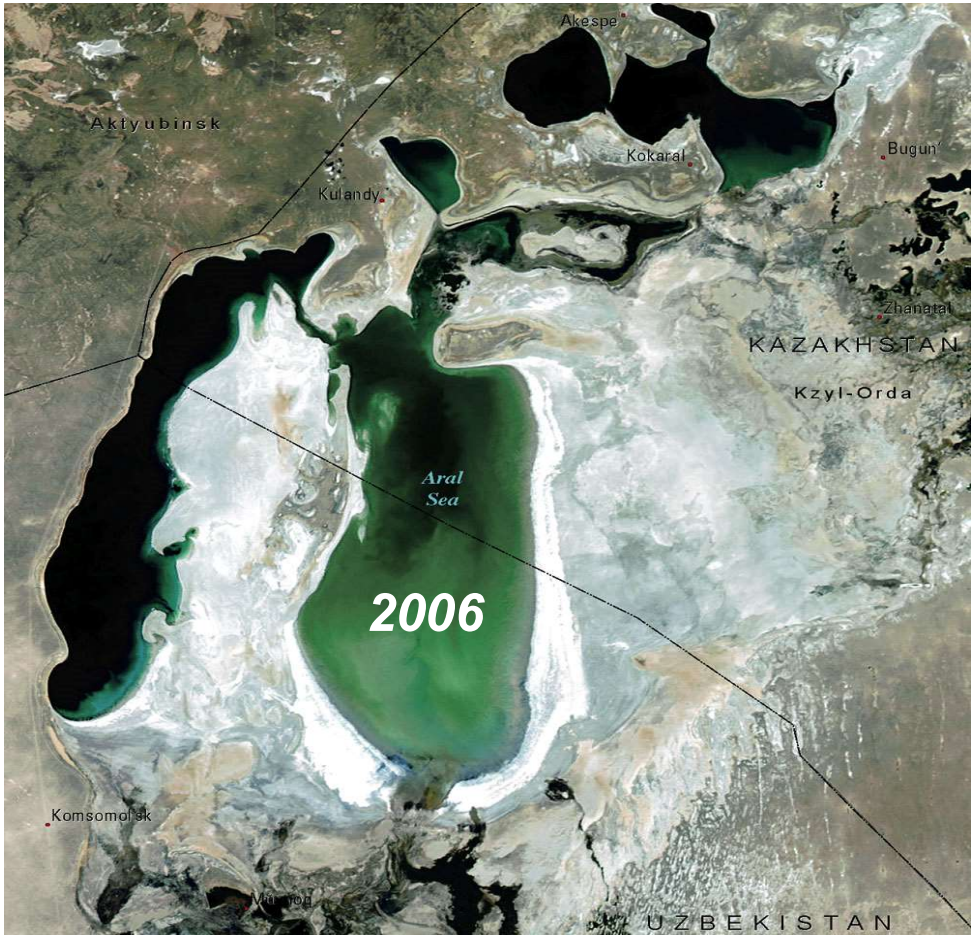
Increasing freshwater supplies

- Transporting surface water from one area to another

California Water Project and the Central Arizona Project transfer massive amounts of water from water-rich areas to water-poor areas.

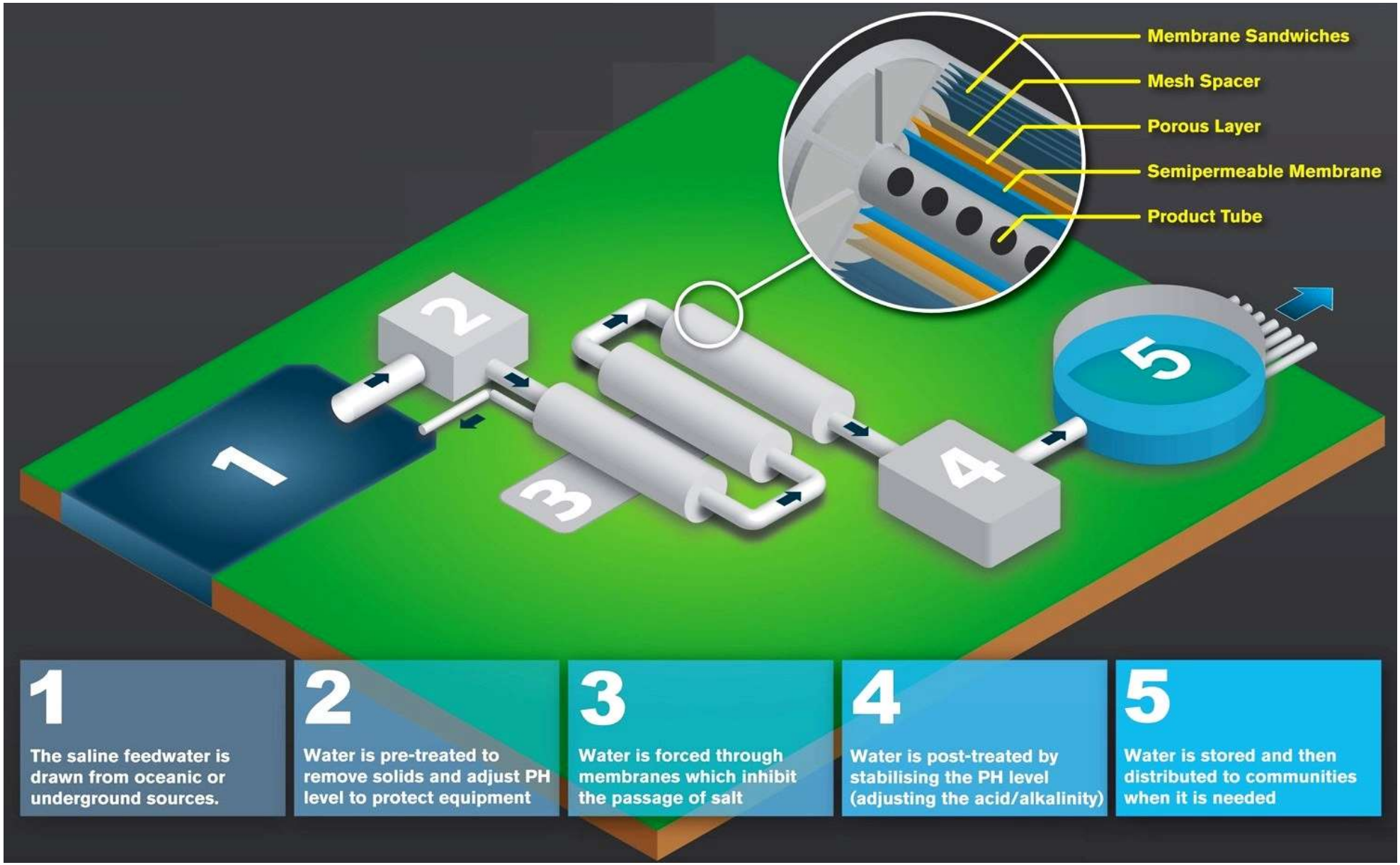
- **Aral Sea Disaster:** The Aral Sea was one of the world's largest saline lakes. Since 1960, it has been shrinking and getting saltier because most of the water from the rivers that replenish it has been diverted to grow cotton and food crops. As the lake shrank, it split into two lakes and left behind a salty desert, economic ruin, increasing health problems, and severe ecological disruption.





Increasing freshwater supplies

- Converting saltwater to freshwater (desalination)



- Two leading technologies for desalinating water:

