Objective/EKs/Skill

LEARNING OBJECTIVE

STB-3.A

Identify differences between point and nonpoint sources of pollution.

ESSENTIAL KNOWLEDGE

STB-3.A.1

A point source refers to a single, identifiable source of a pollutant, such as a smokestack or waste discharge pipe.

STB-3.A.2

Nonpoint sources of pollution are diffused and can therefore be difficult to identify, such as pesticide spraying or urban runoff.

Unit 8
Aquatic & Terrestrial Pollution

LEARNING

ENG-3.A

Identify diffe
nonrenewabl
energy sourc

SUGGE

⬡ *c*

1.C

8.8

Biomagnification

Objective/EKs/Skill

SUGGESTED SKILL

✎ *Scientific Experiments*

4.A

Identify a testable hypothesis or scientific question for an investigation.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
STB-3.I Describe bioaccumulation and biomagnification.	**STB-3.I.1** Bioaccumulation is the selective absorption and concentration of elements or compounds by cells in a living organism, most commonly fat-soluble compounds.
	STB-3.I.2 Biomagnification is the increase in concentration of substances per unit of body tissue that occurs in successively higher trophic levels of a food chain or in a food web.
STB-3.J Describe the effects of bioaccumulation and biomagnification.	**STB-3.J.1** Some effects that can occur in an ecosystem when a persistent substance is biomagnified in a food chain include eggshell thinning and developmental deformities in top carnivores of the higher trophic levels.
	STB-3.J.2 Humans also experience harmful effects from biomagnification, including issues with the reproductive, nervous, and circulatory systems.
	STB-3.J.3 DDT, mercury, and PCBs are substances that bioaccumulate and have significant environmental impacts.

Bioaccumulation

⚠️ **Absorption and concentration of compounds (especially fat-soluble ones like POPs) in the cells & fat tissues of organisms**

- B/c fat-soluble compounds like POPs and methylmercury don't dissolve easily in water, they don't enter blood easily & don't leave body in urine easily
    - Instead they build up in fat tissue
    - This leads to them building up to reach higher and higher concentrations in the organism over time
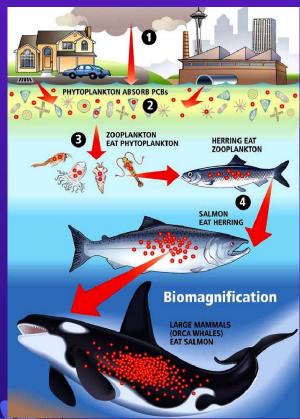

Bioaccumulation

TIME

Contaminant Levels

Biamagnification

⚠️ **Increasing concentrations of fat-soluble compounds like methylmercury and POPs in each level up the trophic pyramid or food web/chain**

- Biomagnification begins with POPs or methylmercury in sediments or plants in an ecosystem (phytoplankton, grass)
  - Primary consumers (zooplankton, bottom feeding fish, insects) take in POPs by eating producers, causing bioaccumulation of POPs in their tissues
  - Secondary consumers eat primary consumers and take in the POPs in their tissues
    - Because of the 10% rule, organisms at each successive trophic level need to eat more and more biomass to receive enough energy, leading to higher and higher POP levels over their lifetimes
    - Large predators like salmon, dolphins, and whales have highest POP/methylmercury levels

Biomagnification (DDT)

⚠️ **DDT was banned in many developed nations, but still persists in sediments of many bodies of water**

- Taken in by bottom feeders/zooplankton & biomagnified at higher trophic levels

- Reach highest levels in top predators, esp. predatory birds like eagles & osprey
  - Causes thinning of the eggshells in these birds
  - Linked to massive pop. decline of bald eagle in US, which prompted passage of Endangered Species Act (73')

Diagram 3: DDT Exposure and Eggshell Thickness (Peregrine Falcon Eggs)
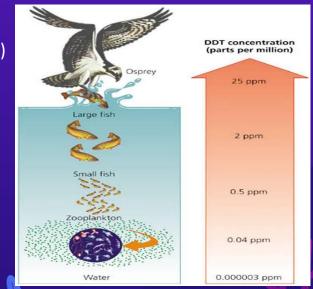
Normal Egg   DDT Exposure
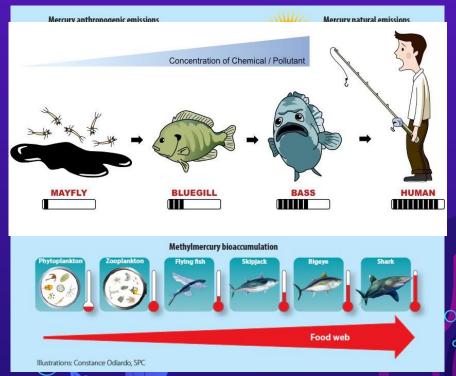

DDT concentration (parts per million)

Osprey — 25 ppm

Large fish — 2 ppm

Small fish — 0.5 ppm

Zooplankton — 0.04 ppm

Water — 0.000003 ppm

Biomagnification (methylmercury)

⚠️ **Mercury is emitted from burning coal & by volcanoes, carried by wind, and deposited in water where bacteria convert it into toxic methylmercury**

- Taken in by phytoplankton & biomagnified at higher trophic levels

- Reach highest levels in top predators, tuna, sharks, whales
    - Neurotoxicant: damages the central nervous system of animals

- Human exposure to methylmercury & POPs comes from eating large predatory fish like tuna & salmon (and other seafood)
    - Damage to human nervous system (esp. developing fetus) and disrupt reproductive system

Mercury anthropogenic emissions — Mercury natural emissions

Concentration of Chemical / Pollutant

MAYFLY → BLUEGILL → BASS → HUMAN

Methylmercury bioaccumulation

Phytoplankton — Zooplankton — Flying fish — Skipjack — Bigeye — Shark

Food web

Illustrations: Constance Odiardo, SPC

BIOMAGNIFICATION AND BIOACCUMULATION

How can pollutants have long-term effects on organisms?

Even when pollutants are not dangerous enough to kill animals outright, their presence can have lasting effects on food webs through **bioaccumulation** and **biomagnification**.

Toxins may increase in concentration as they are passed up the food chain, a process called **biomagnification**.

Pollutants such as **polychlorinated biphenyls (PCBs)** enter the ocean as industrial waste and are absorbed by microscopic **phytoplankton** at the bottom of the food chain.

