Water Pollution

Ch. 14

Water Pollution

- **Water pollution-** the contamination *(human & animal wastes, inorganic & organic compounds, synthetic and nonchemical pollutants)* of streams, rivers, lakes, oceans, or groundwater with substances produced through human activities and that negatively affect organisms *(aquatic & terrestrial).*

Pollution can come from either….

1. Point sources- distinct locations (i.e. particular factory or sewage treatment plant) that pump waste into a waterway.

2. Nonpoint sources- diffuse areas such as an entire farming region that pollutes a waterway (coming from multiple known/unknown sources – more difficult to control)

Three reasons scientists are concerned about human wastewater:

1. Wastewater in bodies of water naturally undergo decomposition by bacteria that put a large demand for oxygen in the water

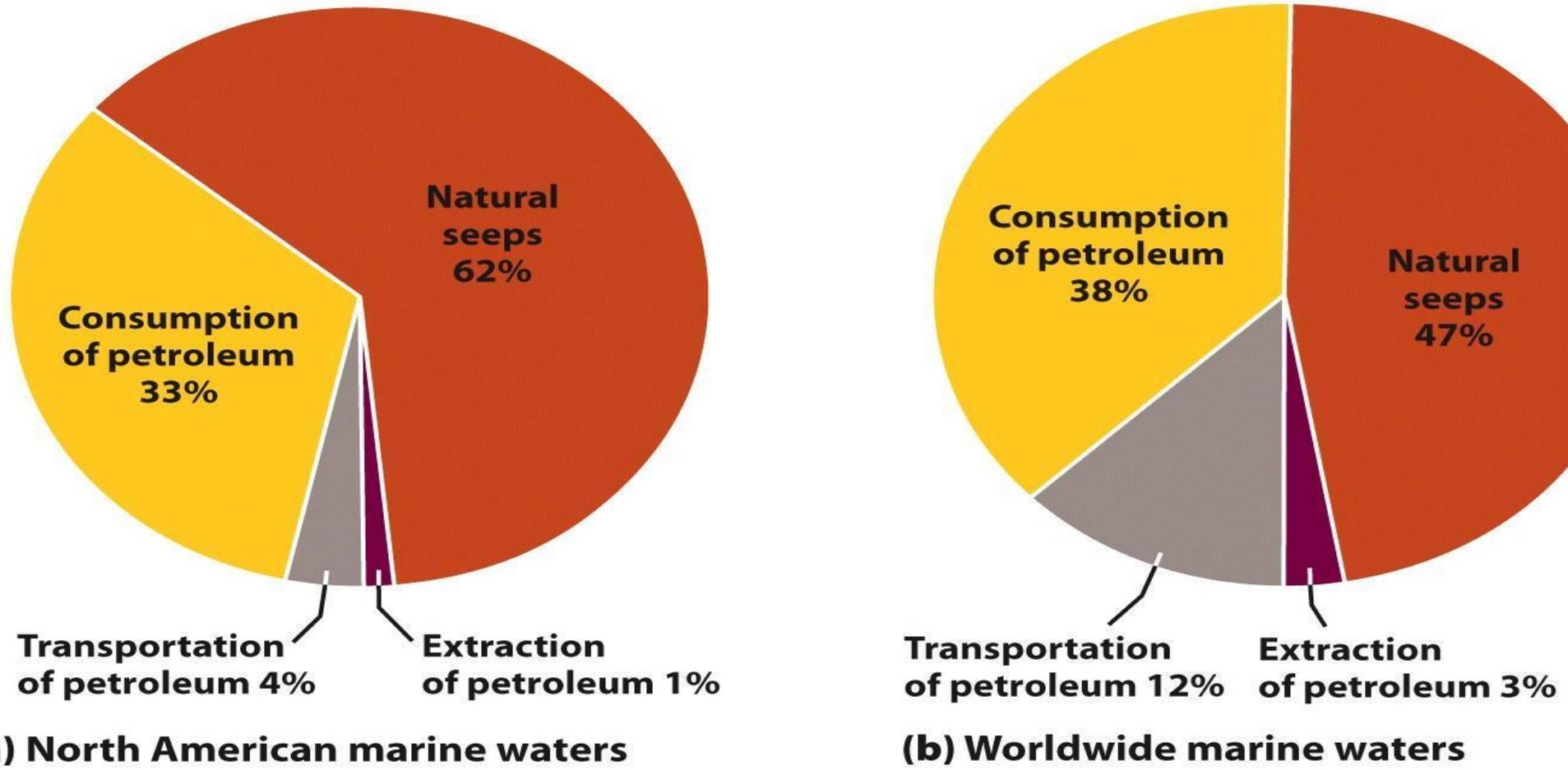
2. Nutrients that are released from wastewater decomposition can make the water more fertile causing eutrophication *(a body of water becomes rich in nutrients)*