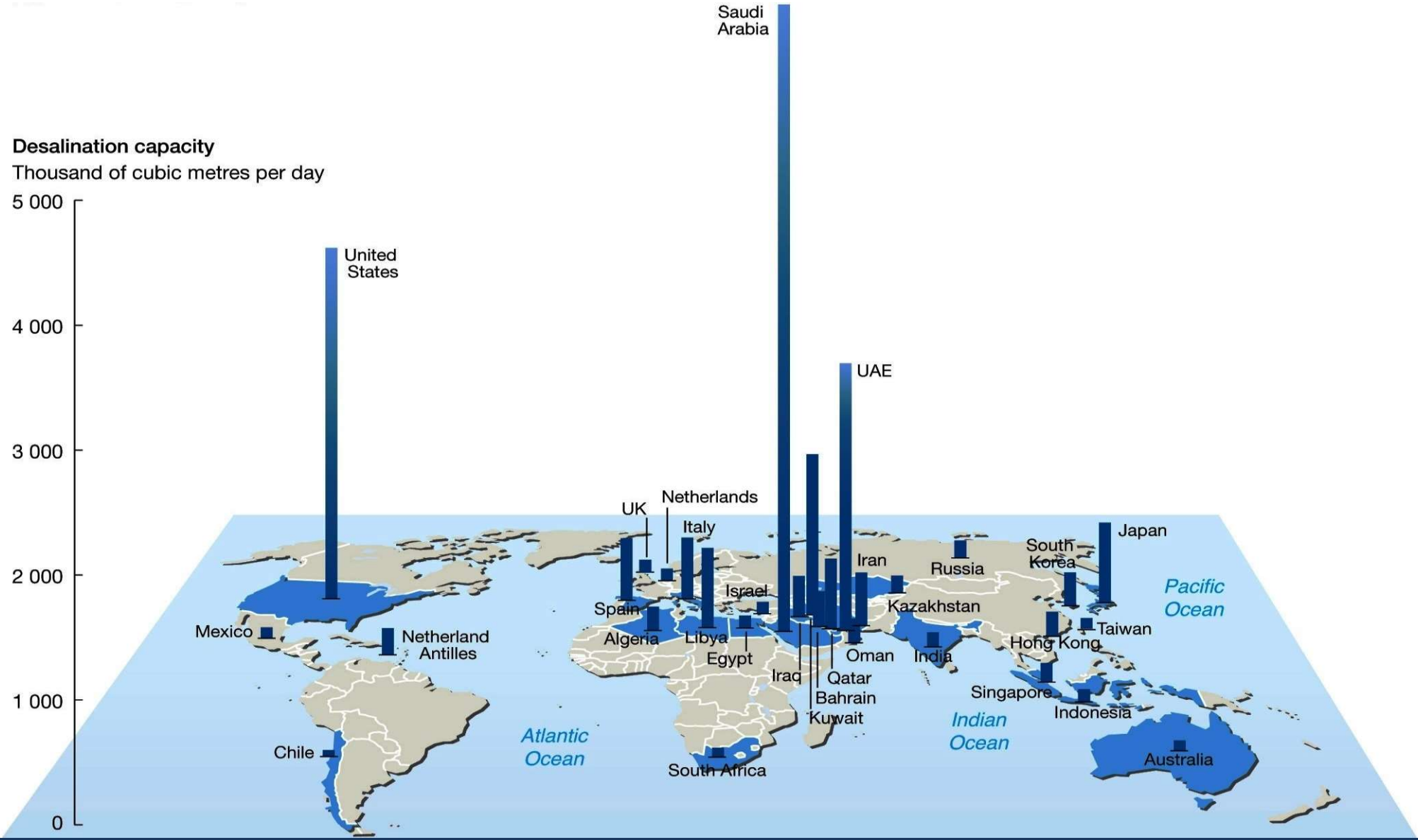
  - **Distillation**

    - Heating saltwater until it evaporates (leaving behind salts in solid form) and condenses as freshwater
    - Complete rejection of non volatiles (e.g., salts, ions, colloids, cells, and organic non volatiles)
    - Less commercialised for large scale desalination plant

  - **Reverse Osmosis**

    - Uses high pressure to force saltwater through a membrane filter with pores small enough to remove the salt
    - Higher productivity of water and high water efficiency
    - Highly commercialised for large scale desalination plant

- About 13,000 desalination plants operate in more than 125 countries, especially in the arid nations of the Middle East, North Africa, the Caribbean, and the Mediterranean.



Using water sustainably

Solutions

Sustainable Water Use

- Waste less water and subsidize water conservation
- Do not deplete aquifers
- Preserve water quality
- Protect forests, wetlands, mountain glaciers, watersheds, and other natural systems that store and release water
- Get agreements among regions and countries sharing surface water resources
- Raise water prices
- Slow population growth

Individual choices make a difference

What Can You Do?

Water Use and Waste

- Use water-saving toilets, showerheads, and faucet aerators
- Shower instead of taking baths, and take short showers
- Repair water leaks
- Turn off sink faucets while brushing teeth, shaving, or washing
- Wash only full loads of clothes or use the lowest possible water-level setting for smaller loads
- Use recycled (gray) water for watering lawns and houseplants and for washing cars
- Wash a car from a bucket of soapy water, and use the hose for rinsing only
- If you use a commercial car wash, try to find one that recycles its water
- Replace your lawn with native plants that need little if any watering
- Water lawns and yards only in the early morning or evening
- Use drip irrigation and mulch for gardens and flowerbeds

Water pollution

- Water pollution is any change in water quality that harms humans or other living organisms or makes water unsuitable for desired uses.

Sources of water pollution

- Pollutants entering water bodies come from two types of sources:
  - **Point sources**
    - Discharge pollutants at specific locations through drain pipes, ditches, or sewer lines into bodies of surface water
    - Easier to identify, monitor, and regulate
    - Example: factories, underground mines, oil tankers
  - **Nonpoint sources**
    - Broad, diffuse areas from which pollutants enter bodies of surface water
    - Little progress in controlling water pollution from nonpoint sources because of the difficulty and expense of identifying and controlling discharges from such sources
    - Example: runoff of chemicals and sediments from cropland, livestock feedlots, logged forests, urban streets, parking lots, lawns, and golf courses

Major water pollutants and their sources

Type/Effects	Examples	Major sources
Infectious agents (pathogens) *Cause diseases*	Bacteria, viruses, protozoa, parasites	Human and animal wastes
Oxygen-demanding wastes *Deplete dissolved oxygen needed by aquatic species*	Biodegradable animal wastes and plant debris	Sewage, animal feedlots, food processing facilities, pulp mills
Plant nutrients *Cause excessive growth of algae and other species*	Nitrates (NO_3^-) and phosphates (PO_4^{3-})	Sewage, animal wastes, inorganic fertilizers
Organic chemicals *Add toxins to aquatic systems*	Oil, gasoline, plastics, pesticides, cleaning solvents	Industry, farms, households
Inorganic chemicals *Add toxins to aquatic systems*	Acids, bases, salts, metal compounds	Industry, households, surface runoff
Sediments *Disrupt photosynthesis, food webs, other processes*	Soil, silt	Land erosion
Heavy metals *Cause cancer, disrupt immune and endocrine systems*	Lead, mercury, arsenic	Unlined landfills, household chemicals, mining refuse, industrial discharges
Thermal *Make some species vulnerable to disease*	Heat	Electric power and industrial plants