TIME

Level of mercury

Bioaccumulation occurs when pollutants build up in a single organism's body over time. Mercury, for example, is a pollutant that has entered waterways and lakes through industrial processes. Fish and shellfish absorb the mercury directly from their environment, and although they may only absorb small amounts at a time, the mercury can remain in the fish's body for months or even longer. This leads to the mercury building up, or **accumulating**, in the fish's body, posing a danger to any organism that eats the fish.

● PCBs

Even though phytoplankton absorb only a tiny amount, small creatures called **zooplankton** eat large quantities of the phytoplankton, taking in all the PCBs from what the phytoplankton eat.

Small fish then feed on the zooplankton, continuing to **magnify** the amount of PCBs up the food chain.

In the waters of the Pacific Northwest, **apex predators** like the killer whale (Orcinus orca) end up with the highest concentrations of toxins due to biomagnification.

Practice FRQ 8.8

SUGGESTED SKILL

Scientific Experiments

4.A

Identify a testable hypothesis or scientific question for an investigation.

Scientists suspect that the compound smedsium, released from worn-down bike tires, biomagnifies in the tissues of aquatic organisms in a nearby lake. **Identify** a testable hypothesis that the scientists may use for their study.

8.9
Solid Waste Disposal

Objective/EKs/Skill

LEARNING OBJECTIVE

STB-3.K

Describe solid waste disposal methods.

ESSENTIAL KNOWLEDGE

STB-3.K.1

Solid waste is any discarded material that is not a liquid or gas. It is generated in domestic, industrial, business, and agricultural sectors.

STB-3.K.2

Solid waste is most often disposed of in landfills. Landfills can contaminate groundwater and release harmful gases.

STB-3.K.3

Electronic waste, or e-waste, is composed of discarded electronic devices including televisions, cell phones, and computers.

STB-3.K.4

A sanitary municipal landfill consists of a bottom liner (plastic or clay), a storm water collection system, a leachate collection system, a cap, and a methane collection system.

ESSENTIAL KNOWLEDGE

STB-3.L.2

Solid waste can also be disposed of through incineration, where waste is burned at high temperatures. This method significantly reduces the volume of solid waste but releases air pollutants.

STB-3.L.3

Some items are not accepted in sanitary landfills and may be disposed of illegally, leading to environmental problems. One example is used rubber tires, which when left in piles can become breeding grounds for mosquitoes that can spread disease.

STB-3.L.4

Some countries dispose of their waste by dumping it in the ocean. This practice, along with other sources of plastic, has led to large floating islands of trash in the oceans. Additionally, wildlife can become entangled in the waste, as well as ingest it.

STB-3.L

Describe the effects of solid waste disposal methods.

STB-3.L.1

Factors in landfill decomposition include the composition of the trash and conditions needed for microbial decomposition of the waste.
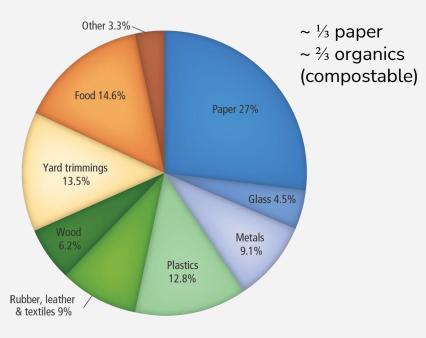
Solid Waste Types and Sources

MSW (Municipal Solid Waste) 🗑

- Solid waste from cities (households, businesses, schools, etc.
- Waste "stream" refers to flow of solid waste to recycling centers, landfills, or trash incineration (burning) facilities

E-Waste 💻📱

- Old computers, TVs, phones, tablets
- Only ~2% of MSW; considered hazardous waste due to metals like cadmium, lead, mercury, and PBDEs (fireproof chemicals)

- Can leach endocrine disrupting chemicals out of landfills if thrown away with regular MSW (should be disposed of at special facilities that recycle parts)
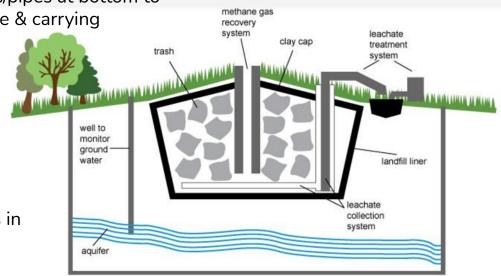
- Aka - trash, litter, garbage, refuse

~ ⅓ paper
~ ⅔ organics (compostable)

Other 3.3%
Food 14.6%
Paper 27%
Yard trimmings 13.5%
Glass 4.5%
Wood 6.2%
Metals 9.1%
Plastics 12.8%
Rubber, leather & textiles 9%

Sanitary Landfills

⚠️**APES lingo for "landfills" or where developed nations dispose of trash; different than "dumps" which are just areas where trash is dumped, without the <u>features below</u>**

- **Clay/plastic bottom liner**: layer of clay/plastic on the bottom of a hole in the ground; *prevents** pollutants from leaking out into soil/groundwater

- **Leachate Collection System**: System of tubes/pipes at bottom to collect leachate (water draining through waste & carrying pollutants) for treatment & disposal

- **Methane Recovery System**: System of tubes/pipes to collect that methane produced by anaerobic decomposition in the landfill
  - Methane can be used to generate electricity or heat buildings

- **Clay Cap**: Clay-soil mixture used to cover the landfill once it's full; keeps out animals, keeps in smell, and allows vegetation to regrow

methane gas recovery system
clay cap
leachate treatment system
trash
well to monitor ground water
landfill liner
leachate collection system
aquifer

Source: Adapted from National Energy Education Development Project (public domain)

Landfills Contents & Decomposition

⚠️**Landfills generally have very low rates of decomposition due to low O$_2$, moisture, and organic material combination**

- Since these 3 factors are rarely present together in landfills, little decomp. occurs and landfills typically remain about the same size as when they were filled

🚯 **Things that should NOT be landfilled**:
- Hazardous waste (antifreeze, motor oil, cleaners, electronics, car batteries)
- Metals like copper & aluminum (should be recycled)
- Old tires; often left in large piles that hold standing water ideal for mosquito breeding

