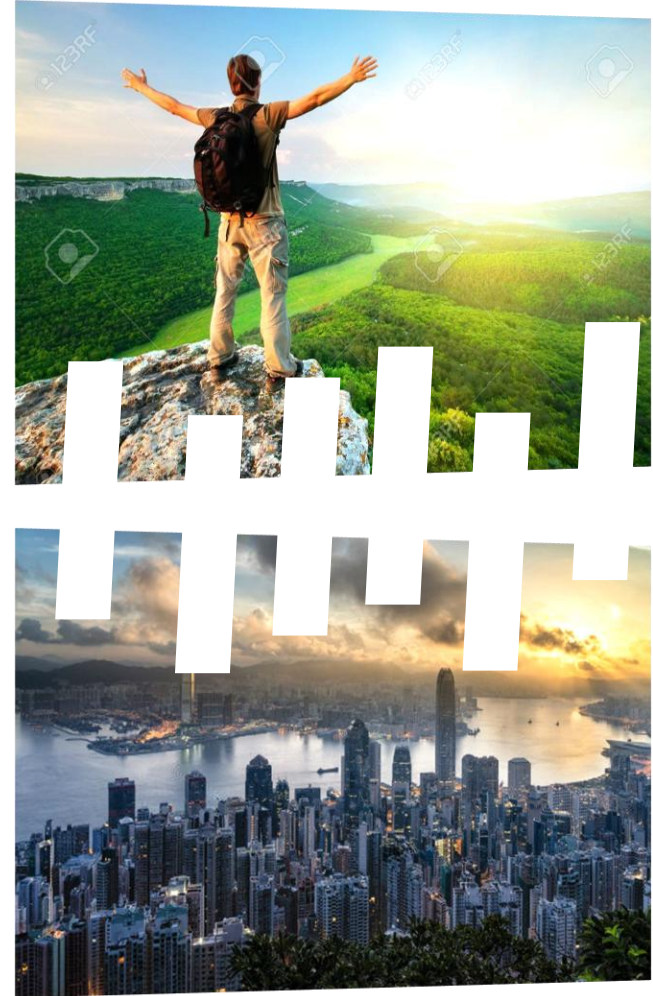
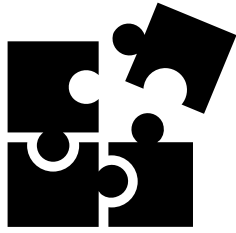


Environmental medicine

Lecture 3



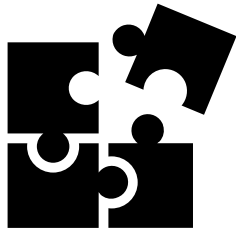


Water Quality and Public Health:

- Water is an essential resource for human survival.
- According to the 2021 World Water Development Report released by UNESCO, the global use of freshwater has increased six-fold in the past 100 years and has been growing by about 1% per year since the 1980s.

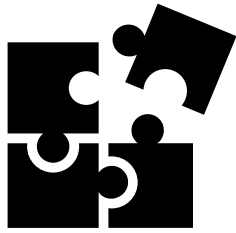


Water Quality and Public Health:



- Water pollution occurs when harmful substances—often chemicals or microorganisms—contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic to humans or the environment.



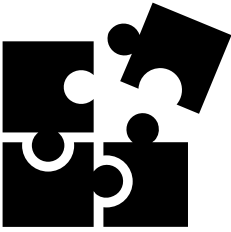


Water Quality and Public Health:

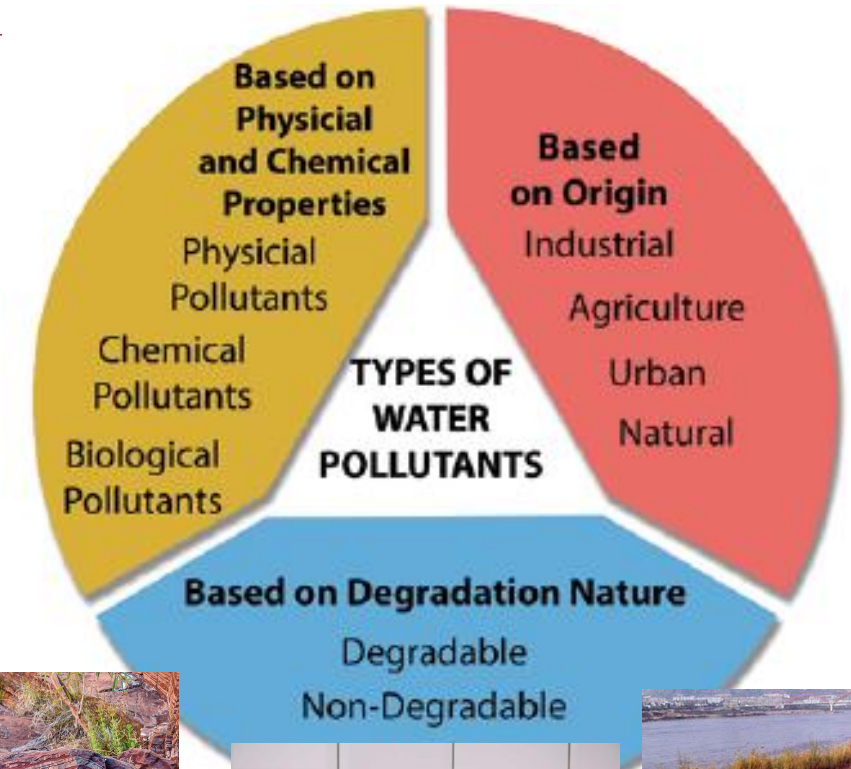
- With the increase of **water consumption**, **water quality** is facing **severe challenges**.
- **Industrialization**, **agricultural production**, and **urban life** have resulted in the degradation and **pollution of the environment**, **adversely affecting** the **water bodies** (rivers and oceans) necessary for life, ultimately **affecting human health** and sustainable social development.



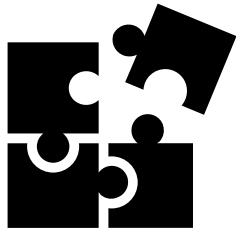
Water Pollution:



- **Natural** sources
- **Human-induced** sources
- **Physical** pollutants
- **Chemical** pollutants
- **Biological** pollutants



Water Pollution:



Natural sources

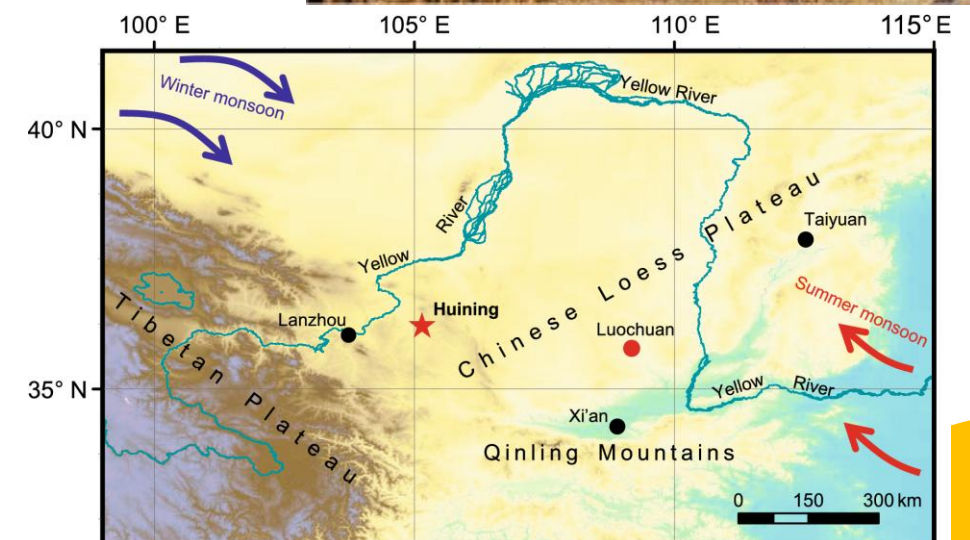




Sources of Water Pollution

Natural factors – SOIL EROSION

- Water pollution related to natural factors.
- Taking **Chinese Loess Plateau** as an example, the **concentration** of **trace elements** in water quality is **higher** than the **average world level**, and trace elements come from **natural weathering** and **manufacture causes**.
- The variation of **trace elements** in natural water is also significant, especially **Al, B, Fe, Mn, and F**.



Yellow River (Huang He), the second-longest river in China

Sources of Water Pollution

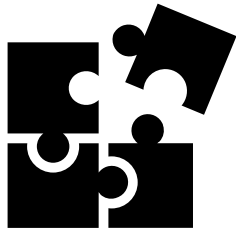
Major Pollutants Affecting Yellow River Water Quality

High Sediment Load

- The Yellow River carries **one of the highest sediment loads** in the **world** due to **soil erosion** from the **Loess Plateau**.

Industrial & Agricultural Pollution

- Heavy Metals** (Lead, Cadmium, Arsenic, Mercury) from mining and industrial discharge.
- Nutrient Pollution** (Nitrate & Phosphate) from fertilizers and livestock waste, leading to **eutrophication** (excessive algae growth).
- Organic Pollutants & Microplastics** from wastewater and plastic waste.



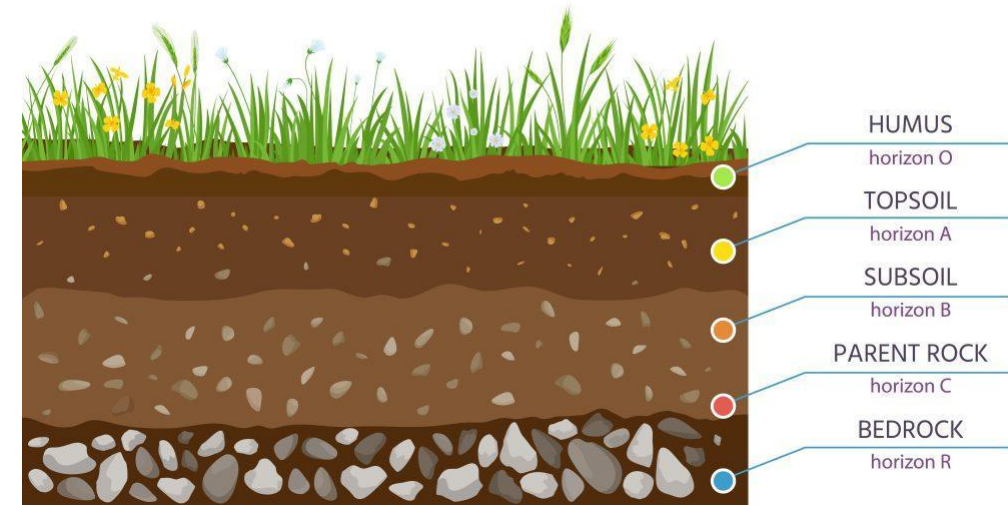


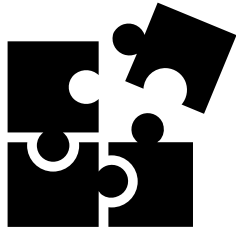
Sources of Water Pollution

Natural factors - Geological Weathering:

- **Natural heavy metal pollution** of waters occurs due to geological processes and the presence of **heavy metals in rocks and soils**.
- Natural weathering of **rocks and minerals** can release **heavy metals** such as **lead, mercury, arsenic, cadmium, and chromium** into water bodies.
- These metals may be **naturally present** in the **Earth's crust** and can be released into water through **erosion, dissolution, and leaching** processes.

SOIL LAYERS





Sources of Water Pollution:

Natural factors - Volcanic eruptions

- **Volcanic eruptions:** can release significant amounts of **heavy metals** into the atmosphere, which can subsequently settle into **water bodies** through **precipitation** or **deposition**.
- **Volcanic ash and lava** contain various heavy metals.
- **Mineral Deposits:** Areas with mineral deposits, such as sulfide ores containing metals like **copper, zinc, and nickel**, can leach **heavy metals** into nearby **water bodies**.



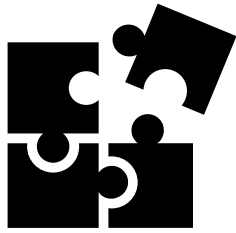


Sources of Water Pollution:

Natural factors

- **Metals** are essentially **non-biodegradable**, they are **environmentally persistent**.
- Excessive metals in the soil may pose certain levels of **ecotoxicity** and **environmental hazard**.
- They may undergo many natural processes, such as **dissolution, complexation, absorption and desorption**, thus affecting the surrounding ecology and human health





Sources of Water Pollution:

Natural factors

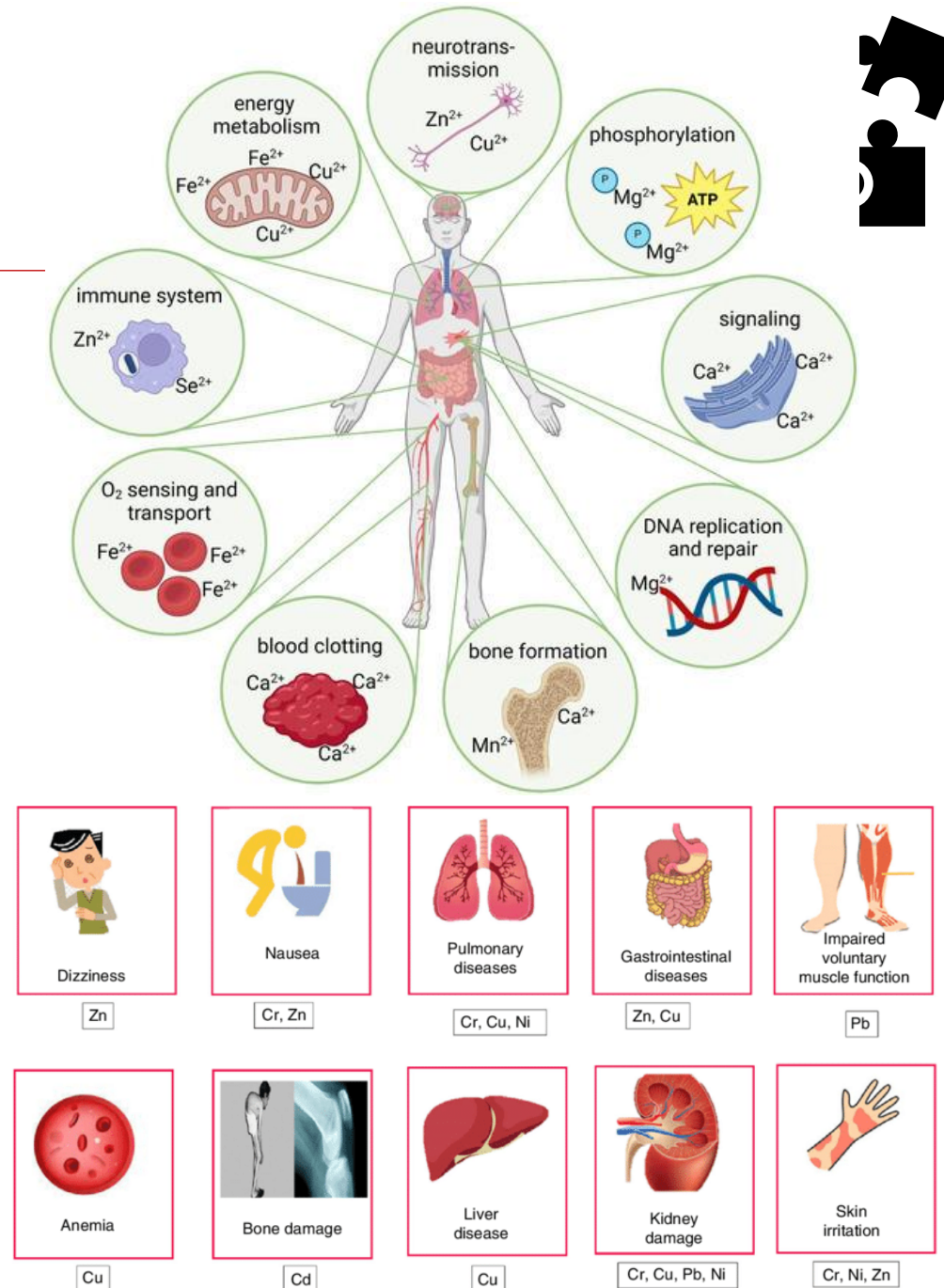
- The toxicity of metals depends on the **dose**, **exposure pathway**, and **duration of exposure**.
- Some trace elements (**Zn, Cu, Mn**) are essential nutrients for metabolism, but **at high concentrations**, these essential elements are also harmful to human health.
- Metals in soil **enter the body** through three major exposure pathways: **ingestion, inhalation and dermal contact**, and may reach levels harmful to human health through the food chain.



Sources of Water Pollution:

Natural factors

- ✓ **Excess metal** can **biomagnify** in human tissues;
- ✓ damage the nervous,
- ✓ kidney and reproductive systems;
- ✓ act as an **endocrine disruptor**;
- ✓ and act as a **carcinogen**.





Sources of Water Pollution:

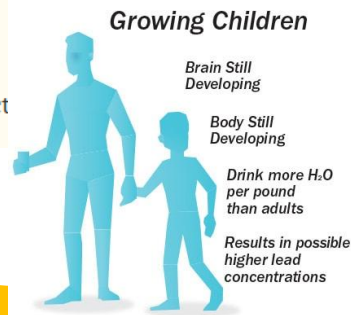
Natural factors

- **Children** are at higher risk of exposure than adults, which may be due to their **developing bodies**, and their **poor ability to detoxify**.

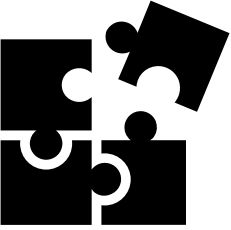
Carcinogenic health risk from metals in the volcanic soil and volcanic ash.

Element	Exposure Pathways	SF	CR	
			Children	Adult
Cr	Ingestion	0.5	1.25×10^{-4}	1.34×10^{-5}
	Inhalation	42	2.94×10^{-7}	1.66×10^{-7}
	Dermal	-	-	-
Ni	Ingestion	0.84	6.77×10^{-5}	7.25×10^{-6}
	Inhalation	0.84	1.89×10^{-9}	1.07×10^{-9}
	Dermal	-	-	-
As	Ingestion	1.5	1.41×10^{-4}	1.51×10^{-5}
	Inhalation	15.1	3.97×10^{-8}	2.24×10^{-8}
	Dermal	3.66	1.96×10^{-6}	2.64×10^{-5}
TCR			3.36×10^{-4}	6.24×10^{-5}

CR is the carcinogenic risk of a single metal; SF is the cancer slope factor

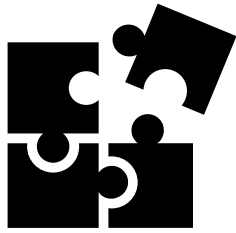


Water Pollution:



Human-induced sources





Sources of Water Pollution:

Human-induced sources

- Increase in **urbanization and industrialization** are an example of anthropogenic sources through which water get contaminated.