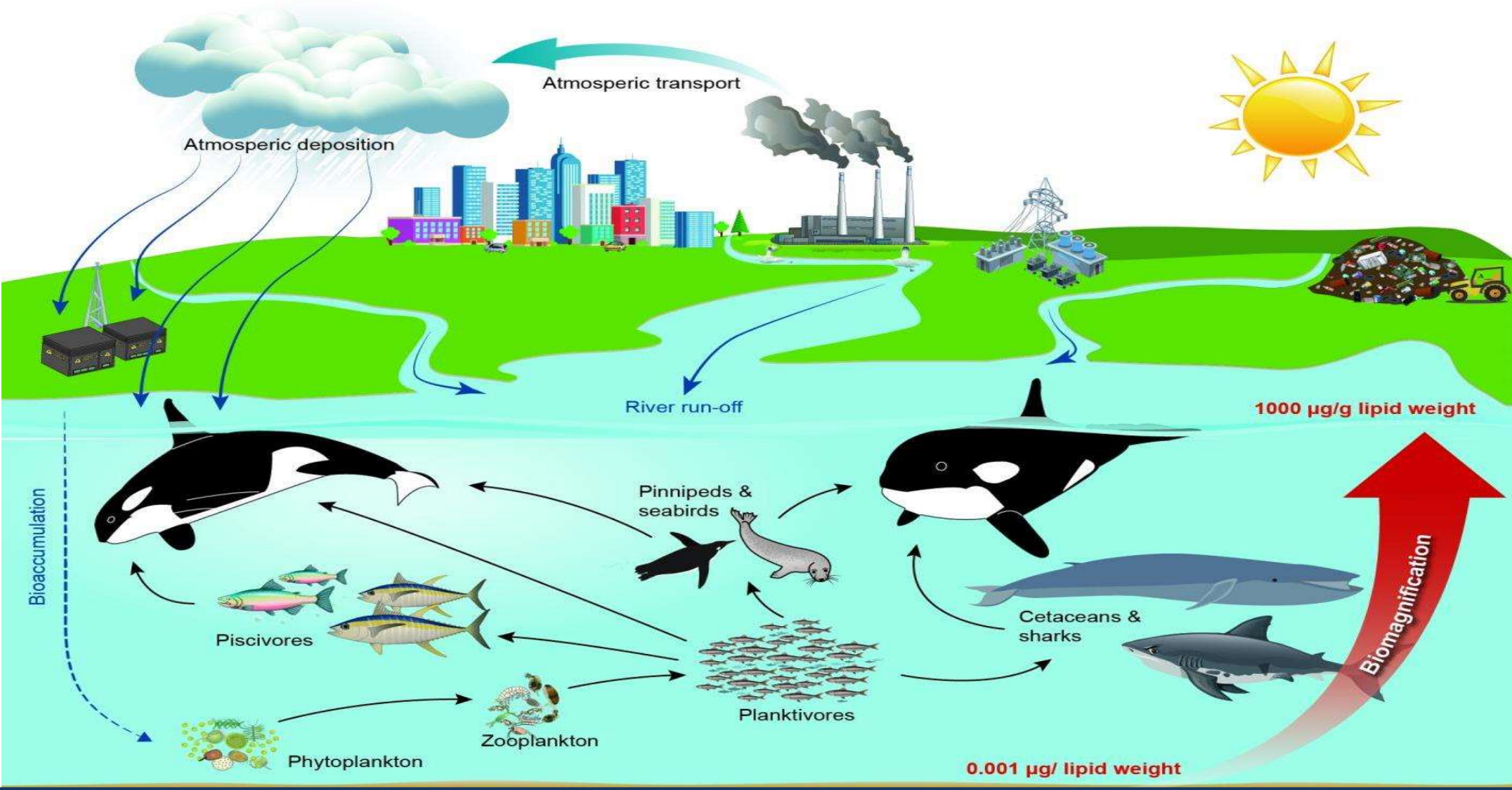
Endocrine disruptors

- Endocrine disrupting compounds (EDCs) are chemicals which can interfere with the normal function of hormones in aquatic animals. They can enter water courses through wastewater discharges from industry and sewage and also in agricultural run-off.

- EDCs are found in various materials such as pesticides, metals, additives or contaminants in food, and personal care products.

- They are known to impair growth and development in animals, lead to reproductive abnormalities and can even cause some species to change sex.

- An important process by which chemicals can affect living organisms is through bioaccumulation. **Bioaccumulation** is the increase in the concentration of a chemical over time in the tissues of organisms compared to the chemical's concentration in the environment. It results from a dynamic equilibrium between exposure from the outside environment and uptake, excretion, storage, and degradation within an organism.



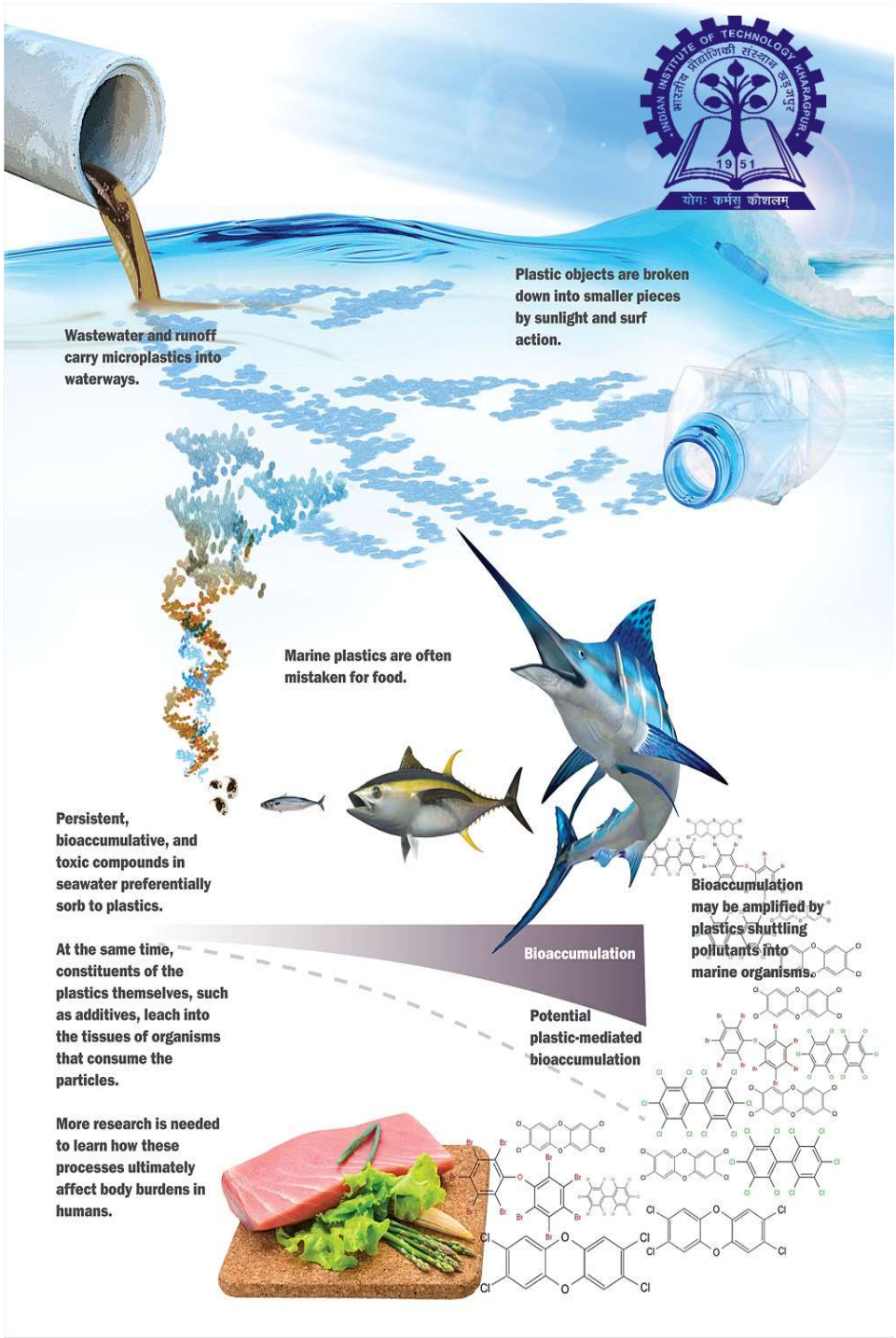
- The extent of bioaccumulation depends on the concentration of a chemical in the environment, the amount of chemical coming into an organism from the food, air or water, and the time it takes for the organism to acquire the chemical and then excrete, store, and/or degrade it.

- The nature of the chemical itself, such as its solubility in water and fat, affects its uptake and storage.

- Equally important is the ability of the organism to degrade and excrete a particular chemical.

- When exposure ceases, the body gradually metabolizes and excretes the chemical.

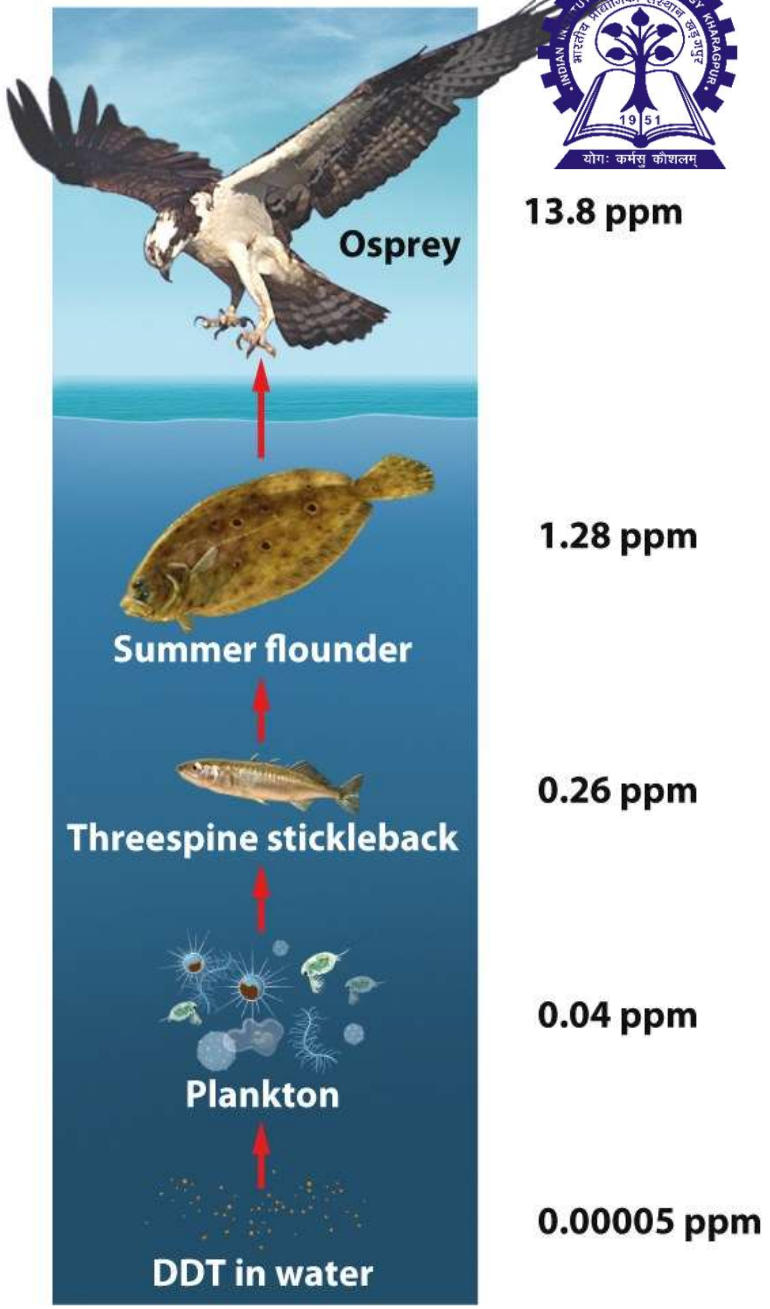
- When a harmful substance gets absorbed by an organism at a higher rate than it can be excreted, the organism is at risk of chronic poisoning.