🗑️ **Things that SHOULD be landfilled**:
- Cardboard/food wrappers that have too much food residue & can't be recycled
- Rubber, plastic films/wraps
- Styrofoam
  - Food, yard waste, and paper *can* and do go in landfills, but *should* be recycled or composted
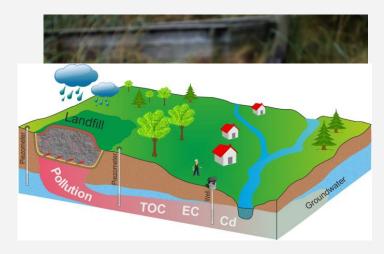

Wool Sock
1-5 years

Glass Bottle
1 million years

Disposable Diaper
450 years

Compostable Packages
2 - 12 weeks
(when disposed of in a proper composting facility)

Cigarette Butt
1-5 years

Landfill Issues

⚠️**Landfills have environmental impacts like groundwater contamination and release of GHGs**

🚫 Groundwater can be underlined contaminated with heavy metals (lead, mercury), acids, medications, and bacteria if leachate leaks through lining into soil/groundwater beneath

🌡️🌍Greenhouse gases (CO_2 and CH_4 - methane) are released from landfills due to decomposition; both contribute to global warming & climate change

⚠️**NIMBY (Not In My Back Yard)** = idea that communities don't want landfills near them for a number of reasons

- Smell & sight
- Landfills can attract animals (rats, crows)
- Groundwater contamination concerns
  - Landfills underlined should be located far from river & streams and neighborhoods to avoid H_2O cont.

🚫⚖️ **Landfills are often placed near low-income or minority communities that don't have the resources or political power to fight against these decisions**

Waste Incineration & Ocean Dumping

⚠️**Waste can be incinerated (burned) to reduce the volume that needs to be landfilled; since most waste (paper, plastic, food) = hydrogen, carbon, and oxygen, it easily combusts at high temp.**

Can reduce volume by 90%, but also releases CO_2 and air pollutants (PM, SO_x, NO_x)
- Bottom ash may contain toxic metals (lead, mercury, cadmium) & is stored in ash ponds, then taken to special landfills
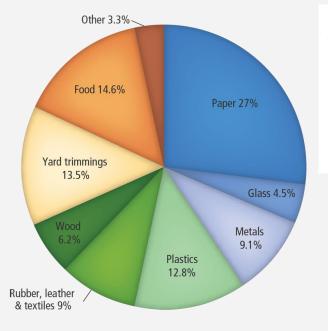- Toxic metals can leach out of storage ponds or be released into atmosphere

⚠️ **Can be burned to generate electricity (covered in 8.10)**

🗑️ ▢→ 🔥🏭 ▢→ ⚡

⚠️**Illegal ocean dumping occurs in some countries with few environmental regulations or lack of enforcement**
- Plastic especially collects into large floating garbage patches in the ocean

- Can suffocate animals if they ingest (eat) it or entangle them so they can't fly or swim and may starve

Practice FRQ 8.9

Pie chart labels:
- Other 3.3%
- Food 14.6%
- Paper 27%
- Yard trimmings 13.5%
- Glass 4.5%
- Metals 9.1%
- Wood 6.2%
- Plastics 12.8%
- Rubber, leather & textiles 9%

Above is the MSW stream composition of the United States. **Propose a solution** the federal government could enact that would reduce the volume of waste entering landfills in the US by at least 15%. Use evidence from the graph above to support your proposed solution.

8.10
WASTE REDUCTION

OBJECTIVE/EKS/SKILL

LEARNING OBJECTIVE

STB-3.M

Describe changes to current practices that could reduce the amount of generated waste and their associated benefits and drawbacks.

ESSENTIAL KNOWLEDGE

STB-3.M.1

Recycling is a process by which certain solid waste materials are processed and converted into new products.

STB-3.M.2

Recycling is one way to reduce the current global demand on minerals, but this process is energy-intensive and can be costly.

STB-3.M.3

Composting is the process of organic matter such as food scraps, paper, and yard waste decomposing. The product of this decomposition can be used as fertilizer. Drawbacks to composting include odor and rodents.

STB-3.M.4

E-waste can be reduced by recycling and reuse. E-wastes may contain hazardous chemicals, including heavy metals such as lead and mercury, which can leach from landfills into groundwater if they are not disposed of properly.

STB-3.M.5

Landfill mitigation strategies range from burning waste for energy to restoring habitat on former landfills for use as parks.

ESSENTIAL KNOWLEDGE

STB-3.M.6

The combustion of gases produced from decomposition of organic material in landfills can be used to turn turbines and generate electricity. This process reduces landfill volume.

REDUCE, REUSE, RECYCLE

THE THREE RS

⚠ **Reducing consumption is the most sustainable because it decreases natural resources harvesting and the energy inputs to creating, packaging, and shipping goods**

Ex: Metal/reusable water bottle to reduce plastic use
Riding bike or walking to reduce gasoline use

- Reusing = the next most sustainable b/c it doesn't require additional energy to create a product

Ex: Buying second hand clothes, using old wood pallets for furniture, washing plastic takeout food containers and reusing

⚠ **Recycling = processing and converting solid waste material into new products**

Ex: Glass being turned into glass again (closed-loop), plastic water bottles being turned into fabric for clothes/jackets (open loop)

- **Least sustainable of the three Rs due to the amount of energy it requires to process and convert waste materials**

RECYCLING PROS AND CONS

PROS OF RECYCLING

⚠️ **Reduces demand for new materials, especially metals and wood which cause habitat destruction & soil erosion when harvested**
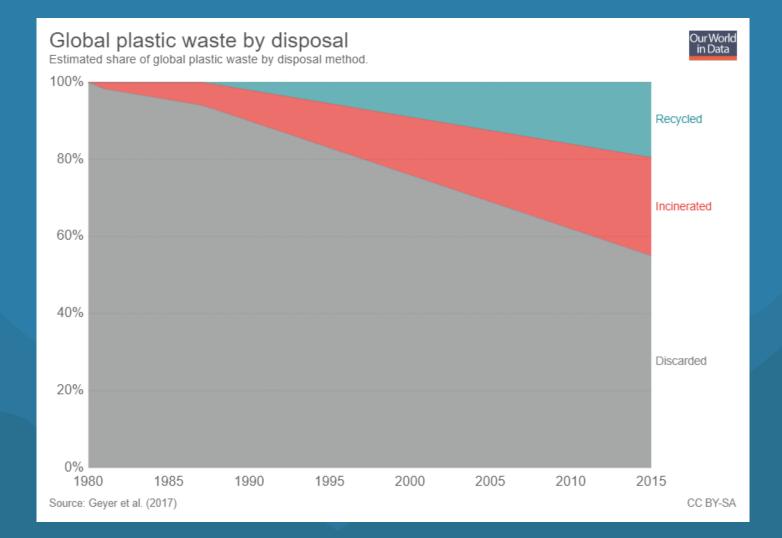
- Reduces energy required to ship raw materials and produce new products (fewer FF comb, less CC)