Heavy metal ion	Common sources
Copper (Cu)	Fertilizers, tanning, and photovoltaic cells
Zinc (Zn)	Soldering, cosmetics, and pigments
Silver (Ag)	Refining of copper, gold, nickel, zinc, jewelry, and electroplating industries
Chromium (Cr)	Leather industry, tanning, and chrome plating industries
Arsenic (As)	Wooden electricity poles that are treated with arsenic-based preservatives, pesticides, fertilizers, the release of untreated effluents, oxidation of pyrite (FeS) and arsenopyrite (FeAsS)
Mercury (Hg)	Combustion of coal, municipal solid waste incineration, and volcanic emissions
Cadmium (Cd)	Paints, pigments, electroplated parts, batteries, plastics, synthetic rubber, photographic and engraving process, photoconductors, and photovoltaic cells
Lead (Pb)	PVC pipes in sanitation, agriculture, recycled PVC lead paints, jewelry, lead batteries, lunch boxes, etc.



Sources of Water Pollution :

Human-induced sources

- Contamination of water sources with pollutants like **heavy metals, pesticides, industrial chemicals, and pathogens** can pose serious health risks.
- Drinking water contaminated with **pathogens** can lead to **gastrointestinal illnesses** such as diarrhea, cholera, and dysentery.
- Exposure to **toxic chemicals** in water can cause long-term health effects, including neurological disorders, reproductive issues, and cancer.

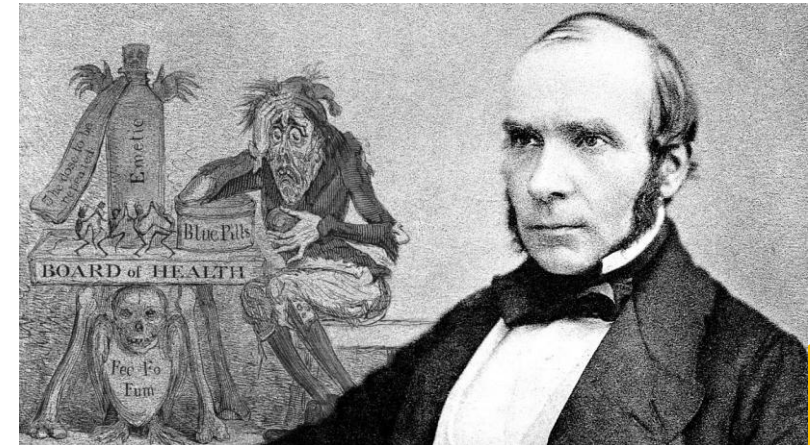




Sources of Water Pollution :

Cholera in London

- During the 19th century, London experienced several **deadly cholera outbreaks**.
- The **first major cholera** epidemic in London occurred in 1831–1832, **killing** over **6,000 people**.
- At the time, the disease was believed to be spread through "**miasma**" (**bad air**).
- 1854 – **Dr. John Snow** identified **contaminated water** as the **source of cholera** in London.
- 1883 – **Robert Koch** discovered ***Vibrio cholerae***, **confirming the bacterial cause** of the disease.





Water Quality and Public Health:

- Globally, an **estimated 80% of industrial and municipal wastewater** is **discharged** into the environment **without any prior treatment**, with adverse effects on human health and ecosystems.
- This proportion is **higher in the least developed countries**, where sanitation and **wastewater treatment facilities are severely lacking**.



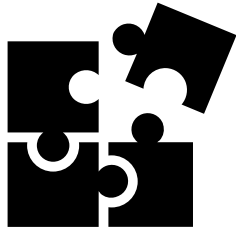


Sources of Water Pollution:

- Water pollution is primarily caused by
- industrialization,
 - agricultural activities,
 - mining,
 - and inadequate sewage treatment facilities.

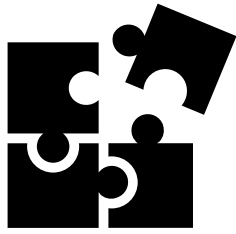


Sources of Water Pollution:



Industry





Sources of Water Pollution:

Industry

- Industrial water pollution occurs when **factories**, **manufacturing plants**, and **processing facilities** **release** harmful substances into water bodies.
- The industrial sector is a major contributor to water pollution, with **key industries** responsible for contamination - **distillery industry**, **tannery industry**, **pulp and paper industry**, **textile industry**, **food industry**, **iron and steel industry**, and **nuclear industry**, among others.



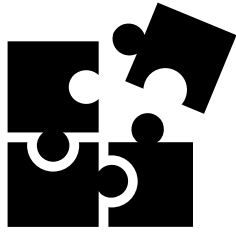


Sources of Water Pollution:

Industry

- Various toxic chemicals, heavy metals, organic and inorganic substances, toxic solvents and volatile organic chemicals may be released in industrial production.
- If these wastes are released into aquatic ecosystems without adequate treatment, they will cause water pollution.





Sources of Water Pollution:

- **Chemical Discharge** – Factories release harmful **chemicals** such **solvents** into rivers and lakes.





Sources of Water Pollution:

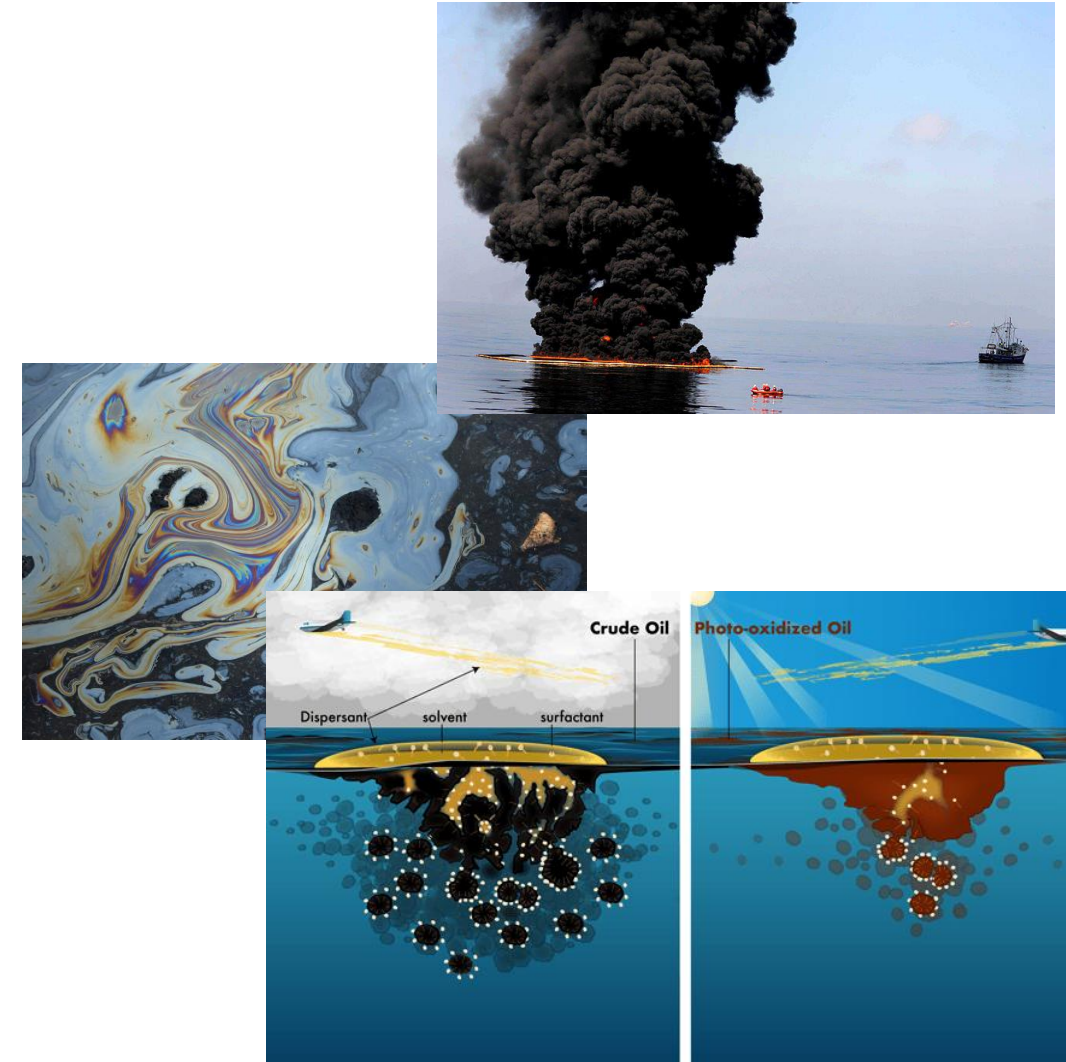
- **Heavy Metals** – Industries such as **mining**, **metal processing**, and **battery production** discharge toxic heavy metals like **cadmium** and **chromium** into water sources.
- **Arsenic**, **cadmium**, and **chromium** are vital pollutants discharged in **wastewater**, and the **industrial sector** is a significant contributor to harmful pollutants.

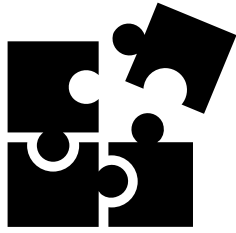




Sources of Water Pollution:

- **Oil Spills and Hydrocarbons** – Refineries and factories dealing with **petroleum products** can cause **oil spills**, contaminating water bodies.
- Oil weathering processes have **wide-ranging implications** for **ecosystem** and **human health**.



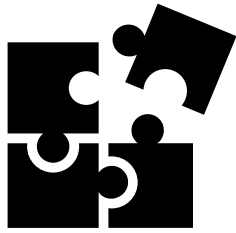


Sources of Water Pollution:

Oil Spills

- **Oil Spills:** Accidental or deliberate releases of oil from **ships, pipelines, and offshore drilling platforms** can result in **oil slicks** that spread across water surfaces, **causing severe damage** to **marine life** and ecosystems.
- Commercially important species such as **oysters, shrimp, grouper, swordfish and tuna** also could suffer **population declines** or become too **contaminated** to be **safely** caught and **eaten**.



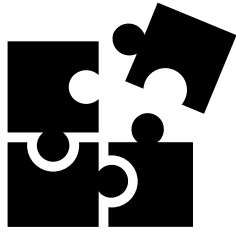


Water Quality and Public Health:

Deepwater Horizon oil spill

- **Largest marine oil spill** in history, caused by an explosion on the **Deepwater Horizon oil rig**—located in the **Gulf of Mexico**, approximately 41 miles (66 km) off the coast of Louisiana—and its subsequent sinking on April 22, 2010.
- The volume of oil escaping the damaged well—originally estimated by BP to be about **1,000 barrels per day**.

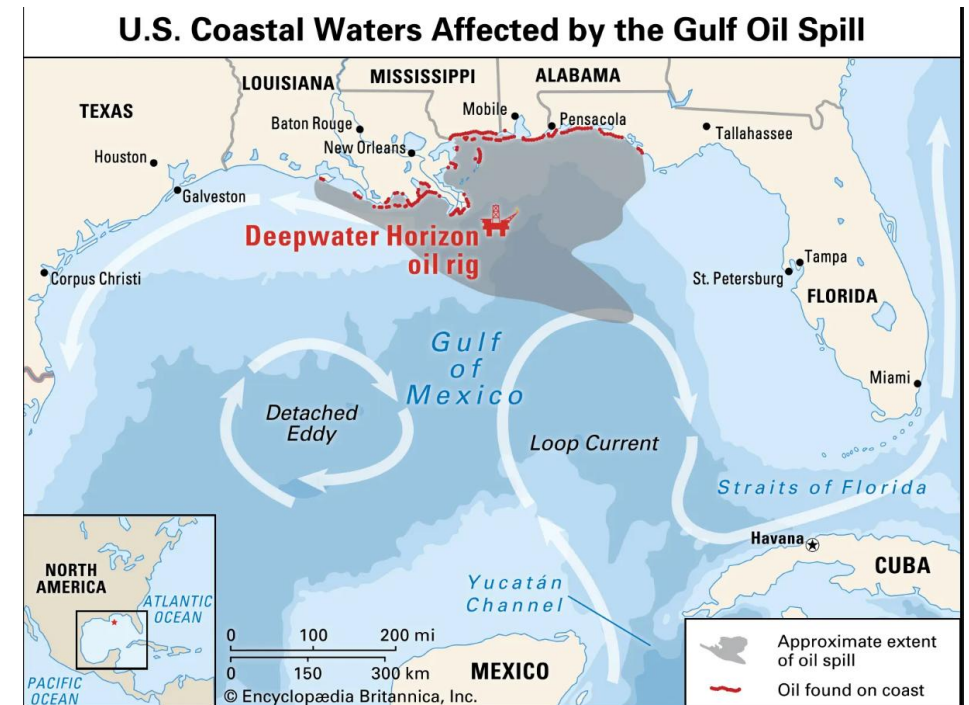


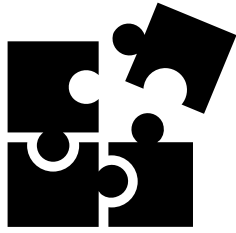


Water Quality and Public Health:

Sources of Water Pollution - Oil Spills

- A massive response ensued to **protect beaches, wetlands and estuaries** from the spreading oil utilizing **skimmer ships, floating booms, controlled burns** and 7,000 m³ of oil dispersant.
- Due to the **months-long spill**, along with adverse effects from the response and cleanup activities, **extensive damage to marine and wildlife habitats, fishing and tourism industries** was reported.

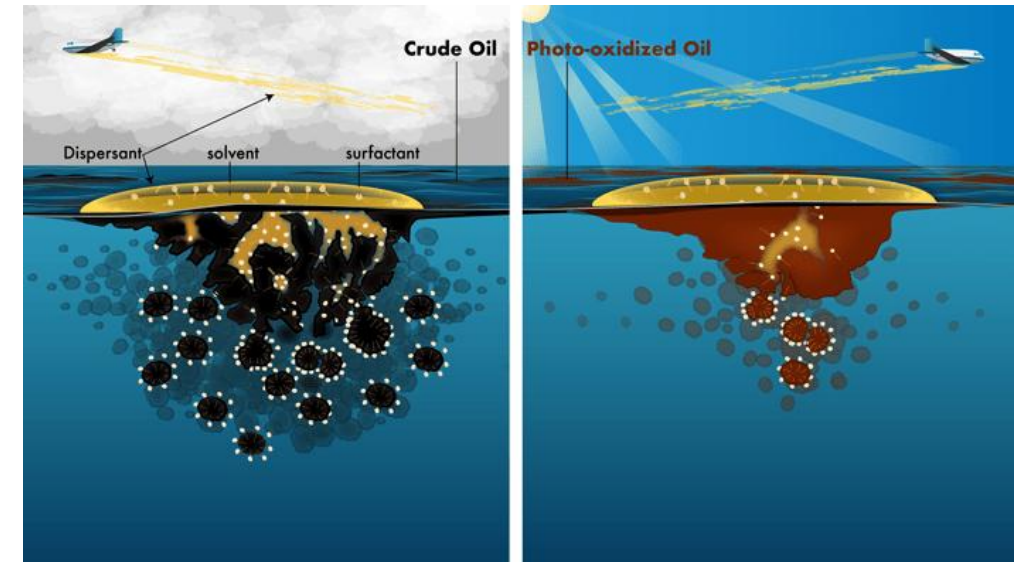


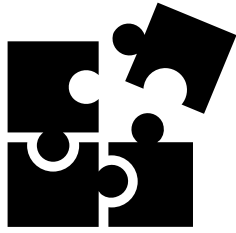


Sources of Water Pollution:

Oil Spills

- When **crude oil** is spilled into water, it undergoes a series of weathering processes, including **dissolution, evaporation, emulsification, biodegradation, and photooxidation**.
- These processes **alter the physical and chemical properties of the oil**, influencing its persistence and impact on the environment.





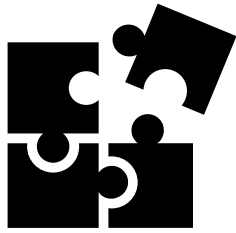
Water Quality and Public Health:

Sources of Water Pollution - Oil Spills

- **Booms** are **floating physical barriers**, made of **plastic, metal** etc., which **slow the spread of oil** and **keep it contained**.
- A boom may be **placed around a tanker that is leaking oil**, to collect the oil, **or along a sensitive coastal** area to prevent oil from reaching it.



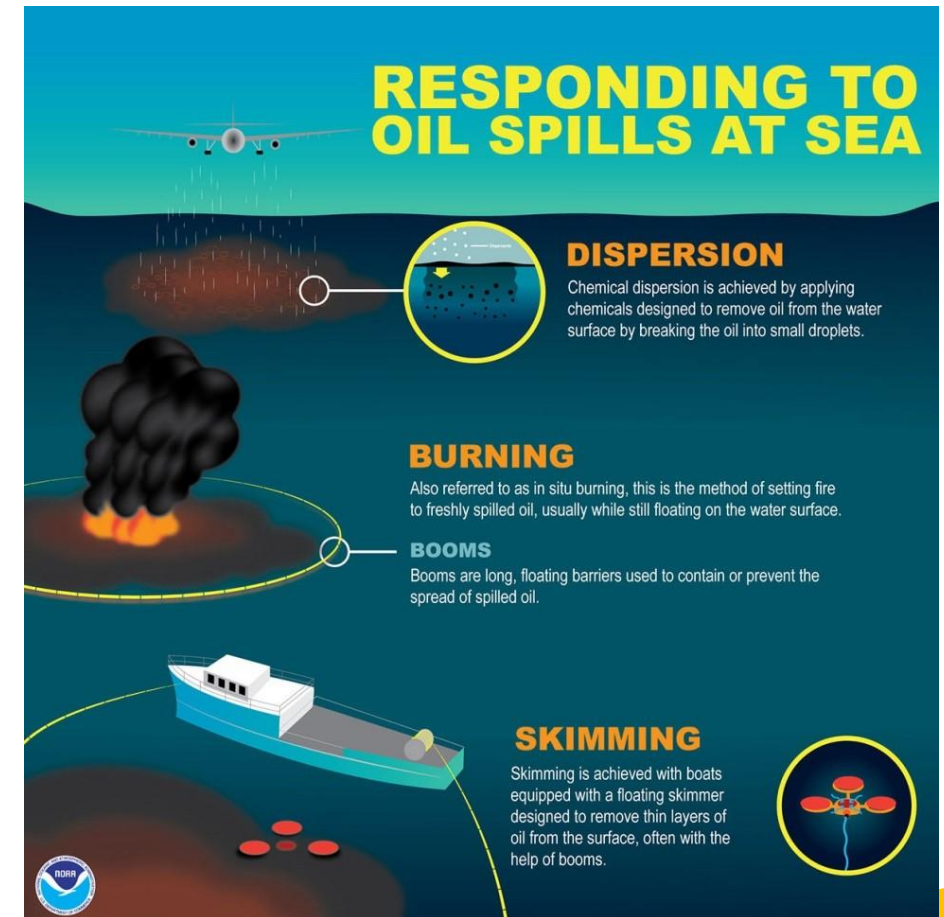
Skimmers come in various designs but all basically work by removing the oil layer from the surface of the water. (U.S. Coast Guard)

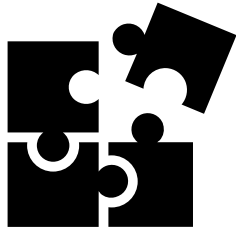


Water Quality and Public Health:

Sources of Water Pollution - Oil Spills

- **Another approach**—dependent in part on the thickness of the slick—is to **contain and remove oil** through **skimmers, boats** and other devices that can **remove oil** from the sea surface before it reaches sensitive areas.
- They skim or scoop oil from the water surface so it can be collected for proper disposal.