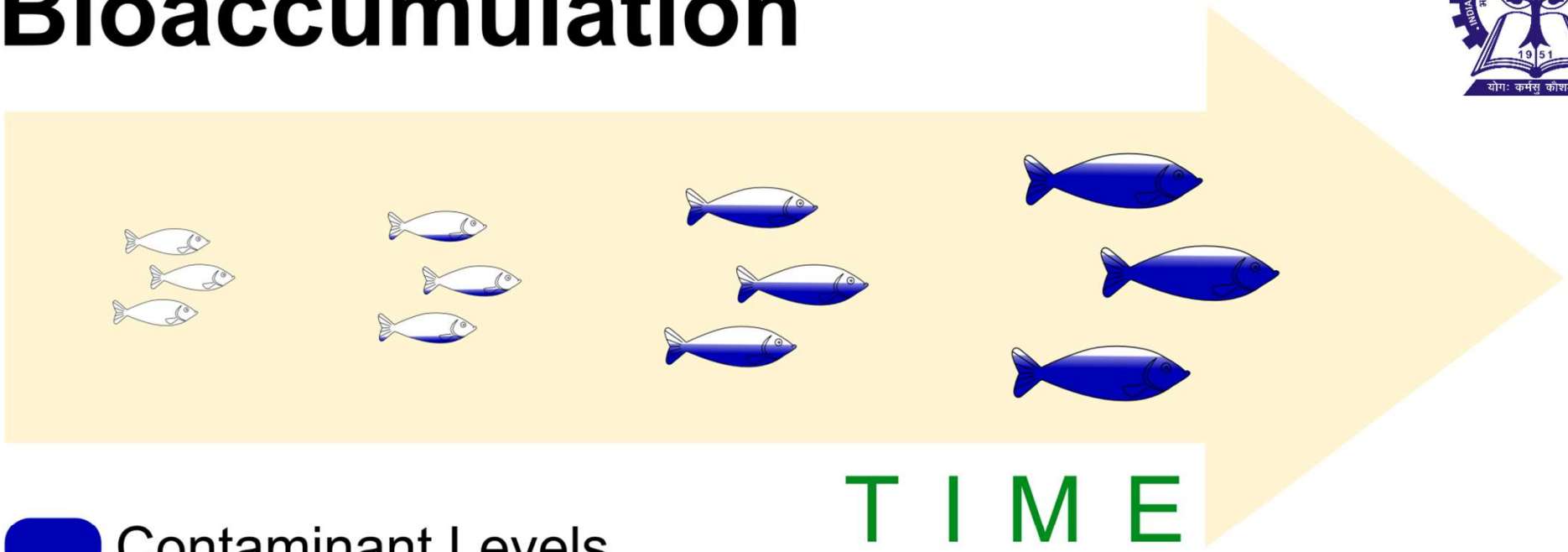
- **Biomagnification** is the process by which toxic chemicals build up within predators. This typically occurs across an entire food chain and affects all of the organisms but animals higher up in the chain are more impacted.

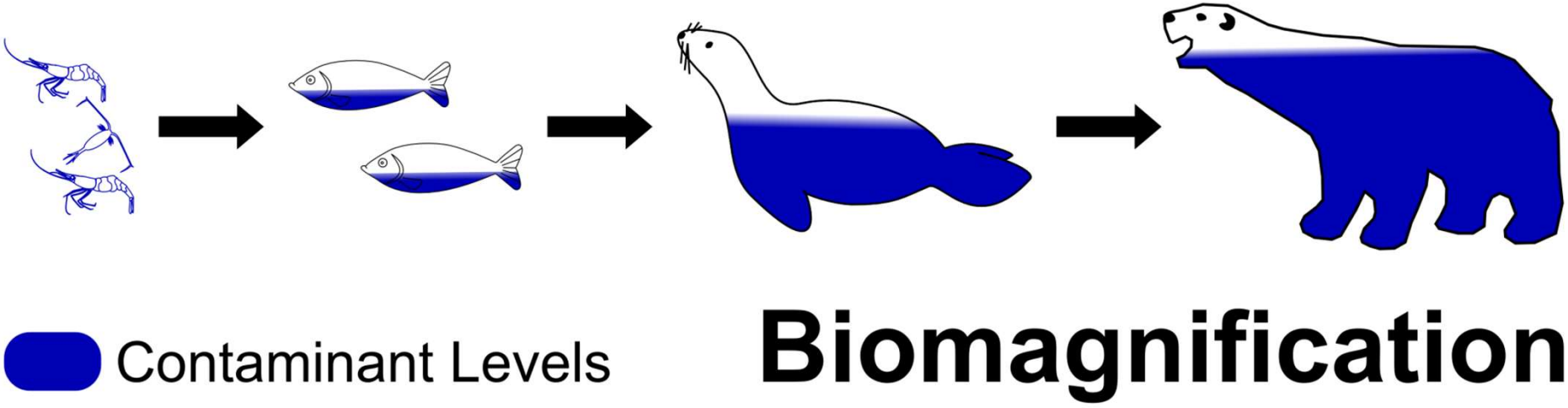
- The initial exposure is primarily in a low trophic group such as the plankton in a lake. Consumption causes the upward movement of the chemical where it is accumulated in the bodies at each trophic level. The combination of bioaccumulation at each trophic level and upward movement by consumption allows the concentration to magnify to the point where it can be substantially more concentrated in the top predator than it was in the water.

- Biomagnification can, therefore, be considered the result of bioaccumulation.