- Reduces landfill volume, conserving landfill space & reducing need for more landfills

CONS OF RECYCLING

⚠️ **Recycling is costly and still requires significant energy**

- Cities that offer recycling services need to process, sort, and sell collected materials; prices change rapidly, leading to "recycled" materials often being thrown away

  - When citizens recycle items that shouldn't be recycled (wrappers with food, styrofoam, etc.) it increases the cost for cities to sort & process

Did you know?
RECYCLING SAVES ENERGY

ENERGY IS USED IN THE
5 STAGES OF PRODUCT DEVELOPMENT:
EXTRACTION OF RAW MATERIALS
MANUFACTURE OF RAW MATERIALS INTO PRODUCTS
DISTRIBUTION OF PRODUCTS TO CONSUMERS
PRODUCT CONSUMPTION
PRODUCT DISPOSAL

ENERGY PLAYS A ROLE IN ALL 5 STAGES. KNOCK OUT ONE OF THESE STEPS BY RECYCLING AND YOU HAVE SAVED ENERGY.

LINEAR ECONOMY MODEL
When we consume

EXTRACT — MANUFACTURE — DISTRIBUTE — CONSUME — DISPOSE

Global plastic waste by disposal

Estimated share of global plastic waste by disposal method.

Our World in Data

Recycled

Incinerated

Discarded

Source: Geyer et al. (2017)

CC BY-SA

COMPOSTING

⚠️**Org. matter (food scraps, paper, yard waste) being decomposed under controlled conditions**

- Reduces landfill volume and produces rich organic matter that can enhance water holding capacity, nutrient levels of agricultural or garden soil
  - Produces valuable product to sell (compost)

- Reduces the amount of methane released by anaerobic decomposition of organic matter in landfills

- Should be done w/proper mix of "browns" (Carbon) to "greens" (N) ~ 30:1
  - Should also be aerated and mixed to optimize decomposition (bacteria need O_2 for decomp.)

⚠️ **Potential drawbacks include the foul smell that can be produced if not properly rotated & aerated and rodents or other pests that may be attracted**

E-WASTE

⚠️ **Waste from electronics (phones, computers, etc.) that often contain heavy metals (lead, merc, cadmium)**

- Can leach these toxic metals into soil & groundwater if disposed of in landfills or open dump

📱♻️ Can be recycled and reused to create new electronics, but often sent to developing nations for recycling due to health hazards, more strict env. & worker protection laws in developing nations

- Can be dismantled and sold to countries that extract valuable metals (gold, silver, platinum) from motherboards

- Often burned or dumped due to less strict env. regulations or lack of enforcement in developing nations
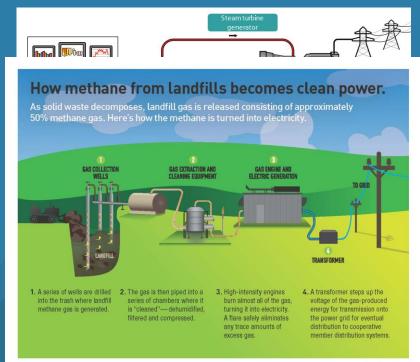
WASTE TO ENERGY

⚠️ **Waste can be incinerated (burned) to reduce the volume & also generate electricity; most waste (paper, plastic, food) = hydrogen, carbon, and oxygen so it easily combusts at high temp.**

- Same process as burning coal, NG, biomass
- Heat → water → steam → turbine → generator → ⚡

⚠️ **Methane gas produced by decomposition in landfill can be collected with pipes & burned to generate electricity**

- Heat → water → steam → turbine → generator → ⚡
- Reduces landfill volume
- Produces electricity without fracking or mining for FFs

How methane from landfills becomes clean power.

As solid waste decomposes, landfill gas is released consisting of approximately 50% methane gas. Here's how the methane is turned into electricity.

1. **GAS COLLECTION WELLS**
2. **GAS EXTRACTION AND CLEANING EQUIPMENT**
3. **GAS ENGINE AND ELECTRIC GENERATION**
4. **TRANSFORMER**

TO GRID

LANDFILL

1. A series of wells are drilled into the trash where landfill methane gas is generated.

2. The gas is then piped into a series of chambers where it is "cleaned" — dehumidified, filtered and compressed.

3. High-intensity engines burn almost all of the gas, turning it into electricity. A flare safely eliminates any trace amounts of excess gas.

4. A transformer steps up the voltage of the gas-produced energy for transmission onto the power grid for eventual distribution to cooperative member distribution systems.

8.10 PRACTICE FRQ

Approximately 30 million mobile devices were sold in 1998 in the US. The number sold increased to 180 million devices in 2007.

(a) Calculate the percent increase of mobile device sales from 1998 to 2007.

(a) Each mobile device sold in 2007 contained an average of 0.03 grams of gold. **Calculate** the number of grams of gold that were used in the production or the mobile devices sold in 2007.

8.11
Sewage Treatment

Objective/EKs/Skill

SUGGESTED SKILL

Visual Representations

2.A

Describe characteristics of an environmental concept, process, or model represented visually.

LEARNING OBJECTIVE

STB-3.N

Describe best practices in sewage treatment.

ESSENTIAL KNOWLEDGE

STB-3.N.1

Primary treatment of sewage is the physical removal of large objects, often through the use of screens and grates, followed by the settling of solid waste in the bottom of a tank.