Water Quality and Public Health:

Sources of Water Pollution - Oil Spills

- **Hydrocarbon-eating bacteria** bloomed to feast on the Deepwater Horizon oil spill in 2010.



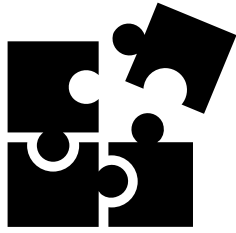
<https://www.youtube.com/watch?app=desktop&v=sPgLJrk0sGQ>



Sources of Water Pollution:

- With the acceleration of urbanization, **wastewater from industrial production** has **gradually increased**.
- **Industrial water pollution** in less developed countries is positively **correlated with foreign direct investment**.

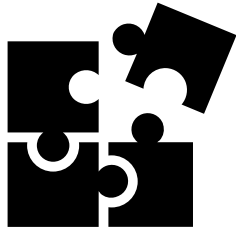




Sources of Water Pollution:

Agriculture



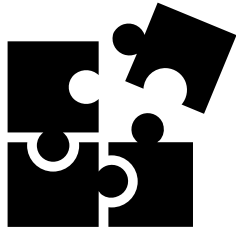


Sources of Water Pollution:

Agriculture

- Second, water pollution is closely related to **agriculture**.
- **Pesticides, nitrogen fertilizers and organic farm wastes** from agriculture are **significant causes** of water pollution.
- Agricultural activities will contaminate the water with **nitrates, phosphorus, pesticides, soil sediments, salts and pathogens**.

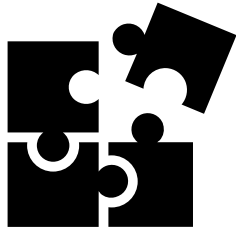




Sources of Water Pollution:

- Untreated or **partially treated wastewater** is widely **used for irrigation** in water-scarce regions of developing countries, including **China and India**, and the **presence of pollutants in sewage** poses **risks to the environment and health**.





Sources of Water Pollution:

- The imbalance in the **quantity and quality** of surface **water resources** has led to the **long-term** use of **wastewater irrigation** in some areas in **developing countries** to meet the water demand of agricultural production, resulting in **serious agricultural land and food pollution, pesticide residues and heavy metal pollution** threatening food safety and Human Health.



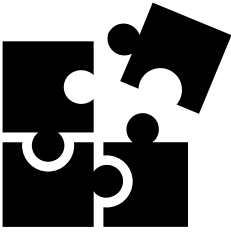


Sources of Water Pollution:

- Pesticides have an adverse impact on health through drinking water.
- Comparing pesticide use with health life Expectancy Longitudinal Survey data, it was found that a 10% increase in pesticide use resulted in increase in the medical disability index over 65 years of age.

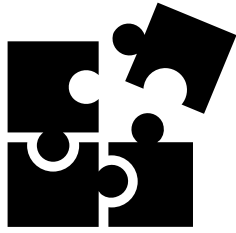


Sources of Water Pollution:



Mining Activities





Sources of Water Pollution:

Mining Activities

- **Mining Activities:** Mining operations can release pollutants such as **heavy metals, sulfur compounds, and toxic chemicals** into water bodies through runoff and leaching from mine sites.



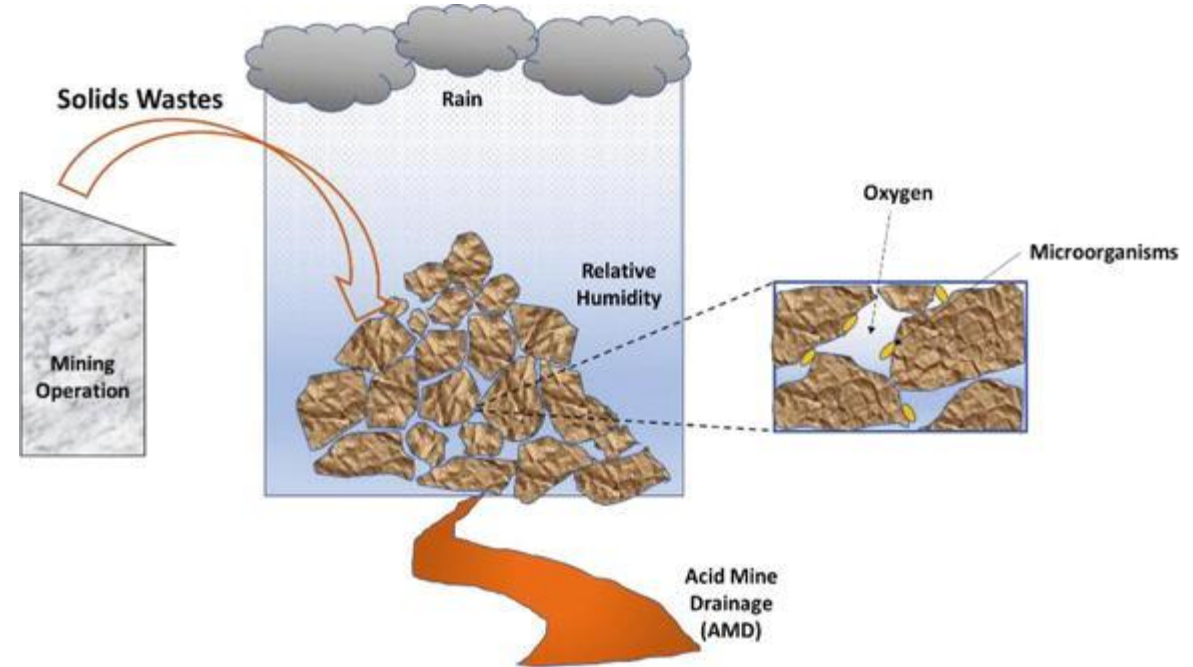


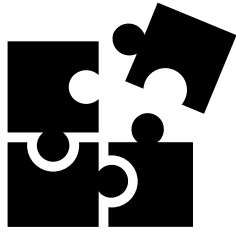
Sources of Water Pollution:

Mining Activities

There are four main types of mining impacts on water quality.

- When large quantities of **rock containing sulphide minerals** are **excavated from an open pit** or opened up in an underground mine, it **reacts** with **water and oxygen** to create **sulphuric acid**.





Sources of Water Pollution:

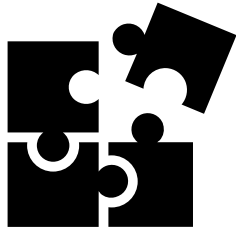
Mining Activities

There are four main types of mining impacts on water quality.

1. **Acid Mine Drainage** - Acid is **carried off** the mine site by **rainwater or surface drainage** and deposited into nearby **streams, rivers, lakes** and **groundwater**.



- **Acid Mine Drainage** - **sulphuric acid** is **produced** when **sulphides** in rocks are **exposed to air** and **water**.



Sources of Water Pollution:

Mining Activities

2. Heavy Metal Contamination & Leaching -

Heavy metal pollution is caused when such metals as **arsenic, cobalt, copper, cadmium, lead, silver and zinc** contained in **excavated rock** or exposed in an underground mine come in contact with water.

- **Metals** are **leached out** and **carried downstream** as water washes over the rock surface.



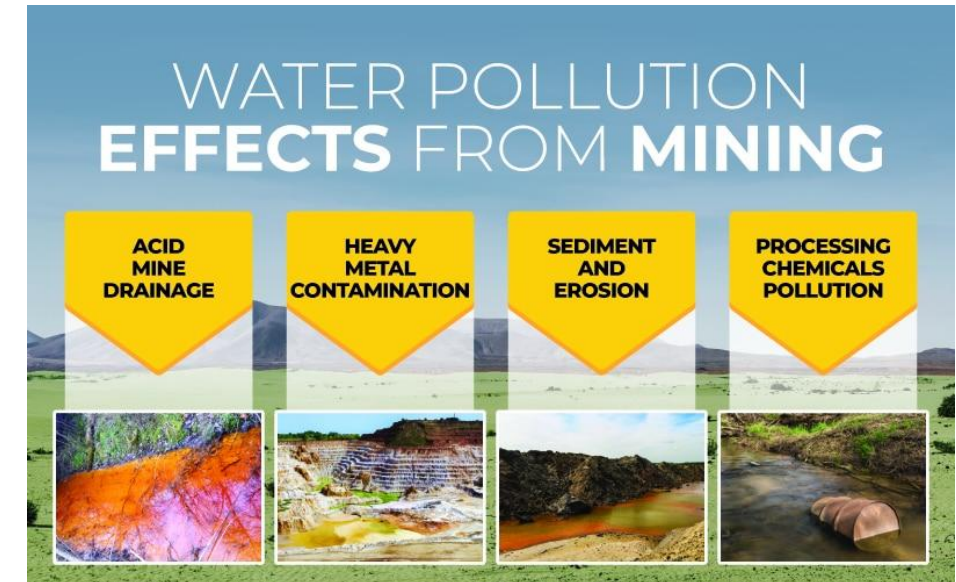


Sources of Water Pollution:

Mining Activities

3. Processing Chemicals Pollution- This kind of pollution occurs when **chemical agents** (such as cyanide or sulphuric acid used by mining companies to separate the target mineral from the ore) **spill, leak, or leach** from the mine site into nearby water bodies.

- These chemicals can be **highly toxic to humans** and **wildlife**.





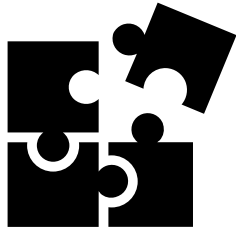
Sources of Water Pollution:

Mining Activities

4. Erosion and Sedimentation- Mineral development disturbs soil and rock in the course of **constructing and maintaining roads, open pits, and waste impoundments.**

- **Excessive sediment** can **clog riverbeds** and smother watershed vegetation, **wildlife habitat** and aquatic organisms.



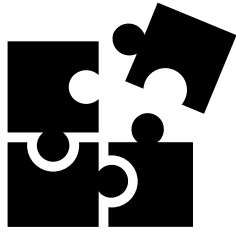


Sources of Water Pollution:

Mining Activities

- Once a mine is in operation **water protection must remain the highest goal of the company**, even if it means **reduced** mineral **productivity**.
- Adopting this common-sense ethic is the only way we can ensure that the **golden dreams** of mining do not turn into the **nightmare of poisoned streams**.



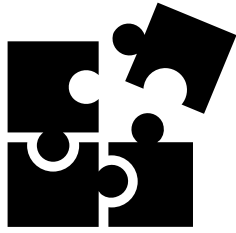


Sources of Water Pollution:

Mining Activities

- Changes in laws, technologies and attitudes have begun to address some of the most immediate threats posed by mineral development, but there are still many areas of mining practices and regulations that need to be addressed.
- Specially with mining, clean up is always more expensive than prevention





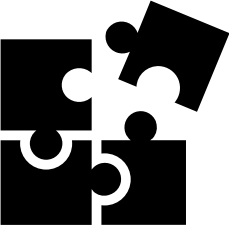
Sources of Water Pollution:

Mining Activities

- **Biomining** is the process of using **microorganisms** to **extract metals of economic interest** from rock ores or mine waste.
- Biomining techniques may also be **used to clean up sites** that have been **polluted with metals**.
- Some microbes can **oxidize metals**, allowing them to dissolve in water.

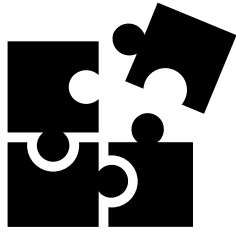


Sources of Water Pollution:



Municipal Wastewater



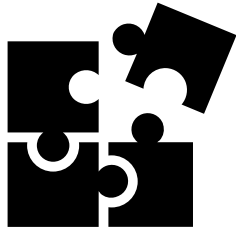


Sources of Water Pollution:

Municipal Wastewater - inadequately treated sewage

- Untreated or inadequately treated sewage and wastewater from households, businesses, and municipal treatment plants can contain harmful pathogens, nutrients, and chemicals that contaminate water sources.



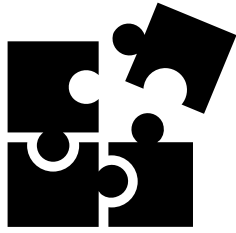


Sources of Water Pollution:

Municipal Wastewater

- **Wastewater management** refers to the **collection, treatment, and disposal or reuse** of wastewater generated from various sources.



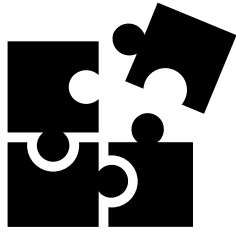


Sources of Water Pollution:

Municipal Wastewater

- **Collection:** Wastewater is collected from **homes, businesses, industries, and stormwater** runoff through a **network of sewer systems** or drainage systems.
- In areas without centralized sewer systems, onsite systems such as **septic tanks** may be used for wastewater collection.





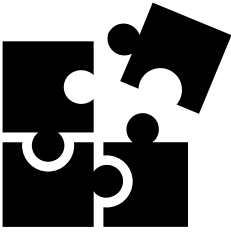
Sources of Water Pollution:

Municipal Wastewater

- **Treatment:** Wastewater undergoes treatment to **remove contaminants and pollutants** before it is discharged into the environment or reused.
- Treatment processes typically include:



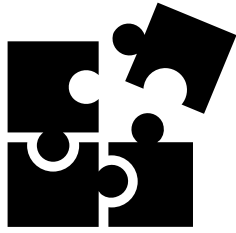
Sources of Water Pollution:



Municipal Wastewater

➤ Preliminary Treatment





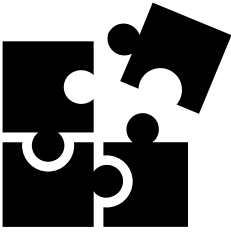
Water Quality and Public Health:

Municipal Wastewater

- **Preliminary Treatment:** Screening and grit removal to **remove large objects and debris.**



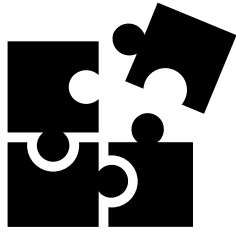
Sources of Water Pollution:



Municipal Wastewater

➤ **Primary treatment**





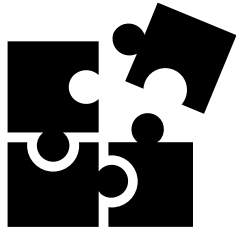
Water Quality and Public Health:

Municipal Wastewater

- **Primary treatment** - the first stage is the **deposition stage**.
- The **organic material** is **streamed** through the **large tanks**; later these tanks are used to **skimming off the grease and oils** from the sludge which are settled in the tanks.
- The **refined filths** are **collected** at the **base** of the **tank** where it is **pumped to filth treatment facilities**.



Sources of Water Pollution:



Municipal Wastewater

➤ Secondary treatment

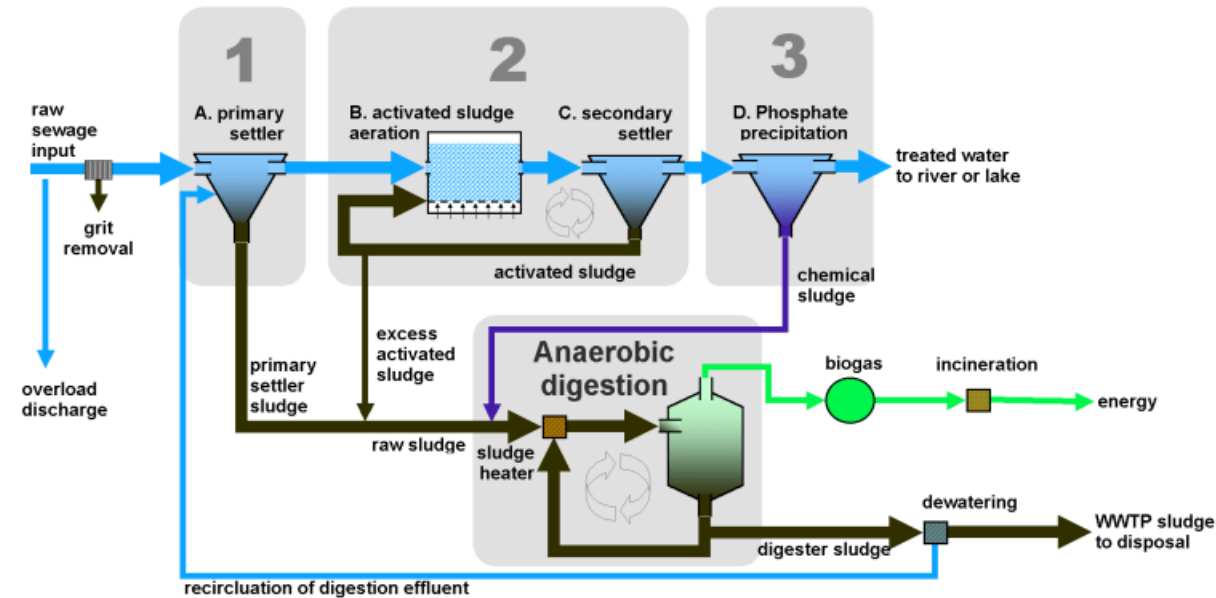




Water Quality and Public Health:

Municipal Wastewater

- **The secondary treatment** is plotted to reduce the **biological pollutants** - human's waste, food, detergents, and soaps.
- The municipal plants treat the filth liquid by the **aerobic biological process**.