Bioaccumulation

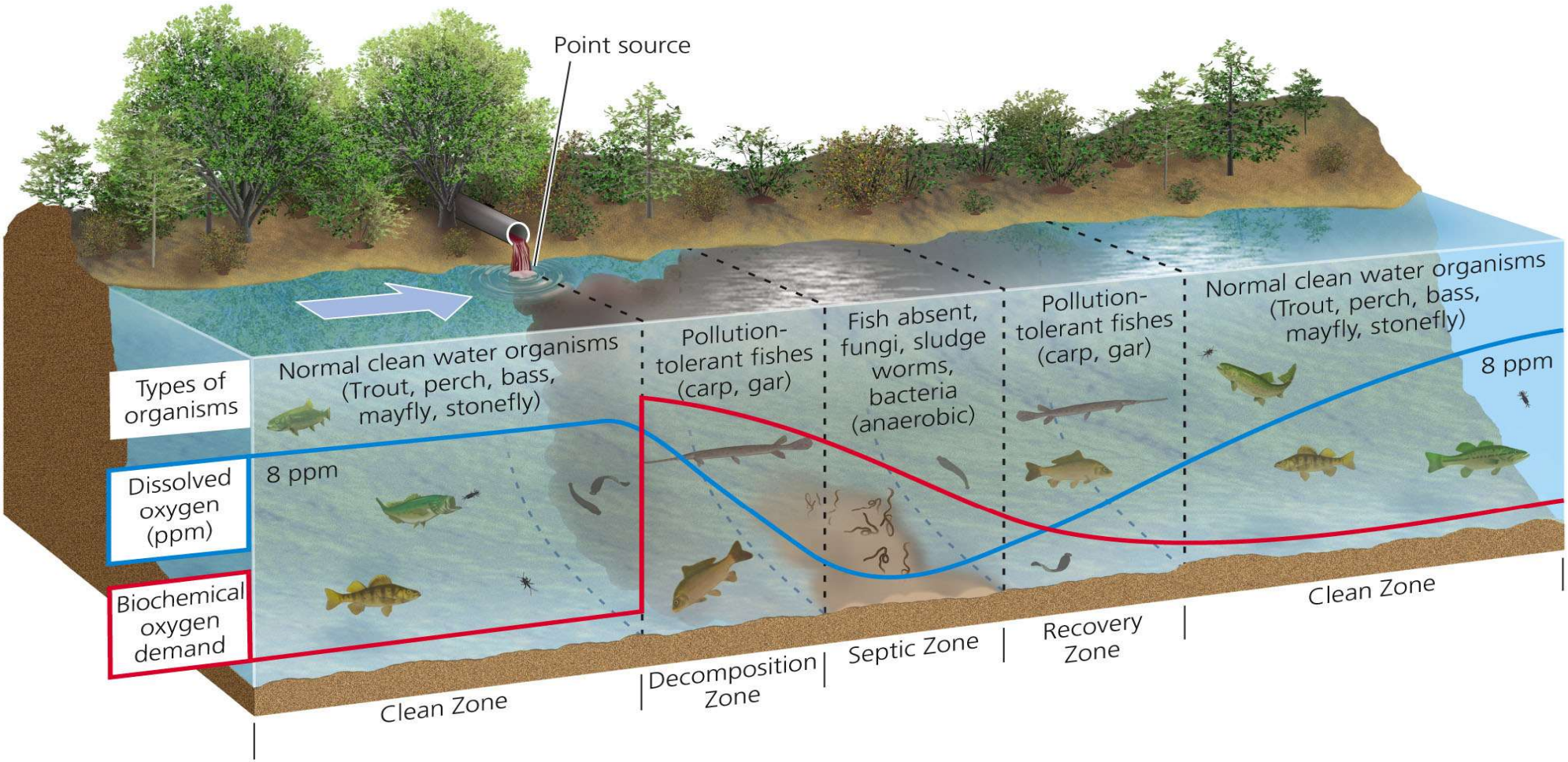




Biomagnification

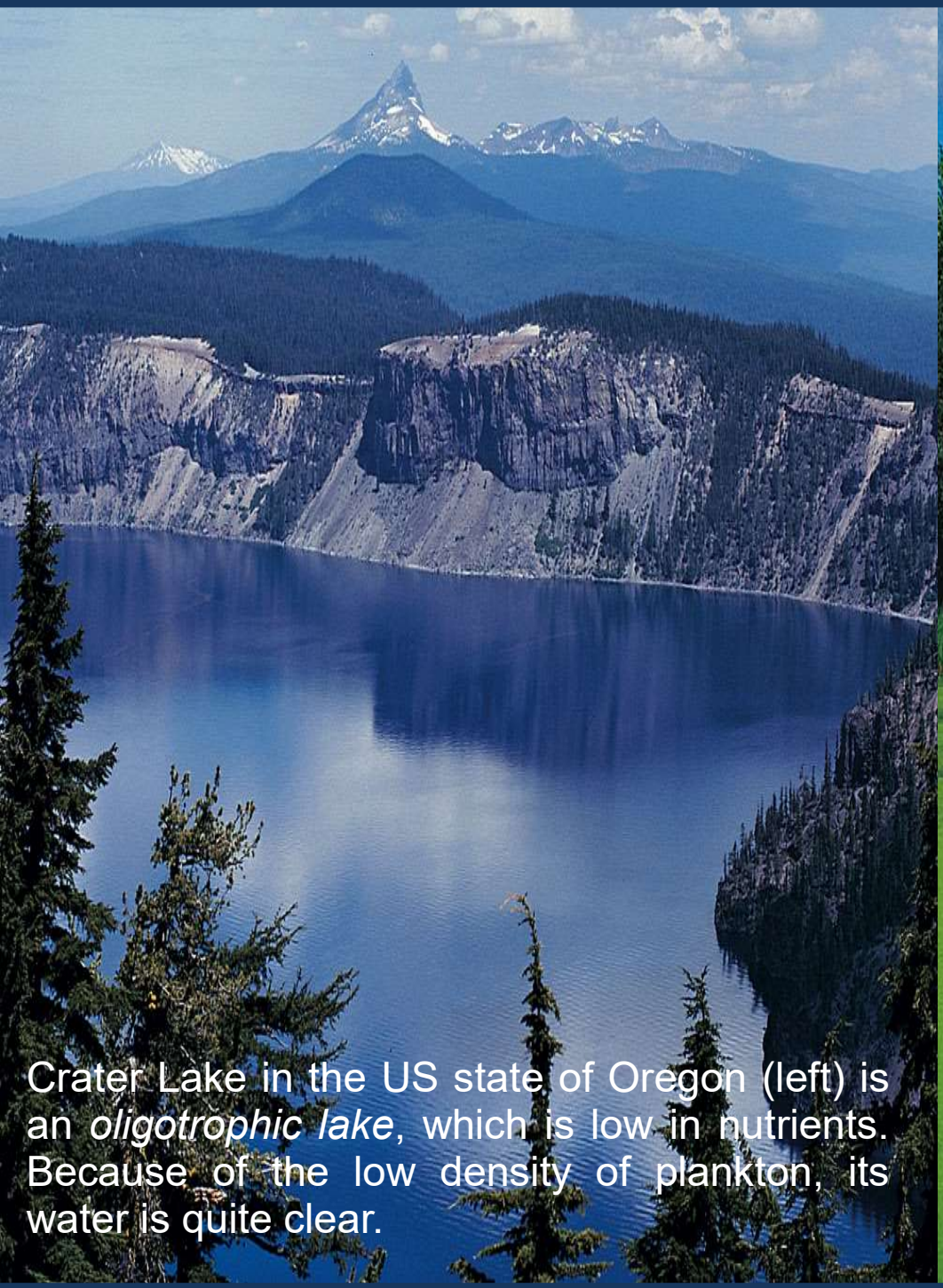
Streams can cleanse themselves

- In a flowing stream, the breakdown of biodegradable wastes by bacteria depletes dissolved oxygen and creates and oxygen sag curve (blue). This reduces or eliminates populations of organisms with high oxygen requirements. Depending on flow rates and the amount of biodegradable pollutants, streams recover from injection of oxygen demanding wastes or heated waste if they are given enough time and are not overloaded