STB-3.N.2

Secondary treatment is a biological process in which bacteria break down organic matter into carbon dioxide and inorganic sludge, which settles in the bottom of a tank. The tank is aerated to increase the rate at which the bacteria break down the organic matter.
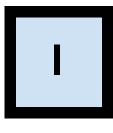
STB-3.N.3

Tertiary treatment is the use of ecological or chemical processes to remove any pollutants left in the water after primary and secondary treatment.

STB-3.N.4

Prior to discharge, the treated water is exposed to one or more disinfectants (usually, chlorine, ozone, or UV light) to kill bacteria.

Water Treatment Process

Primary Treatment

1 Physical removal of large debris (TP, leaves, plastic, sediment) with a screen or grate

Secondary Treatment

2 Biological breakdown of organic matter (feces) by bacteria; aerobic process that requires O_2

Tertiary Treatment

3 Ecological or chemical treatments to reduce pollutants left after primary & secondary (N, P, bacteria)
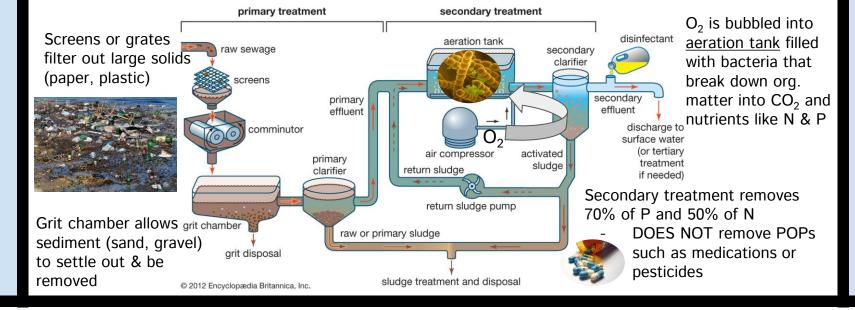
Disinfectant

3 UV light, ozone, or chlorine is used to kill bacteria or other pathogens, such as e. Coli (considered part of 3)

⚠ **Effluent: liquid waste (sewage) discharged into a surface body of water, typically from a wastewater treatment plant**

Screens or grates filter out large solids (paper, plastic)

Grit chamber allows sediment (sand, gravel) to settle out & be removed

O_2 is bubbled into aeration tank filled with bacteria that break down org. matter into CO_2 and nutrients like N & P

Secondary treatment removes 70% of P and 50% of N
- DOES NOT remove POPs such as medications or pesticides

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Sludge: inorganic, solid waste that collects at the bottom of tanks in primary and secondary treatment
- Water is spun/pumped off to concentrate it further
- Dry, remaining physical waste is collected to be put in landfill, burned, or turned into fertilizer pellets

After primary & secondary treatment, some plants go directly to disinfectant (UV, ozone, chlorine) & discharge into surface water, while some will use tertiary treatment to remove more nutrients before discharge

Tertiary Treatment

- **Tertiary treatment** uses chemical filters to remove more of the nitrates & phosphates from secondary treatment discharge

- Critical step because effluent that is discharged into surface waters with elevated nitrate/phosphate levels leads to eutrophication
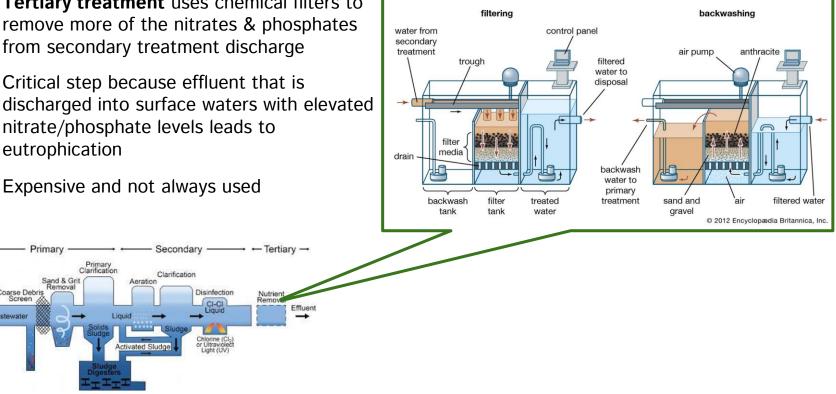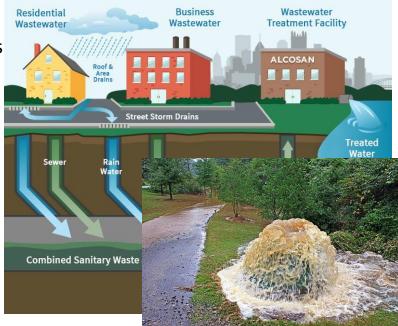
- Expensive and not always used

Tertiary treatment of wastewater

Sewage Treatment Issues

- Combined sewage and stormwater runoff systems can cause wastewater treatment plants to flood during heavy rains, releasing raw sewage into surface waters

  - Beneficial b/c it treats stormwater runoff normally, but causes overflow during heavy rains

  - 💩 Raw sewage release contaminates surface waters with:
    - E. coli
    - Ammonia
    - Nitrates
    - Phosphates
    - Endocrine disruptors (medications)

⚠️**Even treated wastewater effluent released into surface water often has elevated N/P levels and endocrine disruptors**
(medications passed through the body)

Practice FRQ 8.II
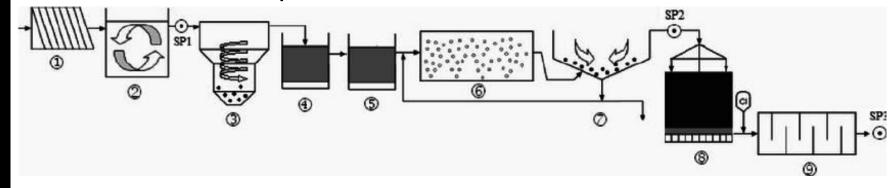
Identify a number on the wastewater treatment diagram below that represents a step of primary treatment. **Describe** a pollutant removed by this process.

8.12 & 8.13
LD$_{50}$ & Dose Response Curve

Objectives/EKs/Skills

LEARNING OBJECTIVE

EIN-3.A

Define lethal dose 50% (LD_{50}).

ESSENTIAL KNOWLEDGE

EIN-3.A.1

Lethal dose 50% (LD_{50}) is the dose of a chemical that is lethal to 50% of the population of a particular species.