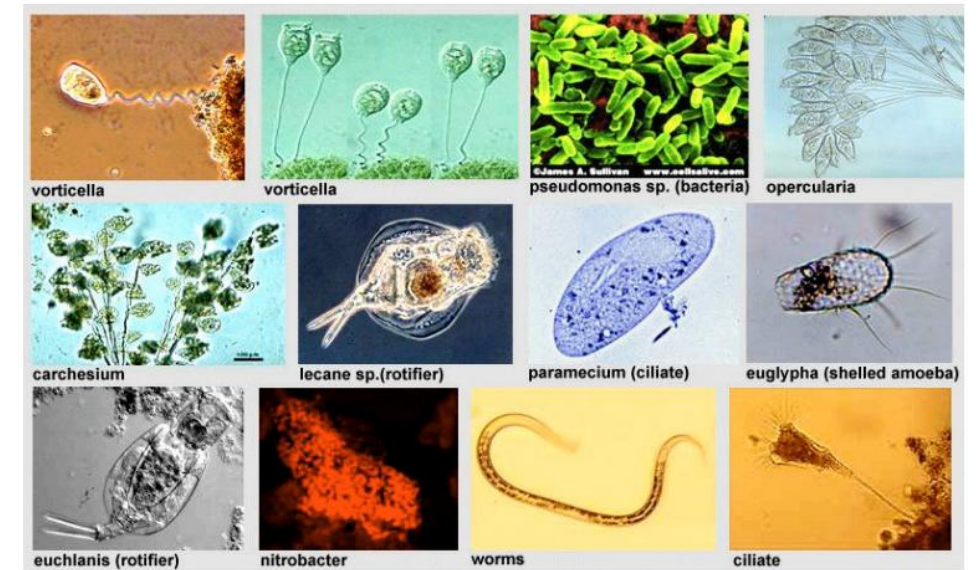


Water Quality and Public Health:



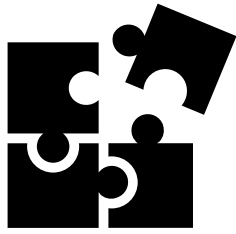
Municipal Wastewater

- In the second stage, the **wastewater** from the **primary stage** enters a **biological treatment**.
- **Micro-organisms** degrade **wastes** in an **aerated tank**.
- These micro-organisms are the **principal performers** and the **most crucial component** of a **wastewater treatment**.



An arbitrary collection of micro-organisms present in activated sludge beds of WWTPs.



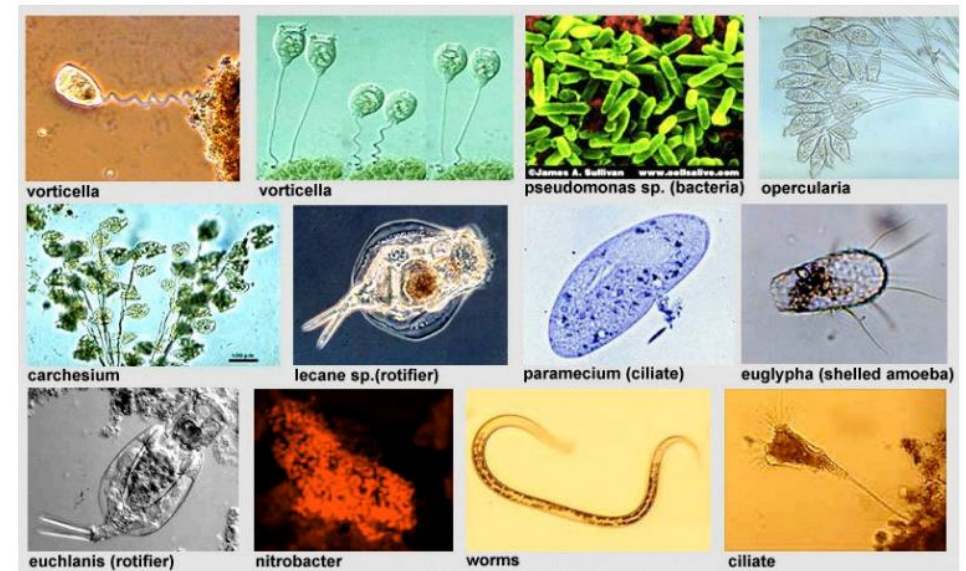


Water Quality and Public Health:

Municipal Wastewater

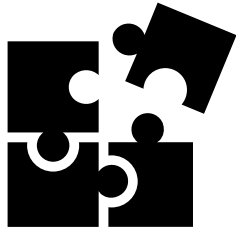
AEROBIC BACTERIA

- are mostly used in **new treatment plants** in what is known as an **aerated environment**.
- This bacterium uses the **free oxygen** within the water to **degrade the pollutants** in the wastewater and then **converts it into energy** that it can use to **grow and reproduce**.



An arbitrary collection of micro-organisms present in activated sludge beds of WWTPs.

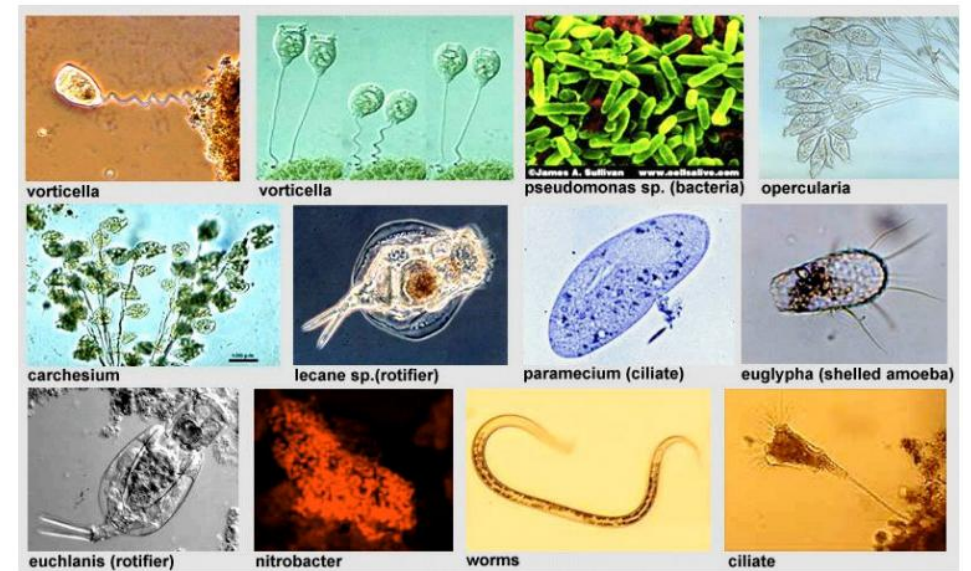
oxygen - to degrade the pollutants in the wastewater -converts it into energy



Water Quality and Public Health:

Municipal Wastewater

- For this type of bacteria to be used correctly, it must have **oxygen added mechanically**.
- This will ensure the **bacteria are able to do their job correctly** and continue to **grow and reproduce** on its food source.



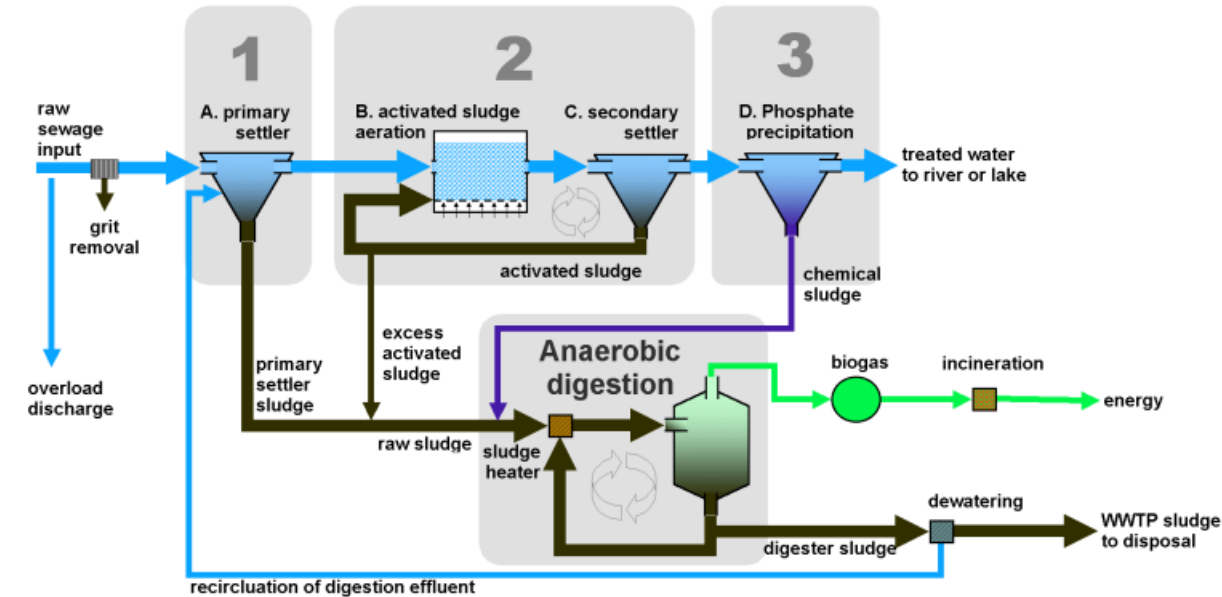
An arbitrary collection of micro-organisms present in activated sludge beds of WWTPs.



Water Quality and Public Health:

Municipal Wastewater

- The degradation processes are fundamentally the same as those occurring in natural waters but occur at a much faster rate and without exposing the natural ecosystem to untreated pollutants.
- The residence time is several hours. The aerobic environment converts ammonium (NH_4) + to nitrate (NO_3)- (nitrification) and organic carbon to CO_2 .
- Growth of micro-organisms leads to an accumulation of biomass in this stage.



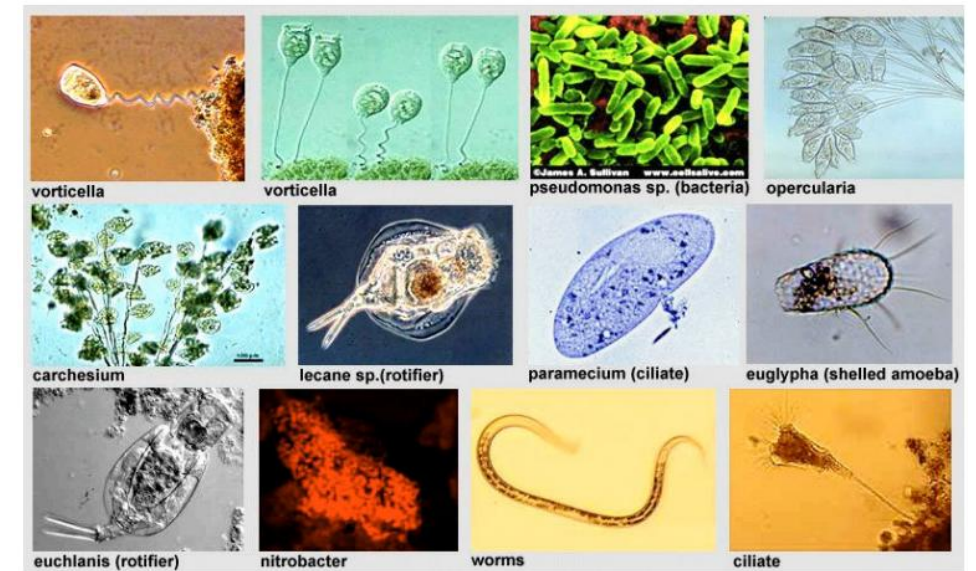


Water Quality and Public Health:

Municipal Wastewater

ANAEROBIC BACTERIA

- Anaerobic bacteria are used in **wastewater treatment** on a normal basis. The main role of these bacteria in **sewage treatment** is to **reduce the volume of sludge** and produce **methane gas** from it.
- This type of bacteria is able to get more than **enough oxygen from its food source** and will **not require adding oxygen** to help do its job.



An arbitrary collection of micro-organisms present in activated sludge beds of WWTPs.

reduce the volume of sludge and produce **methane gas**

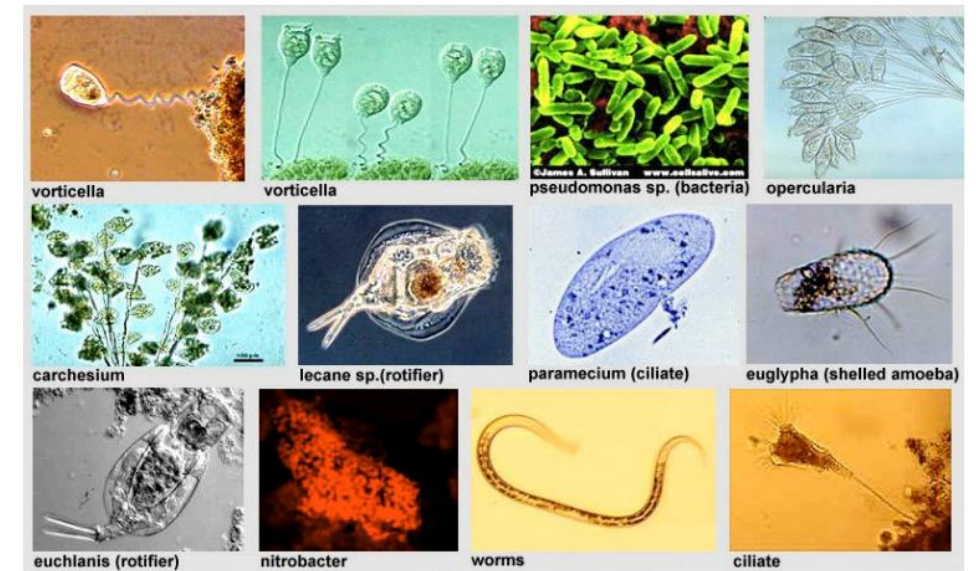


Water Quality and Public Health:

Municipal Wastewater

FACULTATIVE BACTERIA

- Facultative microorganisms in sewage treatment are bacteria that **can change between aerobic and anaerobic** depending on the environment they are in.
- Note that these bacteria **normally prefer** to be in an **aerobic condition**.



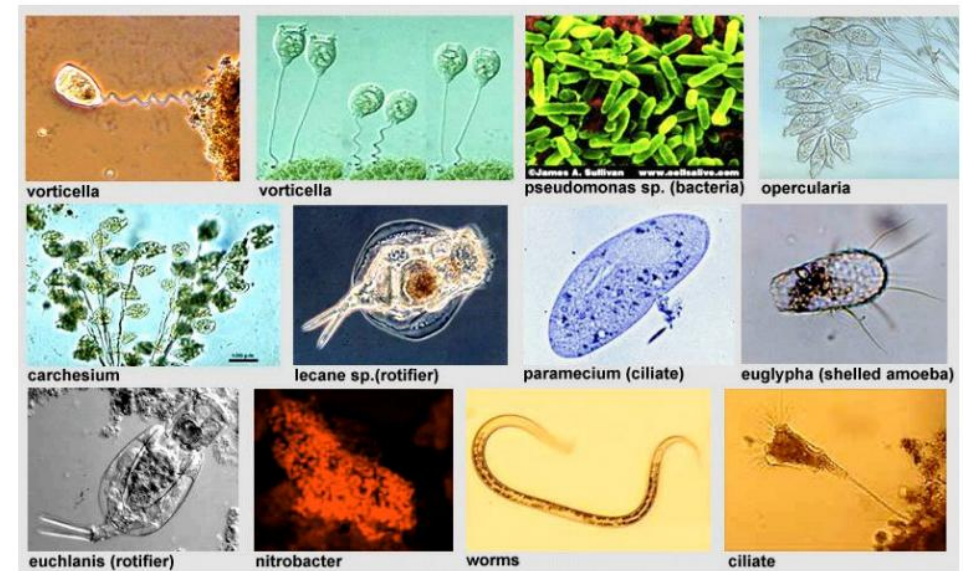
An arbitrary collection of micro-organisms present in activated sludge beds of WWTPs.



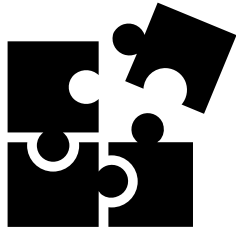
Water Quality and Public Health:

Municipal Wastewater

- **Bacteria** have been digesting human waste for millennia, but it wasn't until the **early 1900s** that microbiology advanced to the point where humans could **deliberately** put them to work in modern sewage treatment.
- Later, we realized that for **nearly any kind of waste** there were **microbes** that could be coaxed into breaking it down.



An arbitrary collection of micro-organisms present in activated sludge beds of WWTPs.

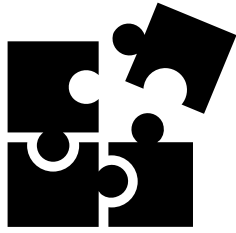


Water Quality and Public Health:

Municipal Wastewater

- **Microbial bioremediation** is used nowadays to clean up **pesticides, metals and organic industrial byproducts in water and soil**. Bacteria are abundant and **quick to adapt**, so if given enough time to get used to a **diet of industrial sludge**, something will most likely **find a way to live on it**.
- They take the **material that nobody else has the biochemical machinery to deal** with and turn it **into energy for themselves** and products that other living things can use.





Water Quality and Public Health:

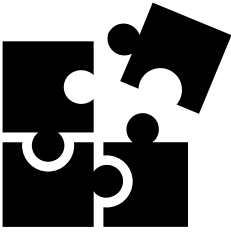
Municipal Wastewater

- This biomass is present as sludge, which is separated by a **second settling tank**.
- This sludge is called '**activated sludge**' since it stems from the **biologically active stage**.
- The activated sludge is recycled to the aeration tank. **Excess sludge is separated**. Some WWTPs feature also **enforced denitrification** in the **secondary stage**.
- In **denitrification** nitrate (NO_3) is **microbially transformed** to elemental **nitrogen** (N_2) which is **emitted to air**. Also some gaseous nitrous oxide (N_2O) is formed.



Activated sludge bed (left) and secondary settling tank (right) of WWTP Luzern

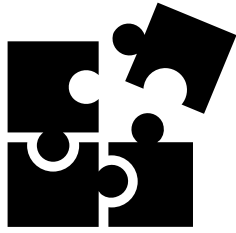
Sources of Water Pollution:



Municipal Wastewater

➤ Tertiary Treatment





Water Quality and Public Health:

Municipal Wastewater

- **Tertiary Treatment:** Advanced processes such as **filtration, disinfection** (e.g., chlorination, UV radiation), and **nutrient removal** (e.g., phosphorus and nitrogen removal) to further improve water quality.