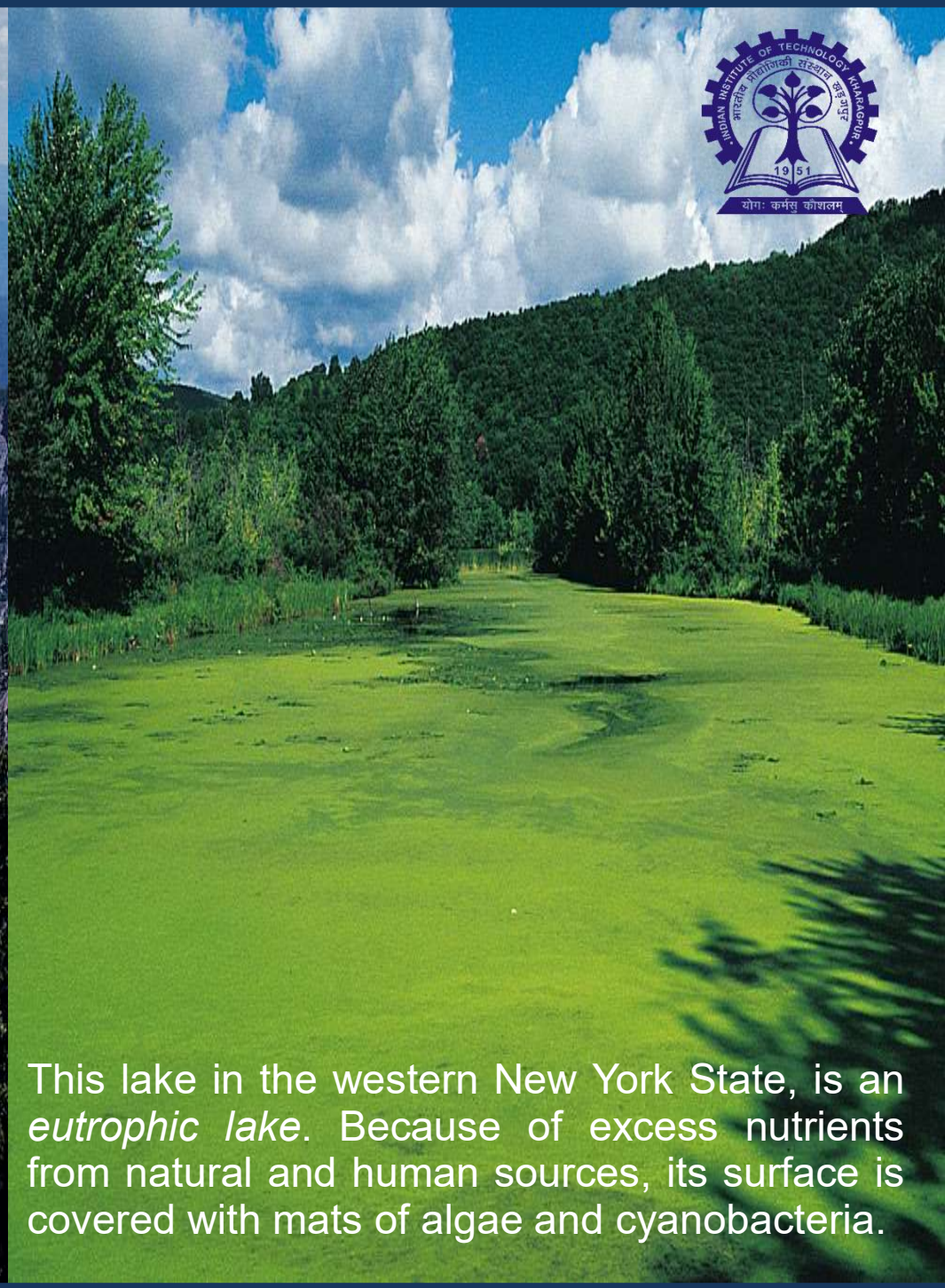


Lakes cannot cleanse themselves

- Lakes and reservoirs less effective at diluting pollutants because
  - they contain stratified layers that undergo little vertical mixing.
  - they have little or no flow.
- Lakes and reservoirs are more vulnerable than streams to contamination by runoff or discharge of plant nutrients, oil, pesticides, and non-degradable toxic substances.
- Eutrophication:
  - enrichment of bodies of fresh water by inorganic nutrients
  - caused mostly by runoff of plant nutrients such as nitrates and phosphates from surrounding land.
  - particularly evident in slow-moving rivers and shallow lakes



Crater Lake in the US state of Oregon (left) is an *oligotrophic lake*, which is low in nutrients. Because of the low density of plankton, its water is quite clear.

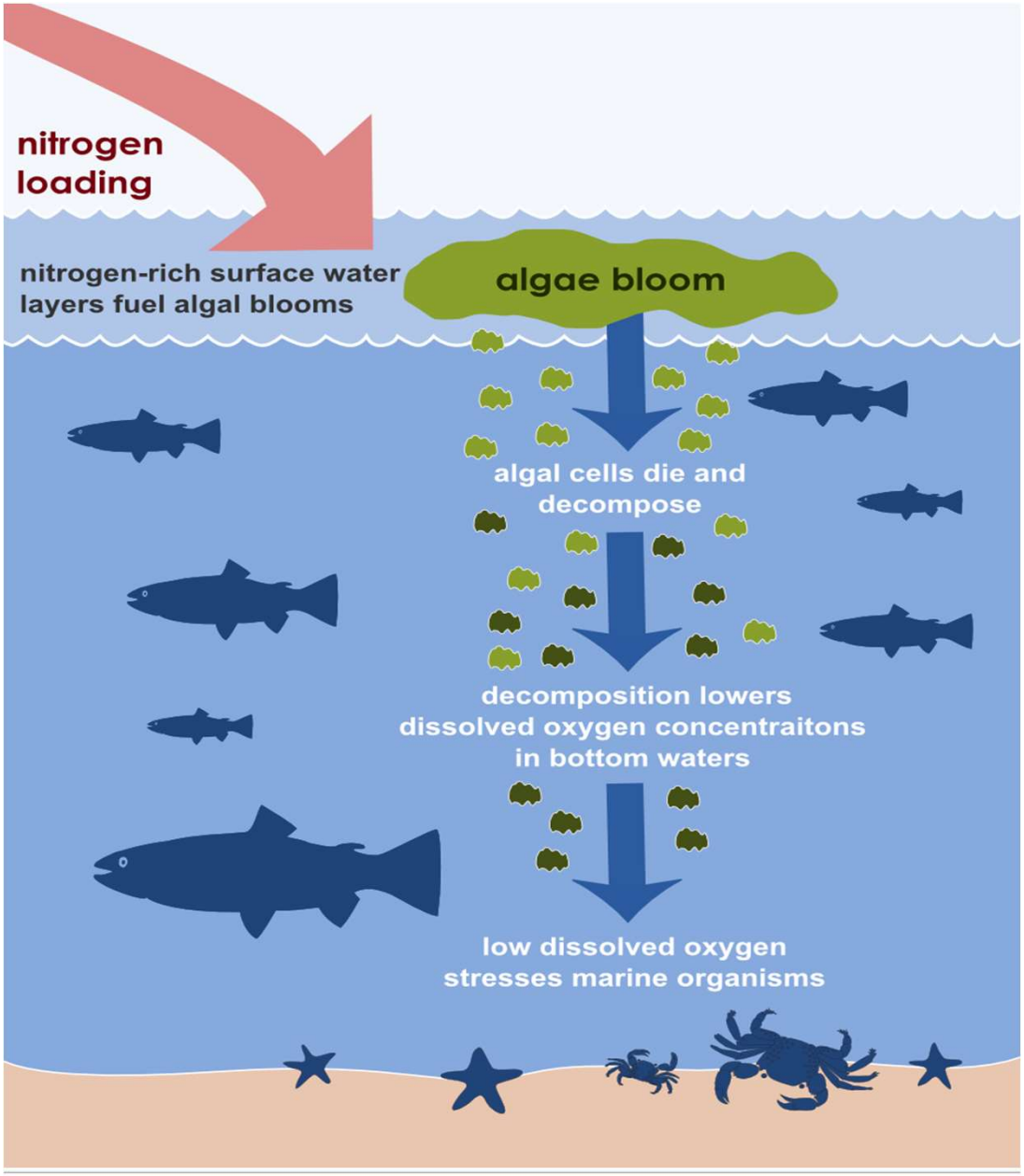


This lake in the western New York State, is an *eutrophic lake*. Because of excess nutrients from natural and human sources, its surface is covered with mats of algae and cyanobacteria.

Cultural eutrophication

- Human activities can greatly accelerate the input of plant nutrients to a lake – cultural eutrophication.
- Sources include farmland, animal feedlots, chemically fertilized suburban yards, mining sites, and treated and untreated municipal sewage outlets.
- Nutrient overload produces dense growth or ‘blooms’ of organisms such as algae and cyanobacteria that reduce lake productivity by decreasing the input of solar energy.
- When the algae die, they are decomposed by aerobic bacteria which deplete dissolved oxygen killing fish and other aerobic aquatic animals.
- Can be prevented by mechanically removing excess weeds, controlling undesirable plant growth with herbicides and algicides, and pumping air to prevent oxygen depletion.