LEARNING OBJECTIVE

EIN-3.B

Evaluate dose response curves.

ESSENTIAL KNOWLEDGE

EIN-3.B.1

A dose response curve describes the effect on an organism or mortality rate in a population based on the dose of a particular toxin or drug.

SUGGESTED SKILL

Mathematical Routines

6.A

Determine an approach or method aligned with the problem to be solved.

SUGGESTED SKILL

Data Analysis

5.E

Explain what the data implies or illustrates about environmental issues.

Dose Response Studies & LD$_{50}$

⚠️ Studies that expose an organism to different <u>doses</u> of concentrations of a chemical in order to measure the <u>response</u> (effect) of the organism

Independent variable = concentration of the chemical (added to food, water, or air)
Dependent variable = response measured in org. (usually death or impairment)
⚠️ LD$_{50}$ refers to the dose or concentration of the chemical that kills 50% of the population being studied (ex: arsenic LD$_{50}$ in mice = 13 mg/kg)
- LD$_{50}$ data are usually expressed as:
    - mass (g, mg)/body unit mass (kg)
    - ppm - parts per million (in air)
    - mass/volume (in water of blood)
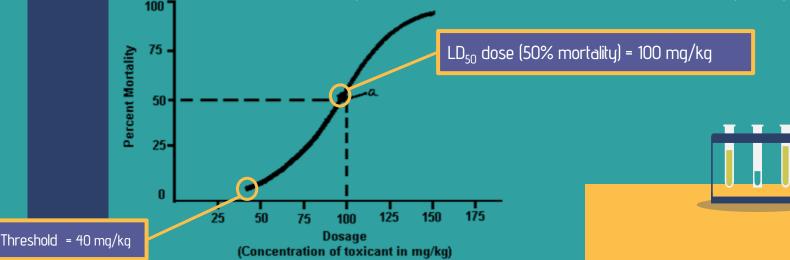
Dose Response Curve

⚠ **The data from a dose response study, graphed with percent mortality or other effect on the y-axis and dose concentration of chemical on x-axis**

- Lowest dose where an effect (death, paralysis, cancer) starts to occur is called the <u>threshold or toxicity threshold</u>
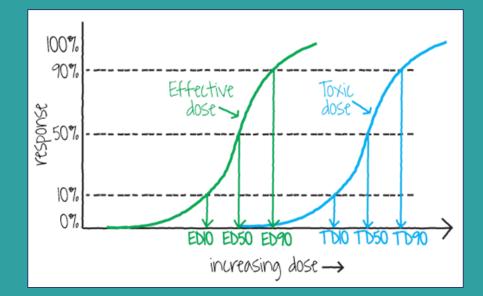
- Dose response curves are usually "S-shaped" – low mortality at low doses, rapid increase in mortality as dose increases, level off near 100% mortality at high dosage

LD_{50} dose (50% mortality) = 100 mg/kg

Threshold = 40 mg/kg

ED$_{50}$ & Other Dose Responses

⚠ **ED$_{50}$ refers to the dose concentration of a toxin or chemical that causes a non-lethal effect (infertility, paralysis, cancer, etc.) in 50% of the population being tested**

- Ex: the concentration of atrazine in water that causes 50% of frogs to become infertile

- Same general "s-shape" as LD$_{50}$ dose response curve, but at lower dose concentrations

Dose Response Data & Human Health

⚠ Dose-response studies for toxic chemicals are not done on humans; data from other mammals (mice, rats) are used to simulate human toxicity

To determine maximum allowable levels for humans, we generally divide LD_{50} or ED_{50} dose concentration by 1,000 for extreme caution

Acute vs. Chronic studies: Most dose-response studies are considered acute, since they usually only measure effects over a short period of time; they're also isolated to a lab, so they don't measure ecological effects of organisms dying (trophic cascades)

Chronic studies are longer-term and follow developmental impacts

Ex: study of fish from hatchlings to adults to study sexual maturation

Practice FRQ 8.12 & 8.13

Drug Discrimination and Lethality, Rat (PO)

RTI No.	ED_{50} (mg/kg)	LD_{50} (mg/kg)	TI (LD_{50}/ED_{50})	Minimum Lethal, PO mg/kg
336	3.54	180	51	100
177	5.7	48.9	8.57	40-60

*PO indicates by mouth.

Above are data from the results of a dose-response study for a drug's toxicity in rats.

a) **Explain** how these data could be used to determine a max. allowable level for humans.

a) **Identify** the lowest dose that triggered a response in the RTI No. 336 rats and the dose that resulted in 50% of the RTI 336 rats dying.

Objective/EKs/Skill

LEARNING OBJECTIVE

EIN-3.C

Identify sources of human health issues that are linked to pollution.

SUGGESTED SKILL

Scientific Experiments

4.C

Describe an aspect of a research method, design, and/or measure used.

ESSENTIAL KNOWLEDGE

EIN-3.C.1

It can be difficult to establish a cause and effect between pollutants and human health issues because humans experience exposure to a variety of chemicals and pollutants.

EIN-3.C.2

Dysentery is caused by untreated sewage in streams and rivers.

EIN-3.C.3

Mesothelioma is a type of cancer caused mainly by exposure to asbestos.

EIN-3.C.4

Respiratory problems and overall lung function can be impacted by elevated levels of tropospheric ozone.

Routes of Exposure & Synergism

⚠ **It's difficult to establish exactly how toxic different pollutants are to humans because we have so many routes of exposure to so many different pollutants, that studying the effects of just one pollutant is difficult.**

Routes of Exposure

- Ways that a pollutant enters the human body
  - Lead → water pipes & paint chips
  - Mercury → seafood (tuna)
  - CO → indoor biomass comb.
  - PM → pollen, dust, etc.
  - Arsenic → rice, groundwater

Synergism

- The interaction of two or more substances to cause an effect greater than each of them individually
  - Ex: Asthma caused by PM from coal PPs and COVID-19 damaging lungs
  - Carcinogenic effect of asbestos combined with lung damage from smoking
- Synergisms make it especially hard to pinpoint the exact effects of one specific pollutant on humans

Dysentery

⚠️Bacterial infection caused by food or water being contaminated with feces (often from sewage release into rivers & streams used for drinking water)

- Causes intestinal swelling and can result in blood in feces
  - Results in severe dehydration due to diarrhea (fluid loss)