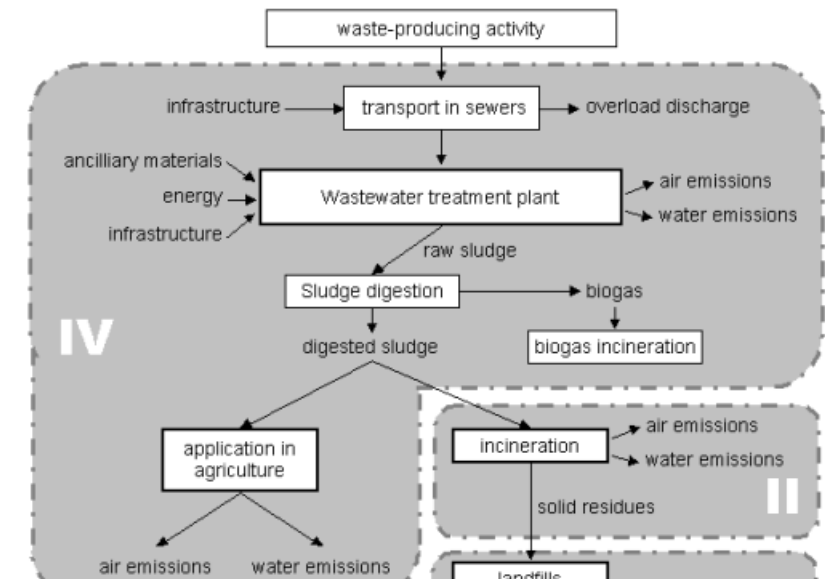


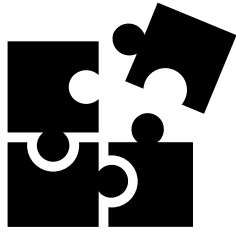


Water Quality and Public Health:

Municipal Wastewater

- **Disposal or Reuse:** Treated wastewater may be **discharged into receiving water bodies** (e.g., rivers, lakes, oceans) or **reused for various non-potable purposes** such as irrigation, industrial processes, and groundwater recharge.
- Reclaimed water may also be treated to meet drinking water standards for potable reuse.



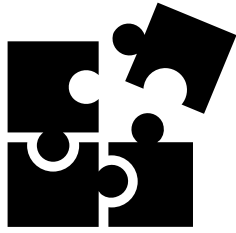


Water Quality and Public Health:

Municipal Wastewater

- **Monitoring and Regulation:** Wastewater management programs are supported by **monitoring and regulatory frameworks to ensure compliance with environmental standards** and protect public health and the environment.
- **Regulatory agencies** set standards for **effluent quality, discharge limits, and wastewater treatment practices**, and oversee compliance through monitoring and enforcement measures.





Water Quality and Public Health:

Municipal Wastewater

- Overall, **effective wastewater management is essential** for protecting **public health**, safeguarding the **environment**, and **ensuring sustainable water resources** for current and future generations.

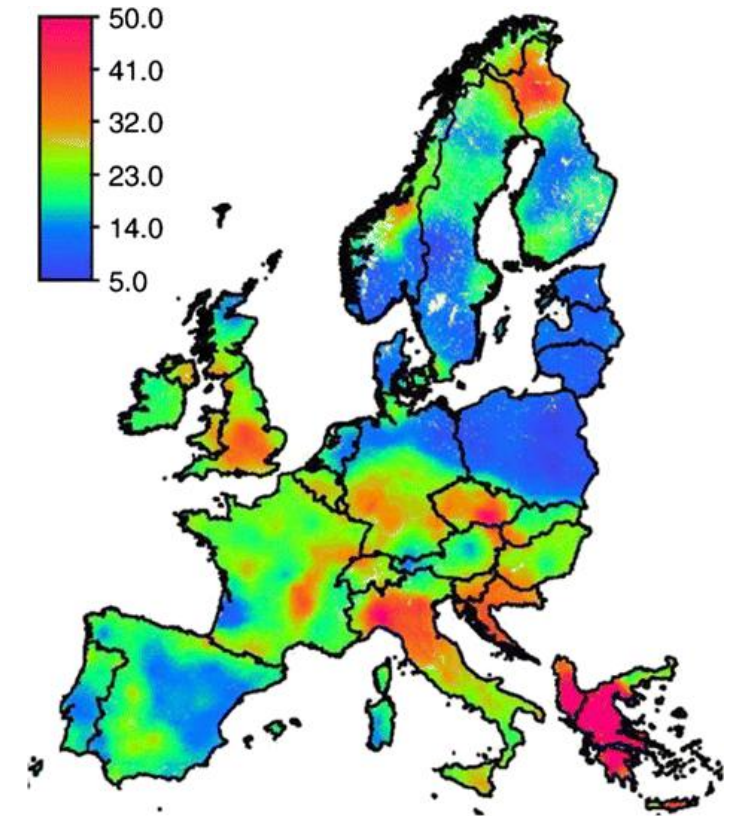


Water Quality and Public Health:

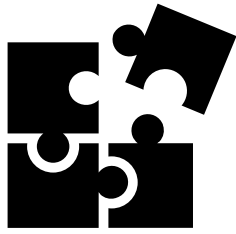


Chromium in Water and Carcinogenic Human Health Risk

- Chromium (Cr), mainly the **hexavalent chromium (Cr (VI))**, is a chemical **associated with cancer** when found in **drinking water**, making it a major public health issue.
- Hexavalent chromium is linked to **stomach cancer, lung cancer, and Hodgkin's disease**, according to the World Health Organization (WHO), and is classified as a **highly carcinogenic** substance in **group A**.



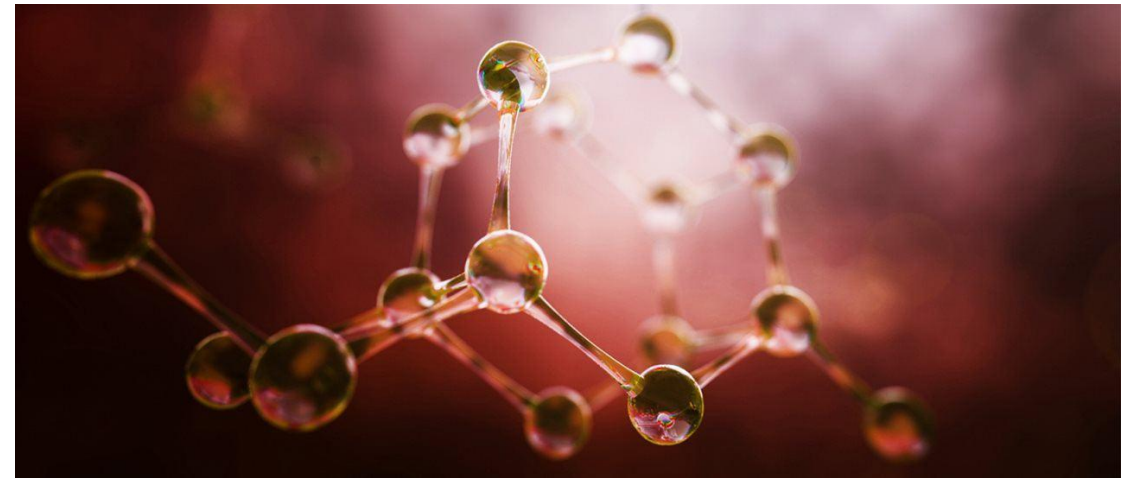
Map showing the natural content of chromium in European soil, expressed in milligrams per kilogram (Lapo et al. 2008)



Water Quality and Public Health:

Chromium in Water and Carcinogenic Human Health Risk

- Many case studies have shown that **continuous exposure to chromium**, even at low levels, can harm the skin, eyes, respiratory and immunological systems, and cause **DNA damage** and **oxidative stress**, leading to the growth of tumors.

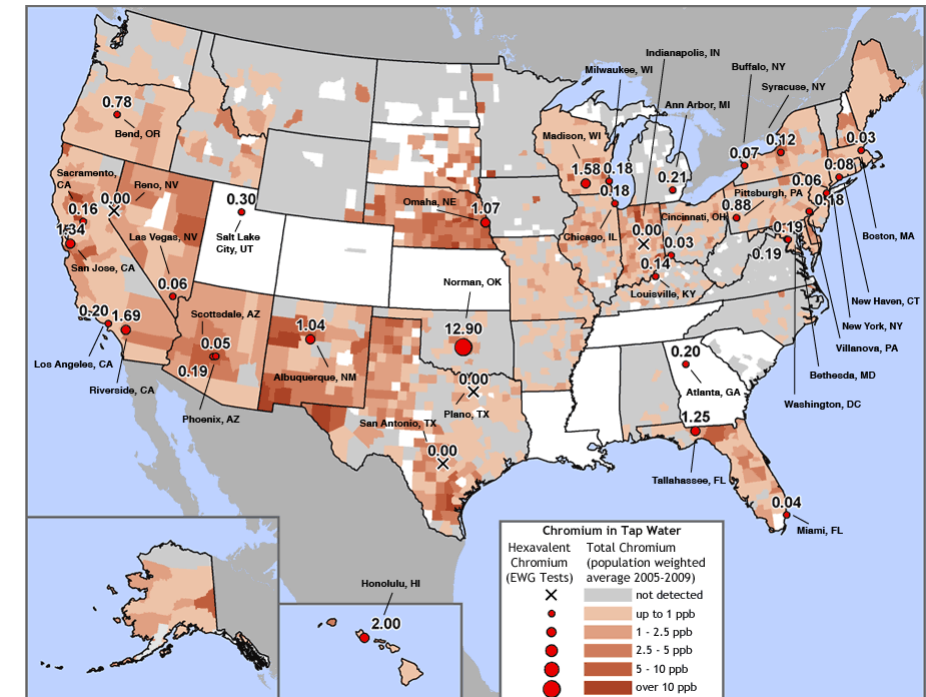




Water Quality and Public Health:

Chromium in Water and Carcinogenic Human Health Risk

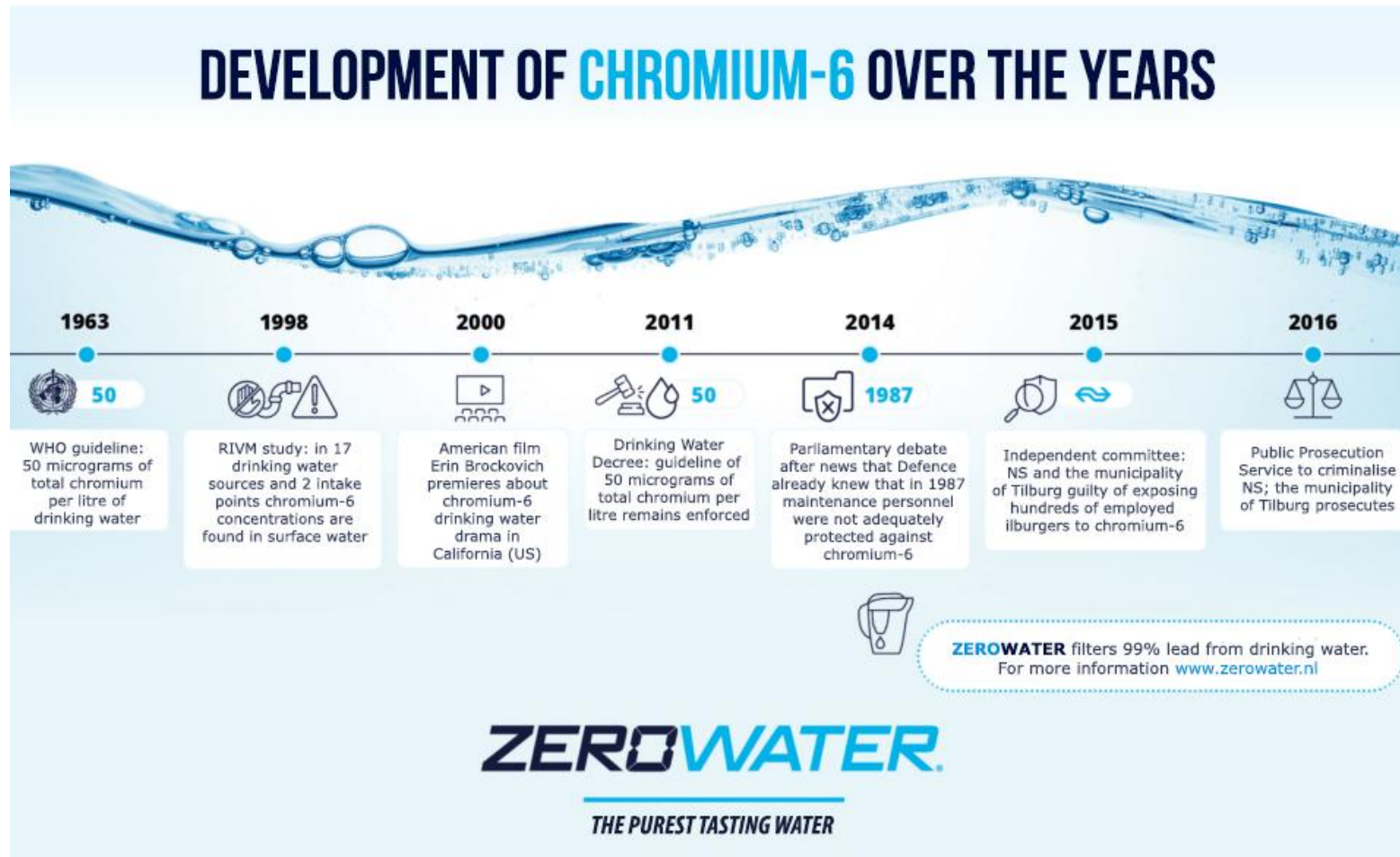
- Chromium 3 is an essential human dietary nutrient found in many vegetables, fruits, meats, grains, and yeast.
- Chromium 6 occurs naturally in the environment due to erosion of natural chromium deposits.
- Is used in industrial and manufacturing processes such as electroplating, tanning, and pulp processing. It can be found in consumer products such as spray paints, tanned leather and stainless steel.





Water Quality and Public Health:

Chromium in Water and Carcinogenic Human Health Risk

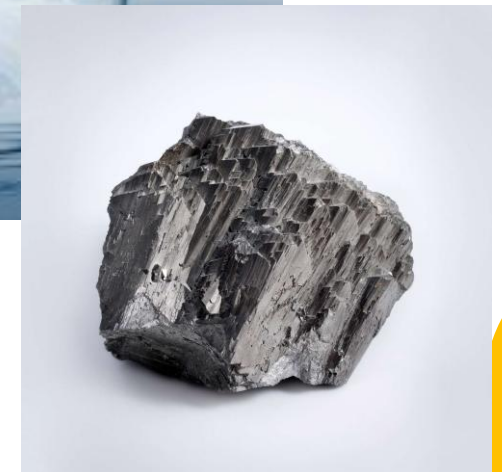


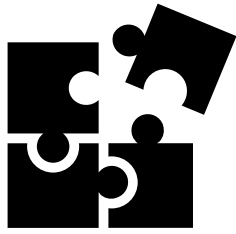


Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Arsenic is a chemical element found in many minerals and mixed in with metals as a strengthening agent.
- The chemical is notoriously poisonous to multi-cellular life, and arsenic contamination of ground water is a problem that affects millions of people around the world.





Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Natural sources (**geothermal**, like the hot springs) contaminate surface waters.
- **Groundwaters** are usually very low in suspended solids and microorganisms, they tend to have **higher concentrations of dissolved metals** and other salts.
- Not all groundwater sources are high in arsenic.
- If you get your **drinking water from a well**, the safest thing is to **test your water regularly (3-5 years)**.
- If the **concentration is above 10 ppb**, you should think about **drinking bottled water**, or **treating** your drinking and cooking water.

Arsenic in Well Water

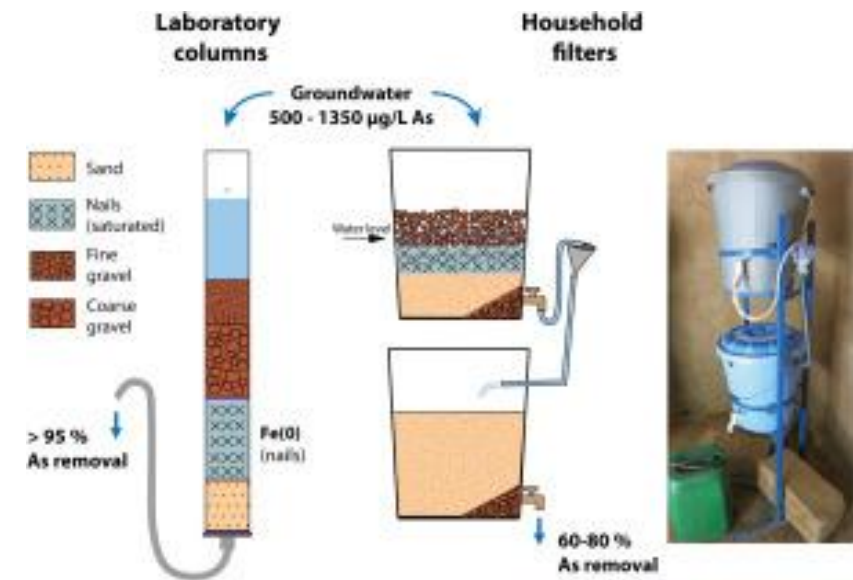




Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Install **arsenic removal systems** – either centralized or domestic – and ensure the appropriate disposal of the removed arsenic.
- There is an **increasing number** of **effective** and **low-cost options** for **removing arsenic** from small or household supplies.

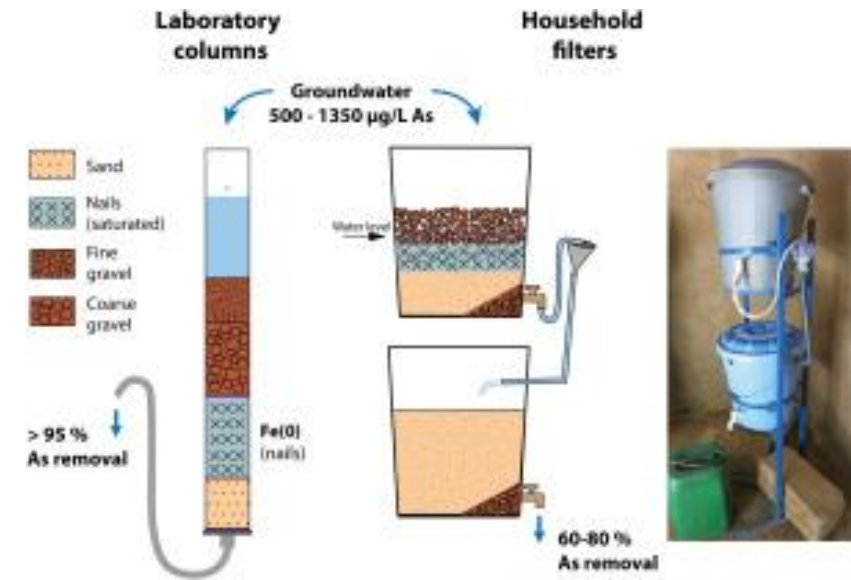




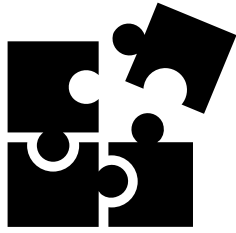
Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- The most common **technologies** used for **arsenic** removal are **adsorption** and **coagulation filtration**.
- **Adsorption** is a more **passive process**, but can have **higher operating costs** for challenging waters when compared to **coagulation filtration**.
- **Coagulation filtration** entails **more operator interface** and **routine sludge handling**.
- **Ion exchange** is sometimes used, but **requires regeneration** and produces a **hazardous liquid waste**.



<https://www.sciencedirect.com/science/article/pii/S0048969720329831>



Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- In mining, **excavated rock** that does not contain useful quantities of the target metals is sometimes **left in a pile**.
- Once it is exposed, it can **react with oxygen**, with or without the help of bacteria, releasing **metals and arsenic**.





Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Strategies for utilities typically include **blending**, **acquiring new or less/uncontaminated sources**, and **treatment**.
- **Smaller water supply systems** often have a **hard time controlling arsenic levels** due to **lack of funds** and other resources.



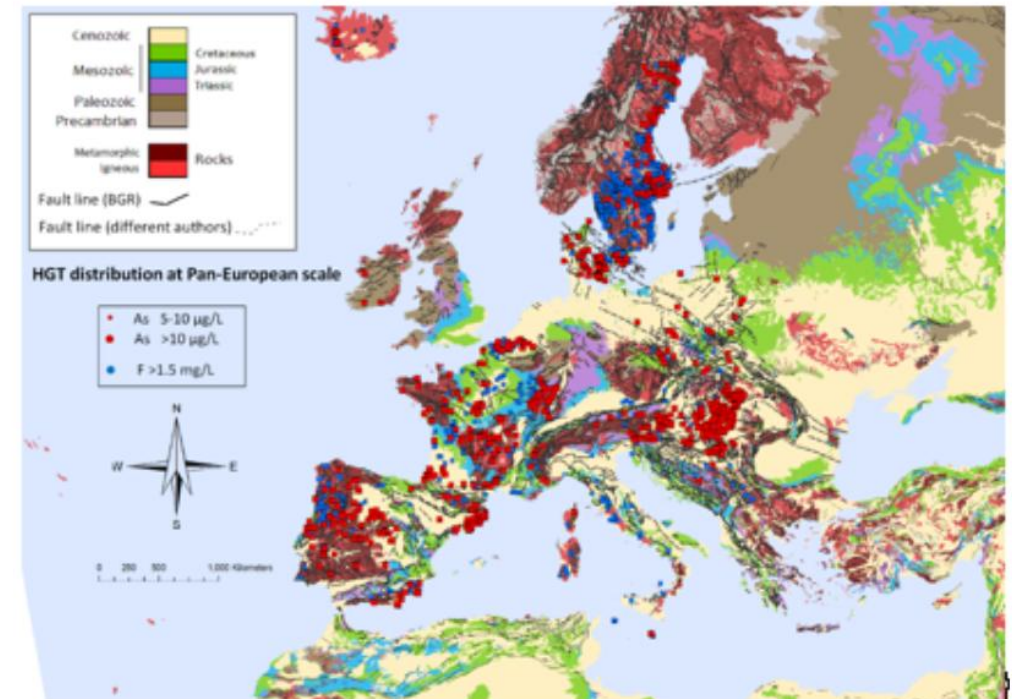


Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Inorganic arsenic is naturally present at high levels in the groundwater of a number of countries, including Argentina, Bangladesh, Cambodia, Chile, China, India, Mexico, Pakistan, the United States of America and Vietnam.
- Drinking-water, crops irrigated with contaminated water and food prepared with contaminated water are the sources of exposure.

<https://www.who.int/news-room/fact-sheets/detail/arsenic>



HGT (Hydrogeotoxicity) distribution at Pan-European Scale for Arsenic and Fluoride.
E. Gimenez Forcada et al., 2021)

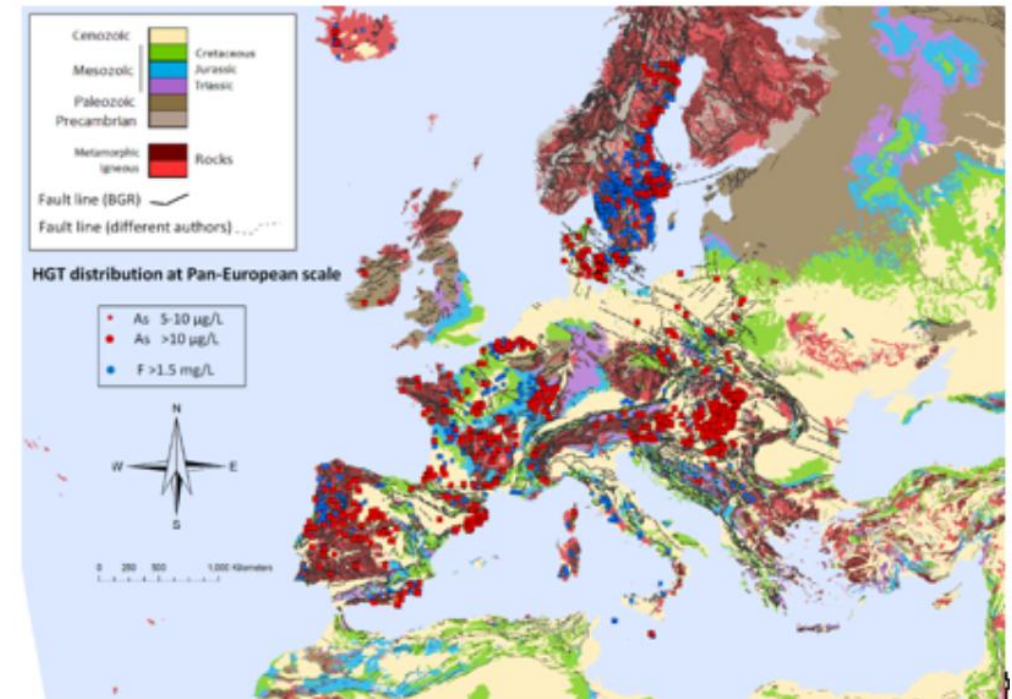
<https://mailchi.mp/267bef123784/hover-geoera-13790171?e=631ca6de85>



Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Inorganic arsenic is a **confirmed carcinogen** and is the **most significant chemical contaminant** in **drinking-water globally**.
- **Inorganic arsenic** compounds (such as those found in water) are **highly toxic** while **organic arsenic** compounds (such as those found in seafood) are **less harmful** to health.



HGT (Hydrogeotoxicity) distribution at Pan-European Scale for Arsenic and Fluoride.
E. Gimenez Forcada et al., 2021)

<https://www.who.int/news-room/fact-sheets/detail/arsenic>

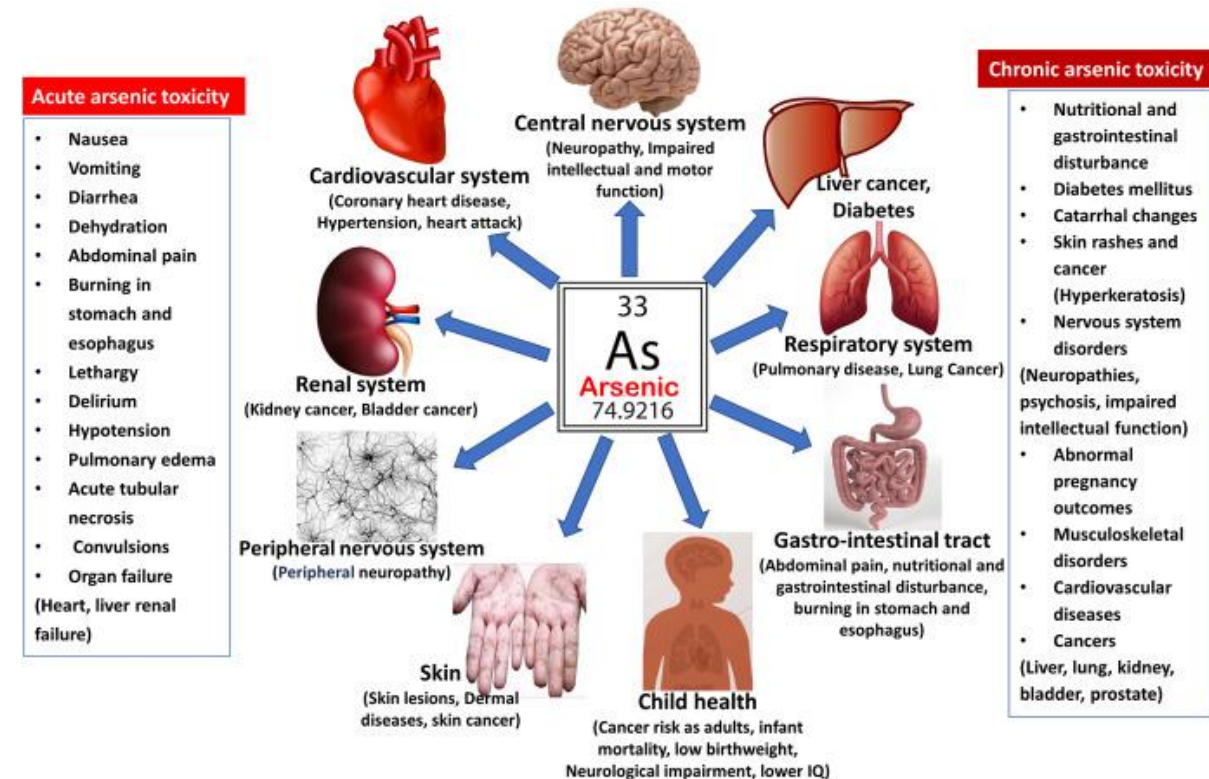
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Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- The **immediate symptoms** of acute arsenic poisoning include **vomiting, abdominal pain and diarrhea**.
- These are followed by **numbness and tingling of the extremities, muscle cramping and death**, in extreme cases.



<https://www.who.int/news-room/fact-sheets/detail/arsenic>

<https://mailchi.mp/267bef123784/hover-geoera-13790171?e=631ca6de85>



Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- **Long-term exposure** to **high levels** of **inorganic arsenic** are usually observed in the skin, and include **pigmentation changes**, **skin lesions** and hard patches on the palms and soles of the feet (**hyperkeratosis**).
- These occur after **a minimum exposure of approximately five years** and may be a **precursor** to **skin cancer**.



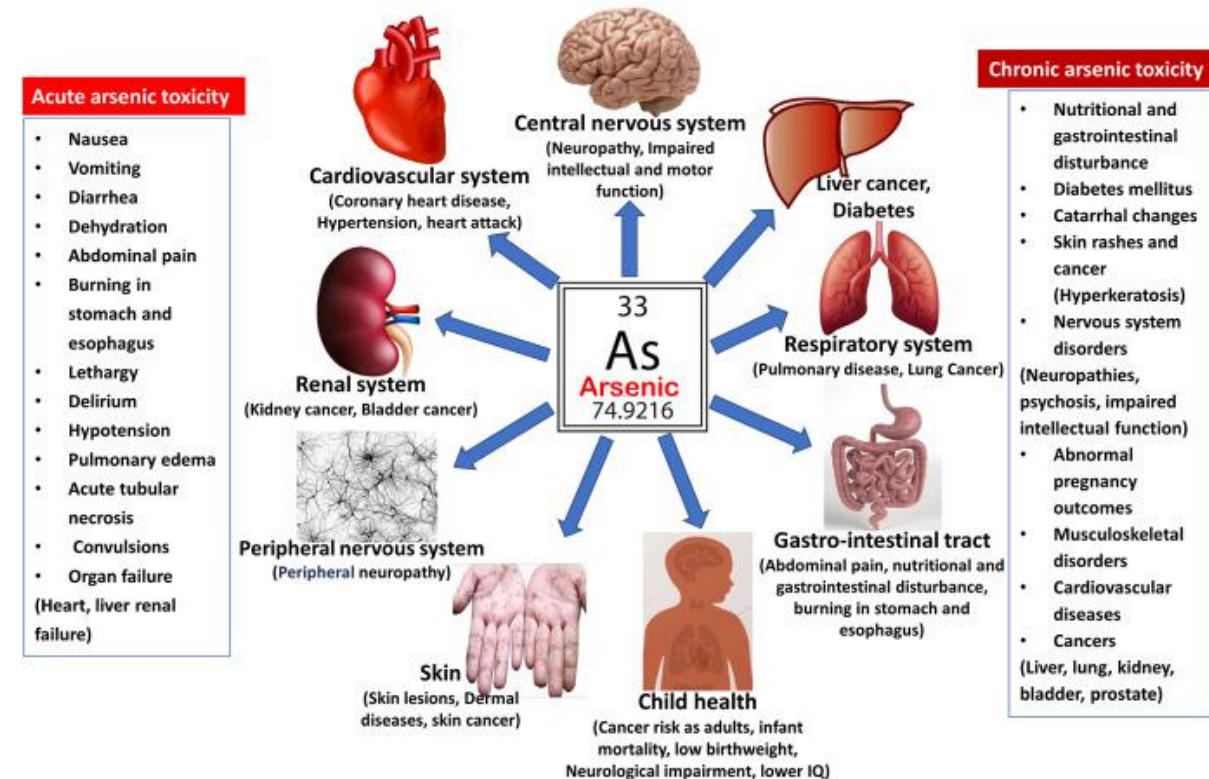
<https://www.who.int/news-room/fact-sheets/detail/arsenic>



Water Quality and Public Health:

Arsenic in Water and Carcinogenic Human Health Risk

- Long-term exposure to arsenic may also cause cancers of the bladder and lungs.
- The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans.



<https://www.who.int/news-room/fact-sheets/detail/arsenic>

<https://mailchi.mp/267bef123784/hover-geoera-13790171?e=631ca6de85>

Water Quality and Public Health:



Methylmercury Contamination of Aquatic Ecosystems

- Mercury exists in various forms, primarily in a mineral called **cinnabar**, which can contain up to 86% mercury. People have been **extracting mercury** from **cinnabar** since at least **Roman times**.
- Mercury is released through the natural weathering of rock and (or) **volcanic activity, geothermal springs, geologic deposits, and the ocean**.
- The most common way people are exposed to mercury is by **eating fish containing methylmercury**.



Cinnabar – use in traditional medicines, alchemy and as a pigment in art - toxic to humans

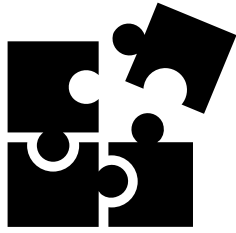


Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- Methylmercury, a **highly toxic** organic compound, is the form of mercury encounter **most frequently**.
- **Almost all people** in the world have **at least trace amounts of methylmercury** in their bodies, reflecting its prevalence in the environment.
- However, **most people** have mercury levels in their bodies **below the level associated** with possible **health effects**.

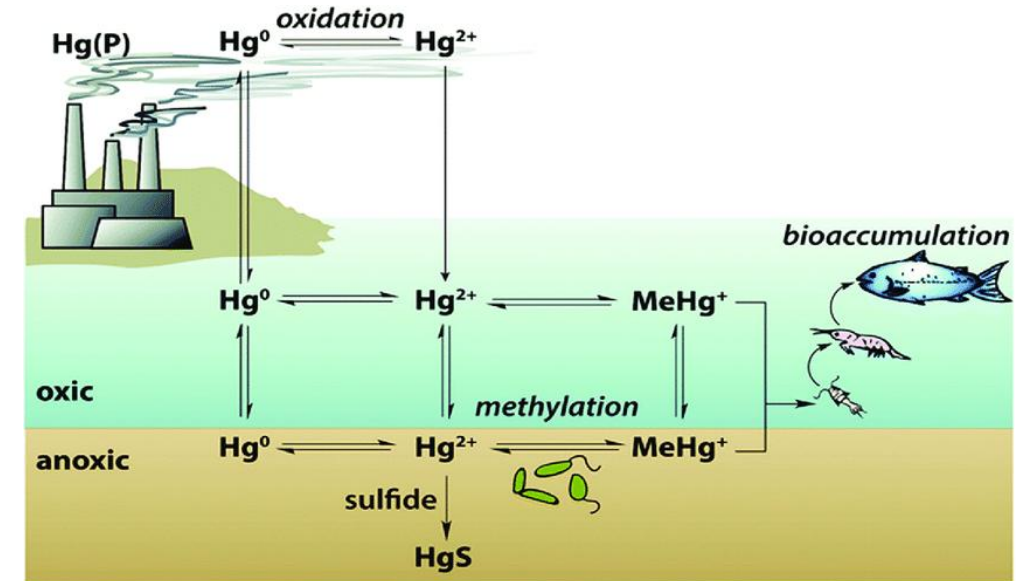




Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- About a **third of the mercury** currently released to the world's atmosphere comes **directly from human activities**.
- Another **third** comes from the **oceans** through **photoreduction** at the surface and volatilization because mercury is incredibly photosensitive.
- The third source comes from **soil emissions**, again, mostly through **photoreduction**.
- **The rest is** reemissions of anthropogenic sources of **mercury** in the **oceans** and **soils** of the world.

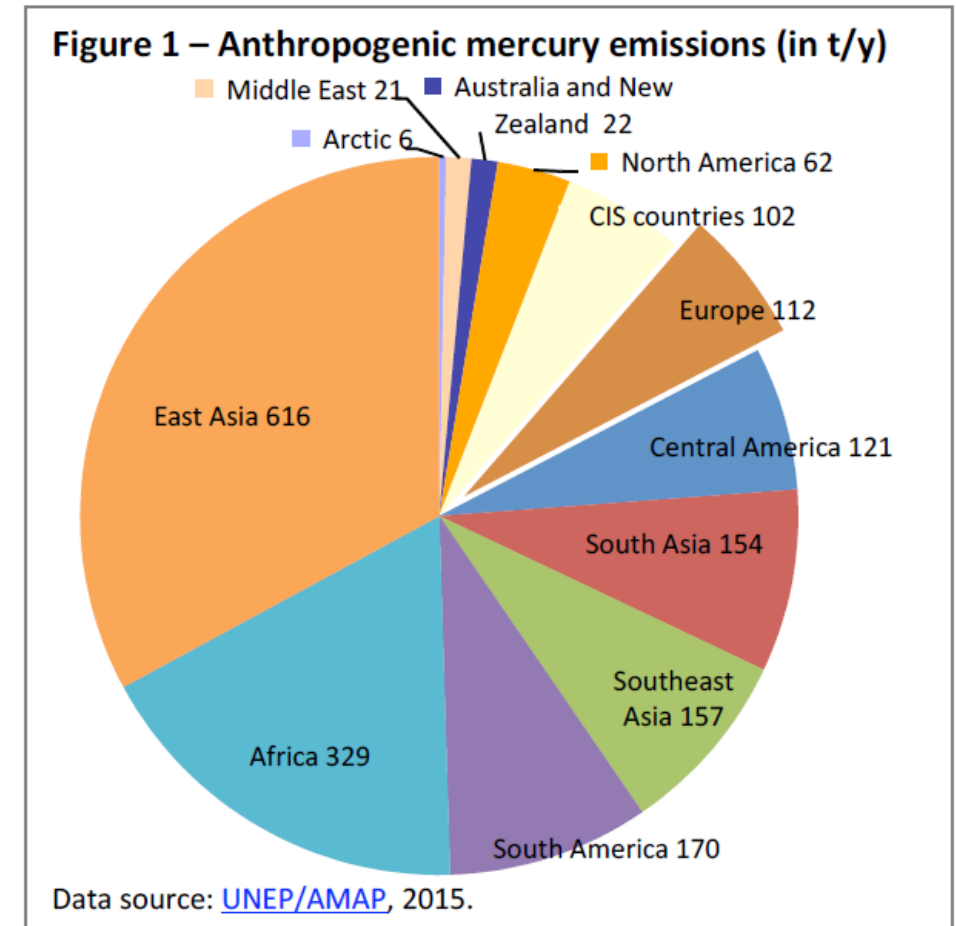




Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- A number of developing countries, particularly **China**, are the **biggest mercury emitters worldwide**, primarily because of their use of energy generated from **coal combustion**.





Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- The **combustion of coal, oil, and wood as fuel**, as well as the **incineration of mercury-containing waste**, can release **mercury** into the **atmosphere**, contributing to **air pollution** and **environmental contamination**.

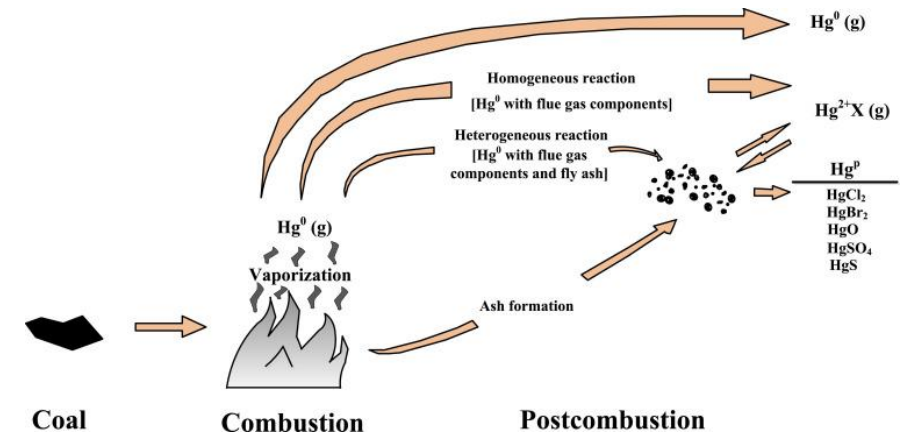


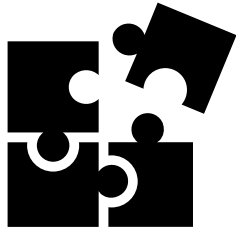


Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- This airborne mercury can **fall to the ground** in raindrops, in dust, or simply due to gravity (known as “**air deposition**”).
- The **amount of mercury deposited** in a given area depends on **how much mercury is released** from local, regional, national, and international sources.

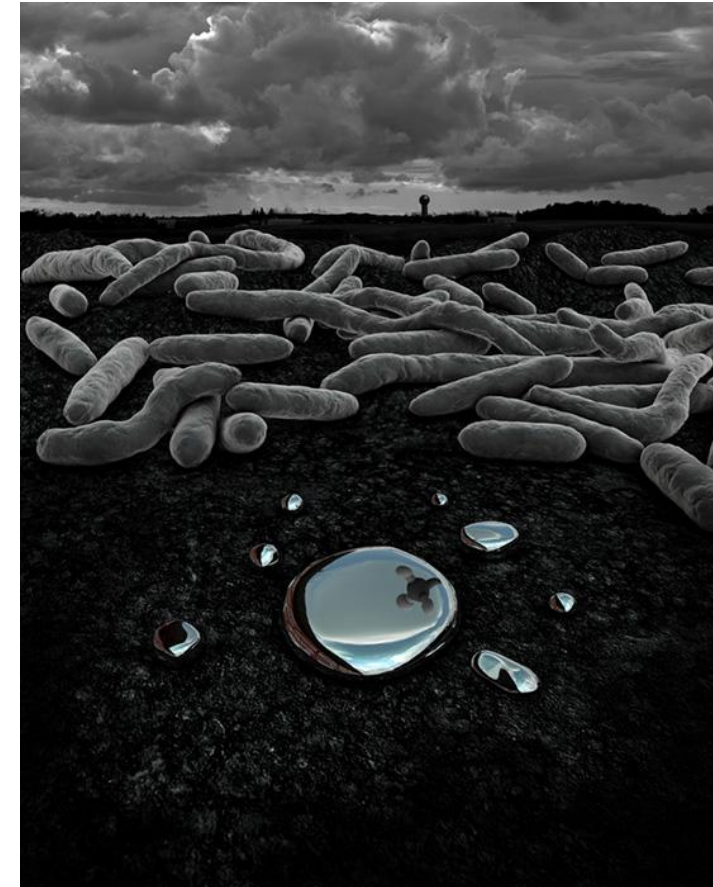


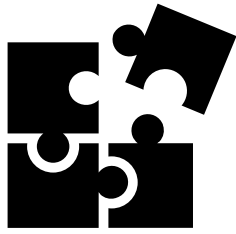


Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- **Microorganisms** in **waterbodies** can change it into **methylmercury**, where it builds up in **fish and shellfish**.
- The levels of methylmercury in fish and shellfish depend on:
 - What they eat?
 - How long they live?
 - How high they are in the food chain?

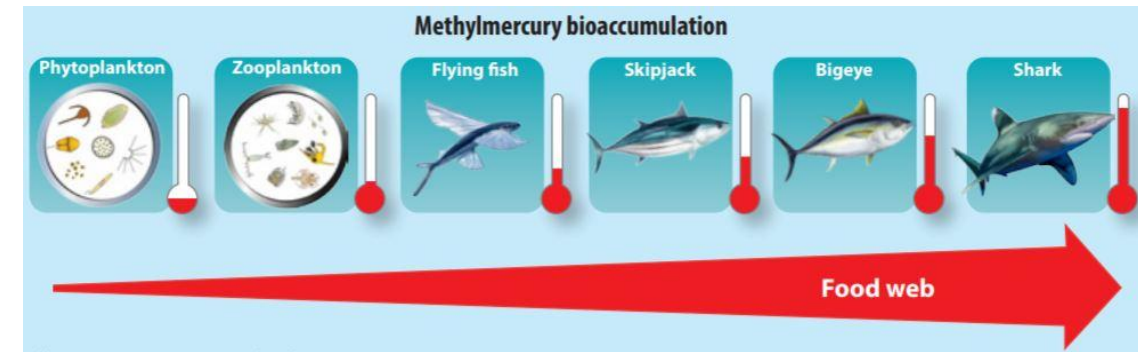




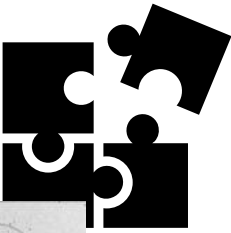
Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- All of the **mercury in consumable fish tissues** and just about all vertebrate systems is **methylmercury**.
- This is the **only form of mercury** that **bioaccumulates** in **humans and wildlife**, the only form of mercury that **crosses the blood-brain barrier** where it causes most of its problems, and the only form that **accumulates in human neurological tissues**.

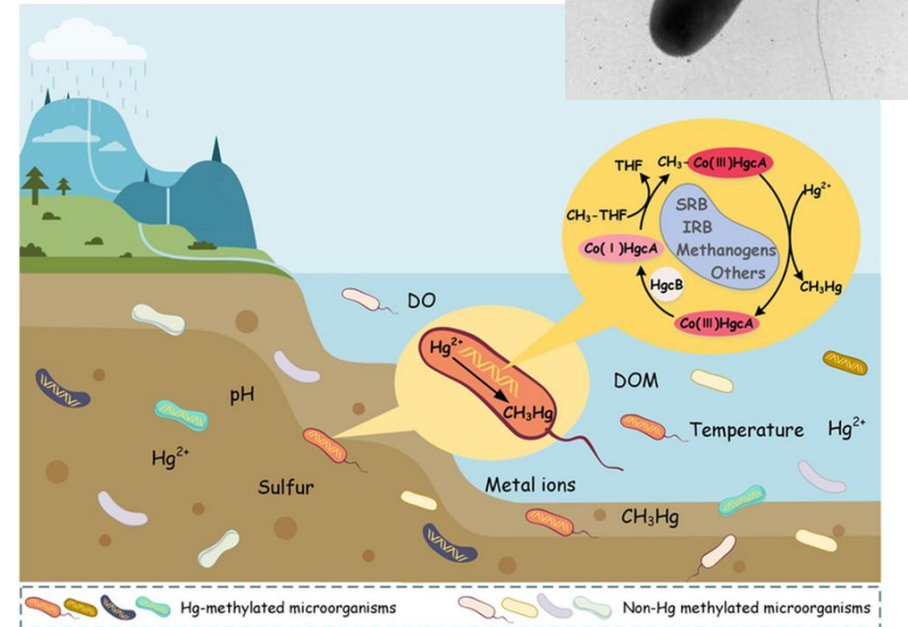


Water Quality and Public Health:



Methylmercury Contamination of Aquatic Ecosystems

- Methylmercury (MeHg) is formed from **inorganic mercury** (Hg^{2+}) through a process called **microbial methylation**.
- **Anaerobic bacteria** (e.g., sulfate-reducing and iron-reducing bacteria) in **sediments and water bodies** convert Hg^{2+} into **methylmercury** (MeHg).



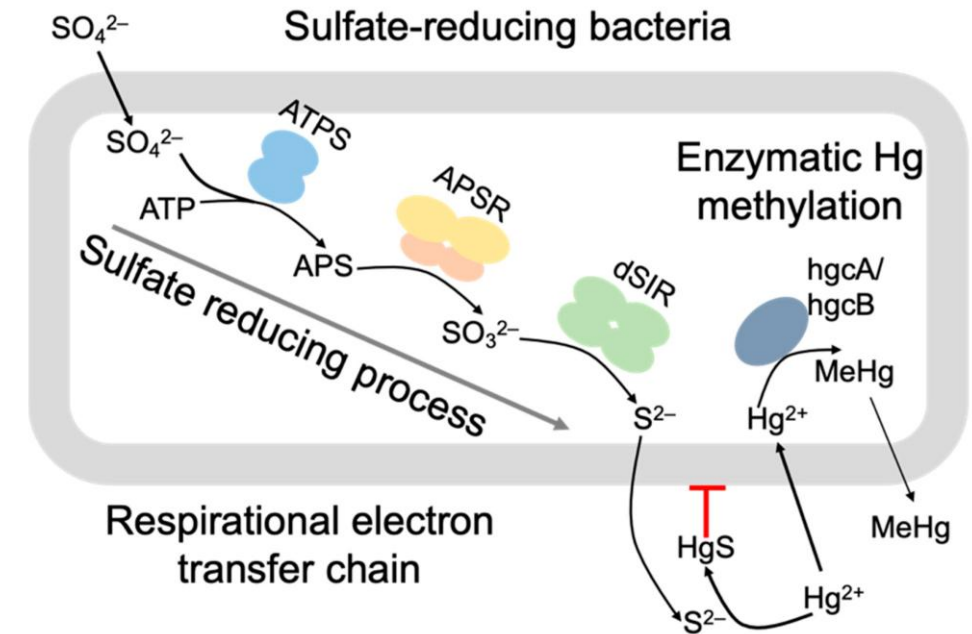
Metabolic processes, attaching a **methyl group** ($-\text{CH}_3$) to Hg^{2+} , forming CH_3Hg^+ (MeHg)



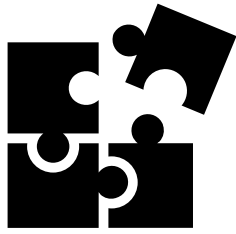
Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- Methylmercury is **lipophilic**, meaning it **easily enters** and **accumulates** in **aquatic organisms**.
- **Small organisms ingest** MeHg, and it moves up the food chain, leading to **high concentrations in predatory fish** (e.g., tuna, swordfish) and **posing risks to human health** when consumed.



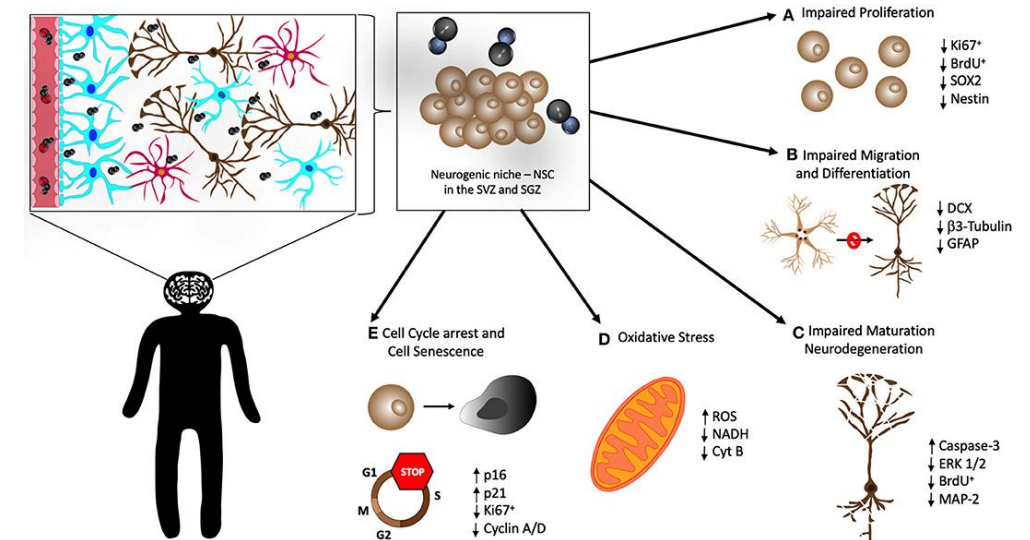
Metabolic processes, attaching a **methyl group** ($-\text{CH}_3$) to Hg^{2+} , forming **CH_3Hg^+ (MeHg)**



Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- The harmful **methylmercury** form of mercury **readily crosses biological membranes** and can accumulate to **harmful concentrations in the exposed organism** and become **increasingly concentrated up the food chain**.



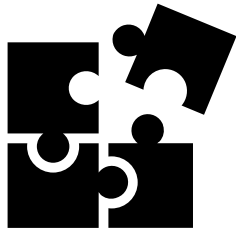


Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- Highly toxic to the nervous system;
- Persistent in the environment;
- **Bioaccumulates** (higher concentrations in tissues of aquatic plants and animals than in water);
- **Biomagnifies** (higher concentrations at increasingly higher levels in the food chain).

Common Mercury Exposure Routes			
	Elemental	Inorganic	Organic
Inhalation	High	Low	Low
Oral	Low	Med	High
Dermal	Low	Med	Low



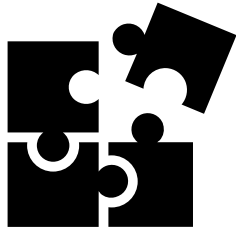
Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- Dental amalgams contain **about 50% elemental mercury**. Liquid mercury in a pre-measured capsule is mixed with **silver, copper, tin, and other elements**, to create the filling.
- Dental amalgams **can leach elemental mercury vapor** during **chewing, brushing** and corrosion into saliva - has been proven to **accumulate in the body**.



Current rules forbid the use of amalgam for treating **children under 15 years old and pregnant or breastfeeding women**.



Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- Mercury, such as **thiomersal** (ethylmercury), is used in very small amounts **as a preservative** in some **vaccines** and pharmaceuticals.
- **Thiomersal - ethylmercury** is broken down by the body quickly and **does not accumulate**.
- WHO has **closely monitored scientific evidence** relating to the use of thiomersal as a vaccine preservative for more than 10 years: there is **no evidence** that the amount of thiomersal used in vaccines poses a health risk.



<https://www.who.int/news-room/fact-sheets/detail/mercury-and-health>



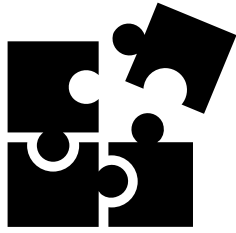
Water Quality and Public Health:

Methylmercury Contamination of Aquatic Ecosystems

- Mercury is **extremely poisonous**, and we can absorb it by **touch, inhalation, or consumption**.
- It **builds up in the body** with each exposure and is very difficult to remove.
- **Mercury poisoning**, which is both **unpleasant and potentially fatal**.



Mercury exists in various forms: elemental (or metallic) and inorganic (to which people may be exposed through their occupation); and organic (e.g., methylmercury)



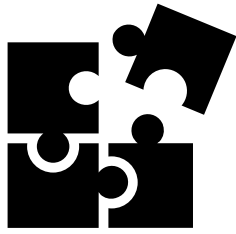
Water Quality and Public Health:

Sources of Water Pollution

- Although many kinds of literature focus on water pollution and a particular disease, there is still a **lack of research** results that systematically analyze the impact of water pollution on human health and the heterogeneity of diseases

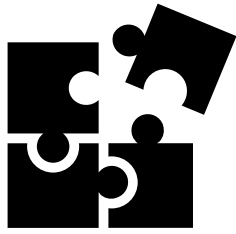


Water Quality and Public Health:



MICROPLASTICS



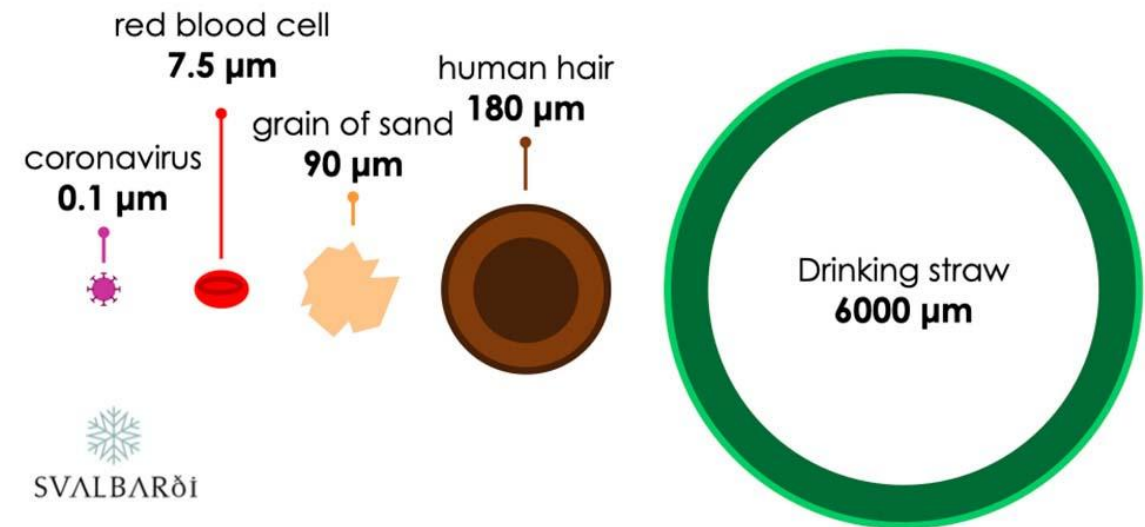


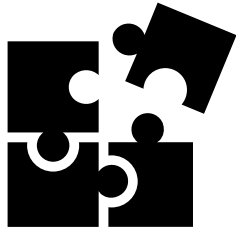
Water Quality and Public Health:

Sources of Water Pollution

- **Microplastics** are **tiny plastic fragments** that are found throughout the **environment**, including in soil and bodies of water.
- **Microplastics** are tiny particles, **less than five millimeters in size**, ranging from the width of a **strand of hair** to the **scale of microscopic organisms**.
- They can vary widely in **shape, size, and chemical composition**.