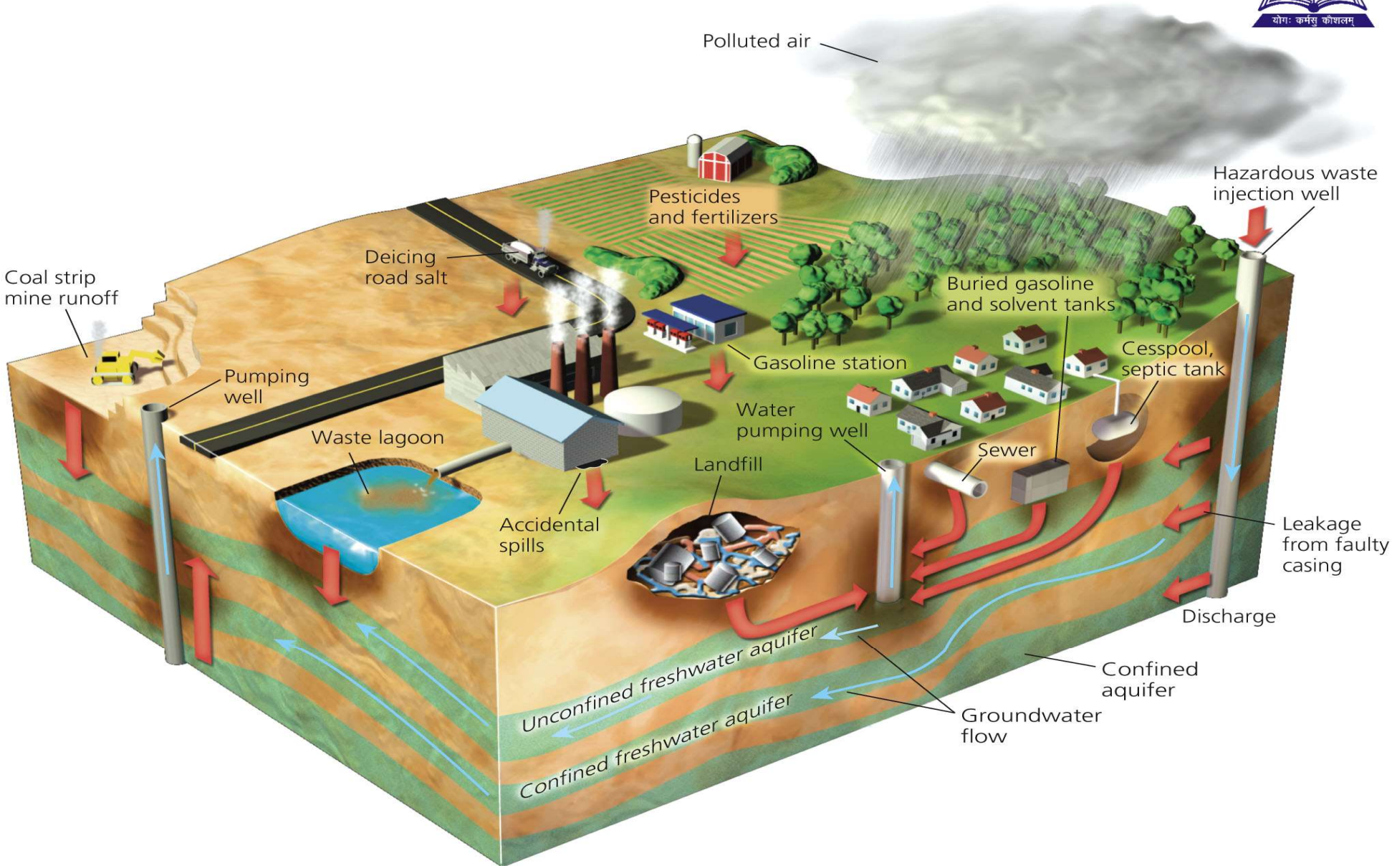
- Cultural eutrophication can lead to the premature aging and death of a body of water.



Groundwater too cannot cleanse itself

- Common pollutants such as fertilizers, pesticides, gasoline, and organic solvents can seep into groundwater from numerous sources.
- Groundwater flows very slowly – contaminants are not diluted and dispersed effectively.
- Lower concentration of dissolved oxygen (which helps decompose many contaminants) and smaller populations of decomposing bacteria.
- Cold temperatures of groundwater further slow down chemical reactions that decomposes wastes.
- Can take decades to thousands of years for contaminated groundwater to cleanse itself.
- Preventing contamination is the least expensive and most effective way to protect groundwater resources.

- The principal sources and causes of groundwater pollution are under four categories: municipal, industrial, agricultural, and miscellaneous.



Purifying drinking water

- Developed countries
  - Water stored in reservoirs for several days to improve clarity and taste by increasing dissolved oxygen content and allowing suspended matter to settle.
  - Water then pumped to purification plant and treated to meet government drinking water standards.

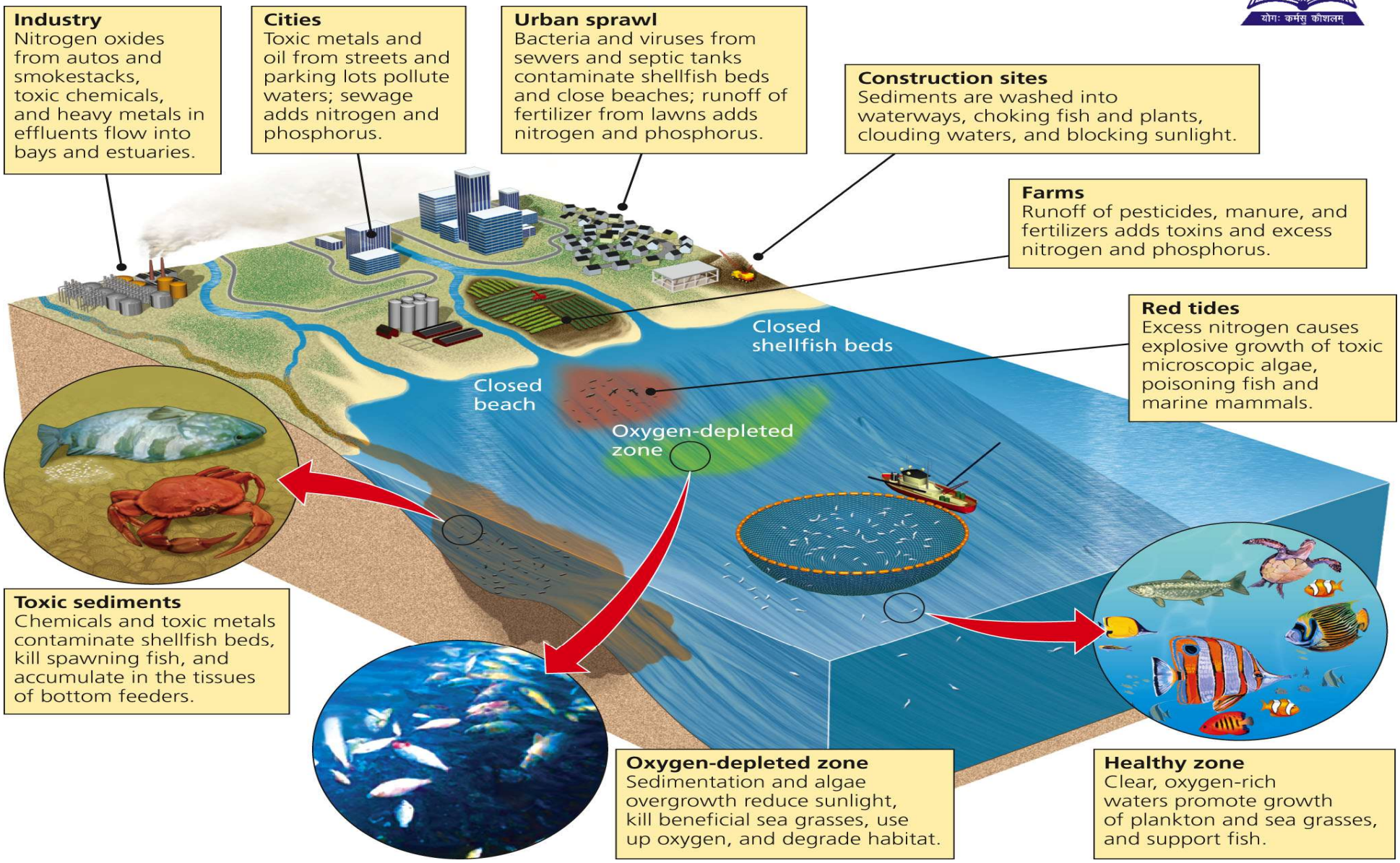
- Developing countries
  - Exposing clear plastic bottle filled with contaminated water to intense sunlight.
  - *LifeStraw* – convert contaminated water into clean, safe drinking water.

- The *LifeStraw*, designed by Torben Vestergaard Frandsen, is a personal water purification device that gives many poor people access to safe drinking water.

Ocean pollution

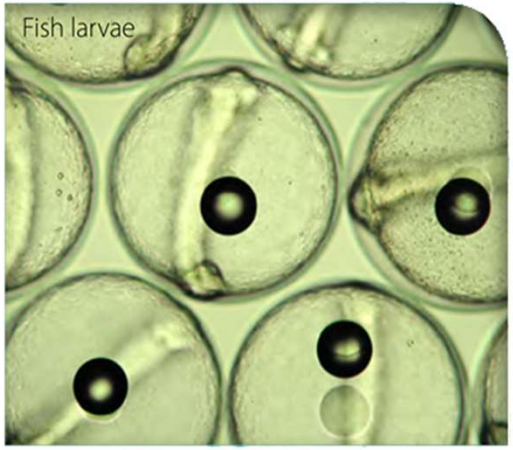
- About 40% of the world's population live on or near a coast and coastal population are projected to double by 2050.
- 80% of marine pollution originates on land and could further rise significantly.
- 80-90% of the municipal sewage from most coastal developing countries and in some coastal developed countries is dumped into oceans without treatment.
- Many cruise ships dump wastes (toxic chemicals, garbage and waste oil) at sea.
- Runoffs of sewage and agricultural wastes into coastal waters can cause explosive growths of harmful algae – algal blooms – creating oxygen depleted zones.
- Key to protecting oceans is to reduce the flow of pollution from land, air, and streams that empty into these waters.

- Residential areas, factories, and farms all contribute to the pollution of coastal waters and bays.