  - Kills 1.1 million people annually, mostly in developing countries with poor sanitation and limited access to water filtration

🏷️🚰 Can be treated with antibiotics that kill the bacteria causing the infection and access to treated/filtered water that can rehydrate
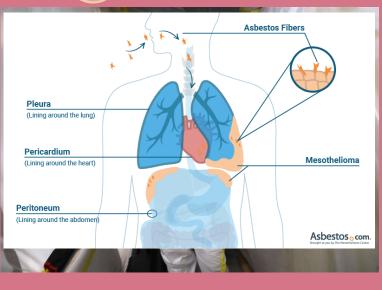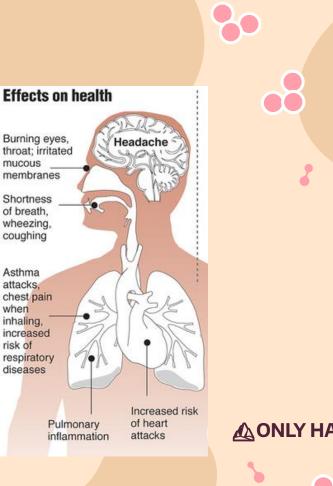
Mesothelioma (asbestos)

⚠ **A type of cancerous tumor caused by exposure to asbestos, primarily affecting the lining (epithelium) of the respiratory tract, heart, or abdominal cavity**

- Asbestos exposure comes primarily from old insulation materials used in attics, ceiling and flooring boards; when the insulation becomes physically disturbed, asbestos particles are released into the air & inhaled

- Removal of asbestos-containing insulation material should be done by professionals with proper training and equipment that protects them from inhaling the asbestos
  - The area where asbestos is removed from should be sealed off from other areas in the building and well-ventilated during the removal process

  - Insulation without asbestos should be used to replace it

Tropospheric Ozone (O$_3$)

⚠ **Worsens respiratory conditions like asthma, emphysema, bronchitis, COPD**

- Limits overall lung function

  - Irritates muscles or resp. tract causing constriction of airways & shortness of breath
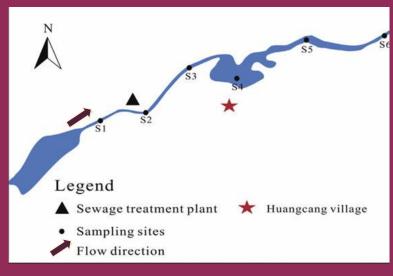
  - Irritates eyes

Sources: photochemical breakdown of NO$_2$ (car exhaust, coal & NG combustion) 🚗 💬 🏭 ⚡

Effects on health

Burning eyes, throat; irritated mucous membranes

Headache

Shortness of breath, wheezing, coughing

Asthma attacks, chest pain when inhaling, increased risk of respiratory diseases

Pulmonary inflammation

Increased risk of heart attacks

⚠**ONLY HARMFUL IN TROPOSPHERE (beneficial in stratosphere)**

Practice FRQ 8.14

SUGGESTED SKILL

Scientific Experiments

4.C

Describe an aspect of a research method, design, and/or measure used.

Below is a map of a river that is used as the main drinking water source for the Chinese village of Huangcang. Chinese scientists suspect that the sewage treatment plant is releasing untreated sewage into the river.

a) If scientists plan to measure fecal coliform bacterial counts at the six sampling sites below, **make a claim** about which site should serve as the control group in the experiment. **Justify** your answer with evidence.

b) **Identify** a disease that scientists could test for in the people of Huangcang and **explain** how the prevalence of this disease would help the researchers determine whether the sewage treatment plant is releasing untreated sewage into the river.

N

S5

S6

S3

S4

S1

S2

Legend

▲ Sewage treatment plant

★ Huangcang village

• Sampling sites

➤ Flow direction

8.15

Pathogens and Infectious Diseases

Objective/EKs/Skill

Visual Representations

2.B

Explain relationships between different characteristics of environmental concepts, processes, or models represented visually:

- In theoretical contexts
- In applied contexts

ESSENTIAL KNOWLEDGE

EIN-3.D.6
Tuberculosis is a bacterial infection that typically attacks the lungs. It is spread by breathing in the bacteria from the bodily fluids of an infected person.

EIN-3.D.7
Malaria is a parasitic disease caused by bites from infected mosquitoes. It is most often found in sub-Saharan Africa.

EIN-3.D.8
West Nile virus is transmitted to humans via bites from infected mosquitoes.

EIN-3.D.9
Severe acute respiratory syndrome (SARS) is a form of pneumonia. It is transferred by inhaling or touching infected fluids.

EIN-3.D.10
Middle East Respiratory Syndrome (MERS) is a viral respiratory illness that is transferred from animals to humans.

EIN-3.D.11
Zika is a virus caused by bites from infected mosquitoes. It can be transmitted through sexual contact.

EIN-3.D.12
Cholera is a bacterial disease that is contracted from infected water.

LEARNING OBJECTIVE

EIN-3.D
Explain human pathogens and their cycling through the environment.

ESSENTIAL KNOWLEDGE

EIN-3.D.1
Pathogens adapt to take advantage of new opportunities to infect and spread through human populations.

EIN-3.D.2
Specific pathogens can occur in many environments regardless of the appearance of sanitary conditions.

EIN-3.D.3
As equatorial-type climate zones spread north and south in to what are currently subtropical and temperate climate zones, pathogens, infectious diseases, and any associated vectors are spreading into these areas where the disease has not previously been known to occur.

EIN-3.D.4
Poverty-stricken, low-income areas often lack sanitary waste disposal and have contaminated drinking water supplies, leading to havens and opportunities for the spread of infectious diseases.

EIN-3.D.5
Plague is a disease carried by organisms infected with the plague bacteria. It is transferred to humans via the bite of an infected organism or through contact with contaminated fluids or tissues.