Items Comparable in Size to Microplastics



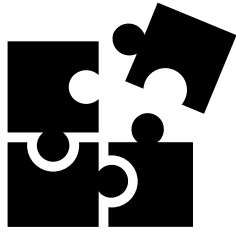


Water Quality and Public Health:

Sources of Water Pollution

- Polyethylene (PE), polybutylene succinate (PBS), and polyvinyl chloride (PVC) are the most common microplastics.
- Secondary microplastics are formed by the breaking up of larger pieces when exposed to UV radiation (from the sun), high temperatures, and weathering in the environment.



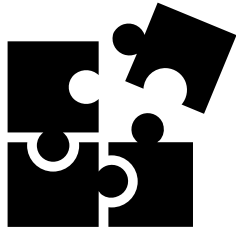


Water Quality and Public Health:

Sources of Water Pollution

- **Microplastics** in water may threaten animal and human health by entering the **food chain or transporting concentrated contaminants** in aquatic environments.
- Microplastics caused **tissue abrasions** leading to **bacterial infections, impairing mucus production**, and could even lead to death.
- The **corals** exposed to **high concentrations** of microplastics **incurred tissue damage** which was **6.5 times that of corals** that were not exposed to microplastics or had ingested low concentrations of microplastic after a period of 14 days.





Water Quality and Public Health:

Sources of Water Pollution

- Other studies cited **showed negative impacts** at **molecular, cellular, and population levels** on fish, **larger marine creatures**, and **plankton**.
- Disturbances in **genetic functions, reproduction, and feeding** were identified.



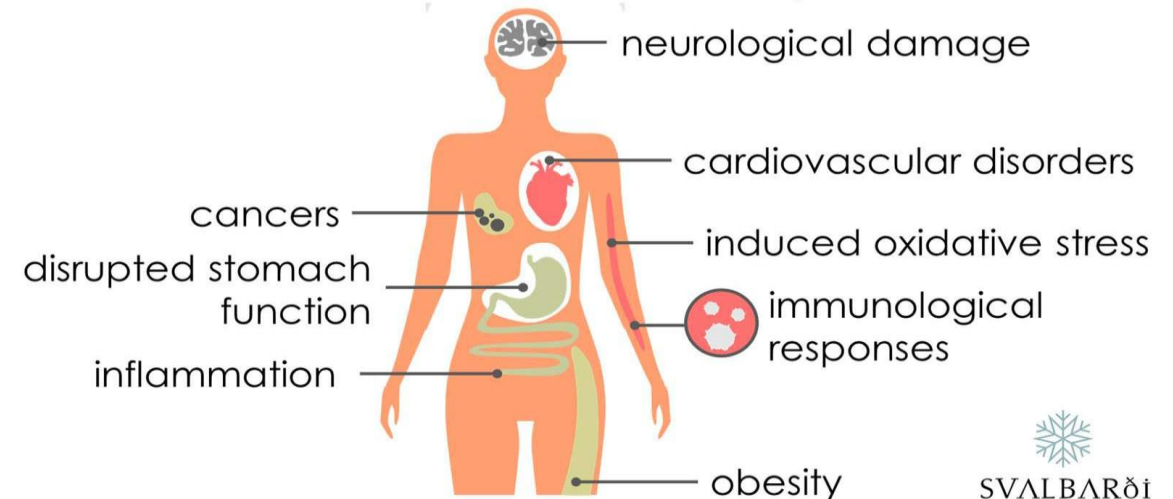


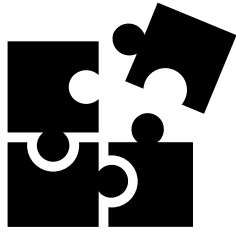
Water Quality and Public Health:

Sources of Water Pollution

- For humans, while there is an **ongoing debate**, drinking water containing microplastics or eating contaminated seafood **may pose health threats**.
- For example, the Woods Hole Oceanographic Institution found that **certain microplastics** in **water** such as **polychlorinated biphenyls (PCBs)** **are linked to cancer**.

Areas of Research on Potential Microplastic Harms



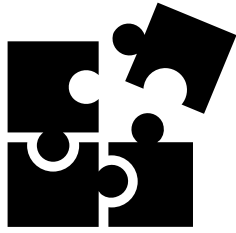


Water Quality and Public Health:

Sources of Water Pollution

- There are five main water types that have microplastics.
- Tap water
- Bottled water (drinking water)
- Marine water
- Waste water
- Arctic water





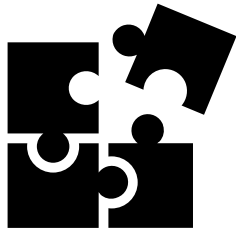
Water Quality and Public Health:

Sources of Water Pollution

- There are five main water types that have microplastics.

1. **Tap water** - Natural sources tend to be of higher initial quality, **but all sources are usually filtered** and treated to some degree before entering the system for general usage.





Water Quality and Public Health:

Sources of Water Pollution

2. Bottled water

- The US Food and Drug Administration (FDA) defines bottled drinking water as **water “intended for human consumption, sealed in containers with no added ingredients except safe and suitable antimicrobials and fluoride within limits”**.
- How much microplastic is in bottled water? With thousands of **bottled water brands** around the world from **different sources** and with **different filtration and manufacturing processes**, it is **not possible to draw a firm conclusion** on the amount of microplastics in the category as a whole.



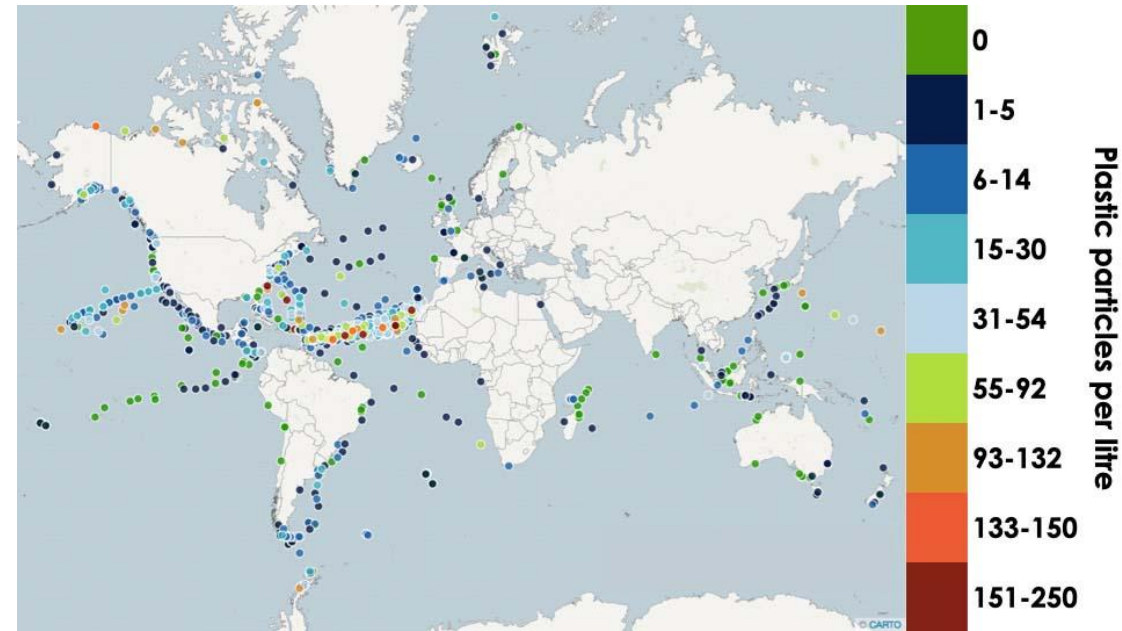


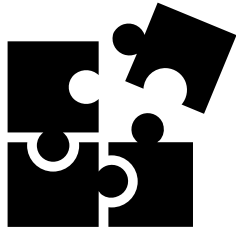
Water Quality and Public Health:

Sources of Water Pollution

3. Marine water

- How much microplastic is in marine water?
- A citizen science study known as the **Global Microplastics Initiative** published a report in the journal Environmental Pollution in 2018 where they showed that **90% of 1393 ocean samples from around the world had microplastics**, with an average concentration of 118 particles per liter.
- **91% were microfibers** from plastic elements in fabrics.

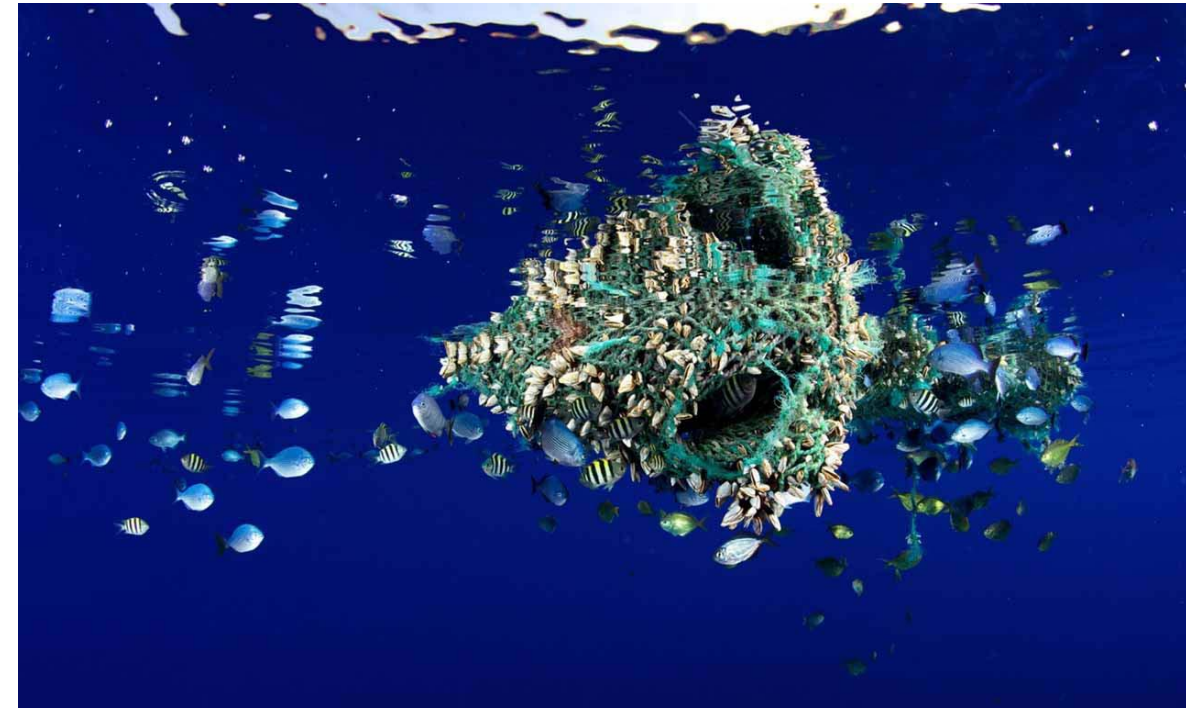


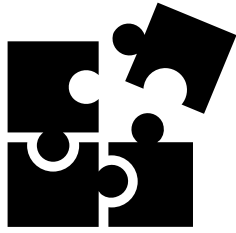


Water Quality and Public Health:

Sources of Water Pollution

- Marine water
- Large plastic debris originating from **urban environments** regularly enters freshwater.
- Microplastics enter the environment directly via **waste streams** that include personal care products, textiles with synthetic fibers (often detached in washing machines), and **cleaning agents**.
- From there they can flow into the ocean environment. **Discarded plastic fishing nets** such as this one erode into microplastics over time.





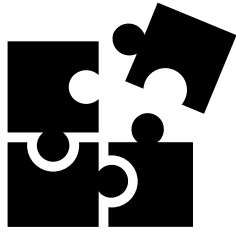
Water Quality and Public Health:

Sources of Water Pollution

4. Wastewater

- Wastewater effluent is a **widely recognized source of microplastic pollution** into freshwater bodies and in agricultural soil, but **effective water treatment can reduce these harmful effects**.



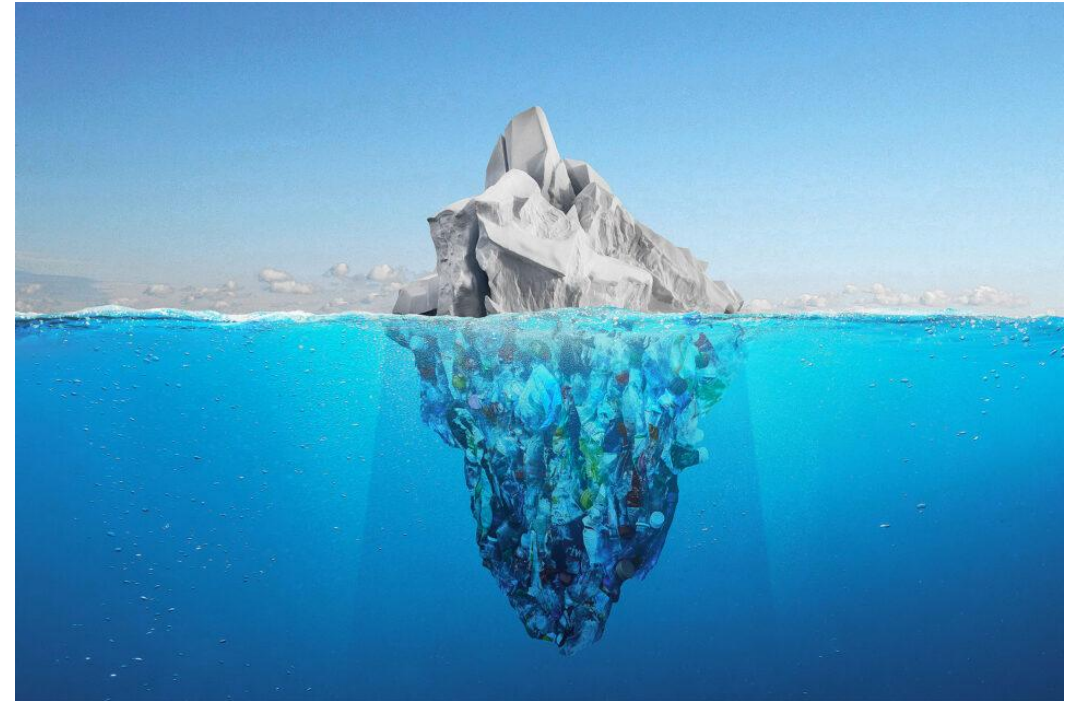


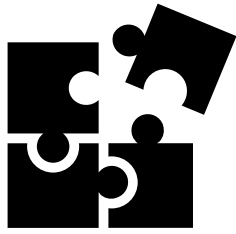
Water Quality and Public Health:

Sources of Water Pollution

5. Arctic Water

- Higher microplastic concentrations were detected towards the eastern Arctic which is influenced by the Atlantic Ocean compared to the western Arctic which is influenced by the Pacific Ocean.

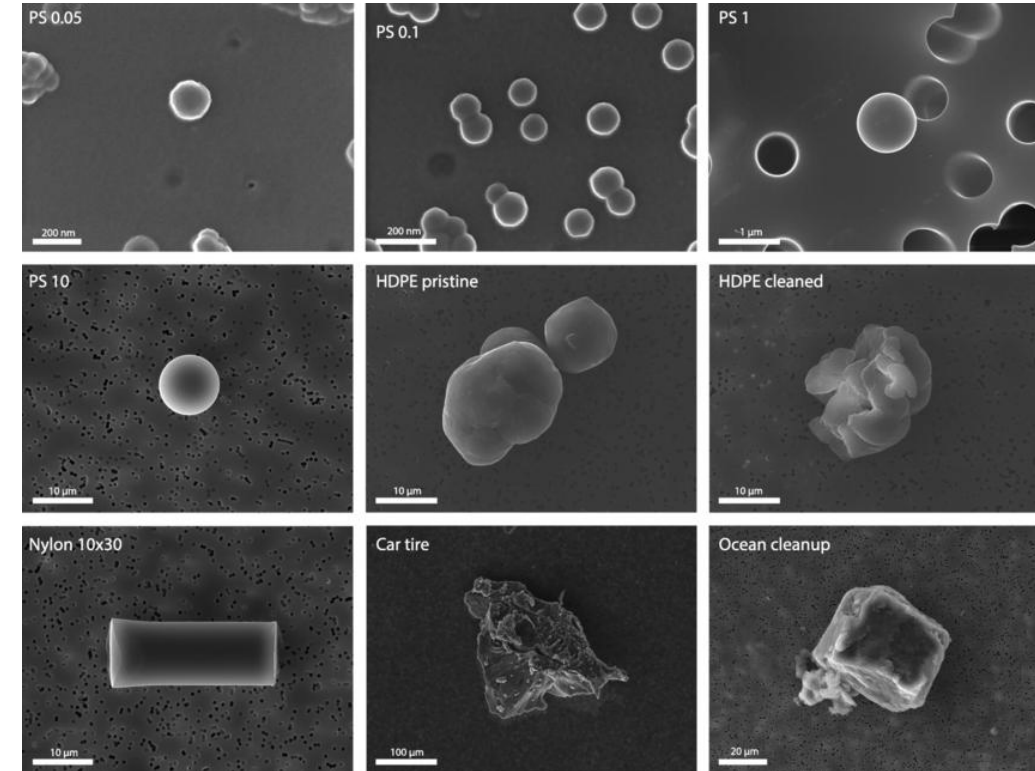


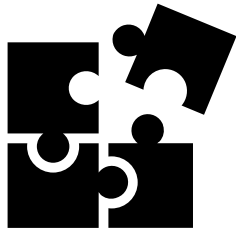


Water Quality and Public Health:

Sources of Water Pollution

- **Plastics** are a part of our **everyday lives**, and plastic pollution is a growing concern.
- **Microplastics**, in turn, can break down into even smaller pieces called **nanoplastics**, which are **less than 1 μm in size**.
- Unable to be seen with the naked eye, these are small enough to enter the **body's cells and tissues**.





Water Quality and Public Health:

Sources of Water Pollution

- Marine microplastic pollution is a **growing problem** for ecotoxicology that needs to be resolved.
- Microplastics are colonized by **bacteria, fungi, viruses, archaea, algae and protozoans**, resulting in the biofilm referred to as the “**plastisphere**.”
- Microorganisms of the plastisphere may play **key roles in degradation of plastic** in the oceans.

Up to now, bacterial species, especially *Bacillus* and *Pseudomonas* as well as some **polyethylene** degrading biocatalysts, have been **shown to be capable of degrading microplastics**.