Oil spills

When an oil spill occurs it can cause a lot of harm to all life in the area. It destroys the insulating ability of fur in mammals such as sea otters and the water repelling properties of birds' feathers. This means they are more exposed to the elements which can lead to hypothermia and death. Recently, it has also been shown that polycyclic aromatic hydrocarbons in oil can cause fish to have heart attacks and in lower concentrations disrupt the development of fish larvae.

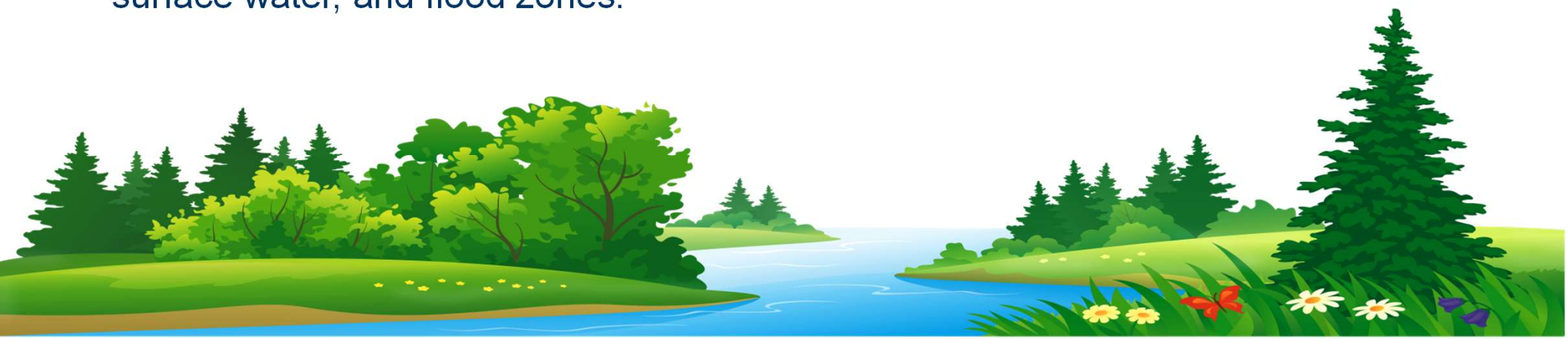


Reducing water pollution from point sources

- Clean Water Act (CWA) & Water Quality Act (WQT)
  - Sets standards for allowed levels of key water pollutants
  - Requires polluters to get permits limiting how much of various pollutants they can discharge into aquatic systems
- Discharge trading policy
  - Uses market forces to reduce water pollution
  - A permit holder can pollute at higher levels than allowed by its permit if it buys credits from permit holders who are polluting below their allowed levels
  - Depends on how low the cap on total pollution levels is set in any given area and how regularly the cap is lowered
  - Could allow pollutants to build up to dangerous levels in areas where credits are bought

Reducing water pollution from nonpoint sources

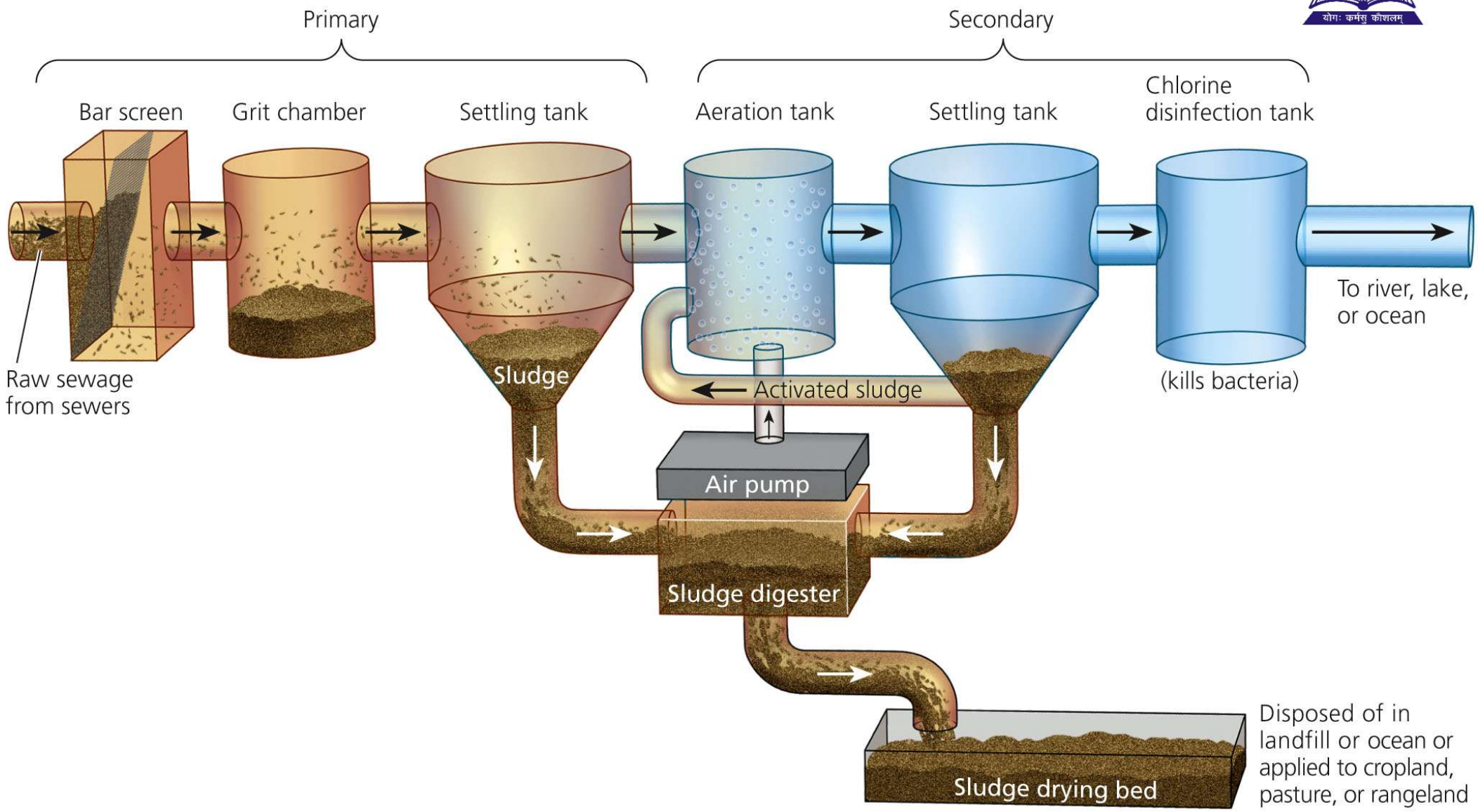
- Reduce soil erosion by keeping cropland covered with vegetation.
- Reduce the amount of fertilizer that runs off into surface waters and leaches into aquifers by using slow-release fertilizer, using no fertilizer on steeply sloped land, and planting buffer zones of vegetation between cultivated fields and nearby surface waters.
- Practice organic farming – does not use commercial inorganic fertilizers.
- Apply pesticides only when needed.
- Rely more on Integrated Pest Management.
- Locate animal feedlots and animal waste sites away from steeply sloped land, surface water, and flood zones.



Sewage treatment systems

- **Rural and suburban areas**
  - Sewage discharged into a septic tank.
  - Grease and oil rise to the top and solids fall to the bottom and are decomposed by bacteria.
- **Urban areas**
  - Wastewater or sewage treatment plants
  - Raw sewage undergoes one or two levels of treatment.
  - Primary treatment: Remove large floating objects and allow suspended solids to settle out.
  - Secondary treatment: Aerobic bacteria remove almost 90% of dissolved and biodegradable, oxygen-demanding, organic wastes.

- Most municipal wastewater treatment facilities use primary and secondary levels of treatment.



Sustainable ways to reduce water pollution

Solutions

Water Pollution

- Prevent groundwater contamination
- Reduce nonpoint runoff
- Reuse treated wastewater for irrigation
- Find substitutes for toxic pollutants
- Work with nature to treat sewage
- Practice the three R's of resource use (reduce, reuse, recycle)
- Reduce air pollution
- Reduce poverty
- Slow population growth

Individual choices make a difference

What Can You Do?

Reducing Water Pollution

- Fertilize garden and yard plants with manure or compost instead of commercial inorganic fertilizer
- Minimize your use of pesticides, especially near bodies of water
- Prevent yard wastes from entering storm drains
- Do not use water fresheners in toilets
- Do not flush unwanted medicines down the toilet
- Do not pour pesticides, paints, solvents, oil, antifreeze, or other products containing harmful chemicals down the drain or onto the ground