Pathogens & Vectors

🦠 Pathogen

⚠ **A living organism (virus, bacteria, fungus, protist, worm) that causes an <u>infectious</u> disease**
- Infectious diseases are capable of being spread or transmitted (HIV, ebola, Covid-19); noninfectious diseases are not transmissible (heart disease, asthma, cancer, diabetes)
- Pathogens adapt and evolve to take advantage of humans as hosts for their reproduction and spread (Covid-19 is a SARS-associated coronavirus that evolved to become especially effective at surviving and reproducing in humans)
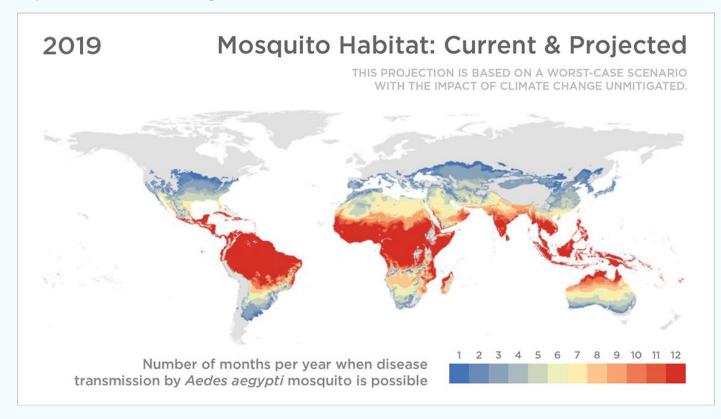
🐀 🦟 Vectors

⚠ A living organism (rat, mosquito) that carry and transmit infectious pathogens to other organisms
- Climate change is shifting equatorial climate zones north and south away from the equator; this brings warmer temperatures to subtropical and temperate regions
- Warmer temperatures allow pathogens and their vectors (mosquitos) to spread north & south to parts of the world previously too cold
  - Many pathogenic bacteria and viruses survive and replicate better in warmer weather

Expanding Aedes aegypti range 🦟

Vector for dengue fever, Zika virus, yellow fever

2019 — Mosquito Habitat: Current & Projected

THIS PROJECTION IS BASED ON A WORST-CASE SCENARIO WITH THE IMPACT OF CLIMATE CHANGE UNMITIGATED.

Number of months per year when disease transmission by *Aedes aegypti* mosquito is possible

1 2 3 4 5 6 7 8 9 10 11 12

Infectious Disease & Development

⚠ **Less developed, poorer countries typically have higher rates of infectious disease**

- Less sanitary waste disposal; pathogens can reproduce in open waste areas where children may play or animals may scavenge & pass to humans

- Less access to healthcare facilities and antibiotic medications to treat infectious diseases cause by bacteria & other pathogens

- Lack of treatment/filtration for drinking water & sewage treatment exposes people to bacterial and viral pathogens in water, often from human waste

- Tropical climates & more open-air living can expose people to vectors like mosquitoes; less money for vector eradication (spraying mosquito breeding grounds)
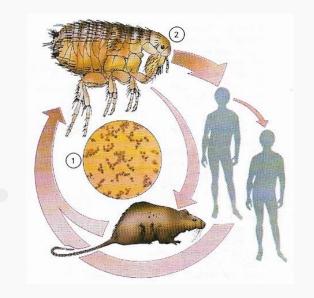
Plague

⚠ **Bacterial (pathogen) infection transmitted by fleas (vector) that attach to mice & rats (vectors as well)**

- Transmitted by flea bite, rodent contact or contaminated human fluids

- Aka "bubonic" or "black" plague; modern antibiotics are highly effective against it, but some isolated instances still occur
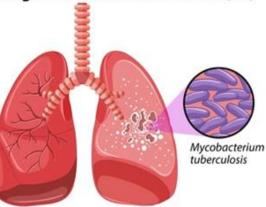
Tuberculosis (TB)

⚠ **Bacterial (pathogen) infection that targets the lungs**

- Transmitted by breathing bacteria from body fluids (resp. droplets) of an infected person, which can linger in air for hours

- Causes night sweats, fever, coughing blood; treatable in developed nations with access to powerful antibiotics

- Leading cause of death by disease in the developing world ~ 9 million cases per year and 2 million deaths (for comparison ~ 2.8 million global deaths from Covid-19)

Lung infected with tuberculosis (TB)

Mycobacterium tuberculosis

Malaria

⚠️ **parasitic protist (pathogen) infection caused by bite from infected mosquitoes (vector)**

- Most common in sub-Saharan Africa (& other tropical regions of Middle East, Asia, South & Central America; recurring flu-like symptoms; kills mostly children under 5

- Can be combated with insecticide spraying that kills mosquitoes; US eradicated in 1951

Incidence of malaria, 2015
Incidence of malaria is the number of new cases of malaria per 1,000 population at risk.

Our World in Data

No data 0   10   25   50   75   100   200   300   400 >500

Source: World Health Organization (WHO)   OurWorldInData.org/malaria • CC BY

West Nile

⚠ **Virus (pathogen) infection caused by bite from infected mosquitoes (vector)**

- Birds are the main host, but the virus can be transmitted to humans by mosquitoes that bite infected birds and then bite humans

- Causes brain inflammation, which can be fatal

Zika Virus

⚠ **Virus (pathogen) infection caused by bite from infected mosquitoes (vector) & sexual contact**
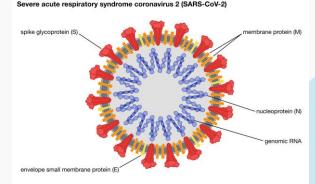
- Causes babies to be born with abnormally small heads and damaged brains; can be passed from mother to infant

- No known treatment currently, so prevention is focused on eliminating mosquito populations

SARS (Severe Acute Respiratory Syndrome)

⚠ **Coronavirus (pathogen) infection caused by respiratory droplets from infected person**

- Primarily transmitted by touching or inhaling fluids from an infected person

- Causes a form of pneumonia

- Initial outbreak was in Southeast Asia

- SARS-CoV-2 is the virus that causes the disease COVID-19

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)

spike glycoprotein (S)
membrane protein (M)
nucleoprotein (N)
genomic RNA
envelope small membrane protein (E)

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MERS (Middle East Respiratory Syndrome)

⚠ **Virus (pathogen) respiratory infection transmitted from animals to humans**

- Originated on Arabian peninsula

Cholera

⚠ **Bacterial (pathogen) infection caused by drinking infected water**

- Vomiting, muscle cramps and diarrhea; can cause severe dehydration

- Can be introduced by water contaminated with human feces or undercooked seafood

Based on this map, **make a claim** about a region of the world that likely has a high incidence of Cholera.

Share of the population with access to improved drinking water, 2015