*Little oxygen, little life – **Dead Zones*** (form algae blooms…blocks sunlight, then algae die, sink to the bottom, and are decomposed by bacteria – strips O_2)

3. Wastewater can carry a wide variety of disease-causing organisms.

Water pollution – chemical based

1. Oil Pollution



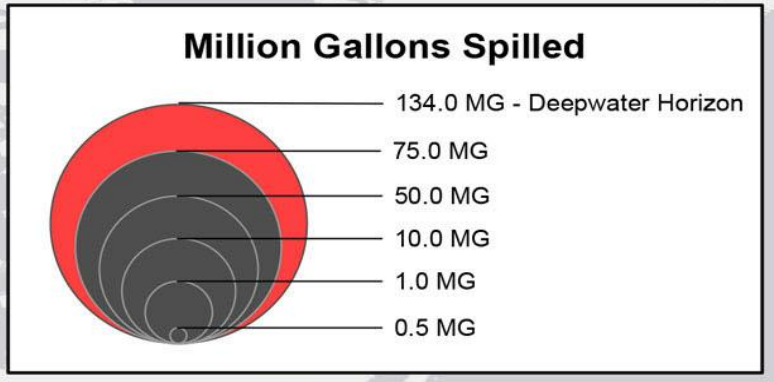
Exxon Valdez oil spill of 1989 Spilled of millions of crude oil onto the shores of Alaska....killing thousands of animals.

BP oil spill of 2010, pipe broke on ocean floor (1 mile below the surface) form of *underwater plumes*

Comes from variety of sources including natural seeps, extraction of oil from underneath the ocean, transport of oil by tanker/pipeline & consumption of petroleum-based products....highly toxic to many marine organisms

Largest Oil Spills Affecting U.S. Waters

1969 - Present



Exxon Valdez - 1989

Tank Barge UMTB 283 - 1988

Tenyo Maru - 1991

USS General M.C. Meigs - 1972

Even relatively small oil spills can cause major harm, depending on location, season, environmental sensitivity, and type of oil. The following spills are examples:

M/V Selendang Ayu - 2004 - AK
M/T Athos I - 2004 - NJ/PA
M/V Cosco Busan - 2007 - CA
M/V New Carissa - 1999 - OR

Oregon Standard - 1971

Puerto Rican - 1984

Santa Barbara - 1969

Sansinena - 1976

Hawaiian Patriot - 1977

Ashland Petroleum - 1988

Kalamazoo River - 2010

Citgo Refinery - 2006

Alvenus - 1984

Tank Barge DBL 152 - 2005

Eagle Otome - 2010

Apex Barges - 1990

Burmah Agate - 1979

Mega Borg - 1990

Nord Pacific - 1988

Tank Barge DM932 - 2008

Hurricane Katrina - 2005

Westchester - 2000

Chevron Main Pass Block 41 - 1970

Ixtoc 1 - 1979

Schuylkill River Spill - 1972

Corinthos - 1975

Grand Eagle - 1985

North Cape - 1996

Argo Merchant - 1976

Hackensack Estuary Tank Farm, Wellen Oil Company - 1976

Cibro Savannah - 1990

Exxon Bayway - 1990

Texaco Oklahoma - 1971

Reedy River - 1996

Amazon Venture - 1986

Deepwater Horizon - 2010

Epic Colocotronis - 1975

Vista Bella - 1991

Hurricane Hugo - 1989

Santa Augusta - 1971

Zoe Colocotroni - 1973

M/V Zannis - 1974

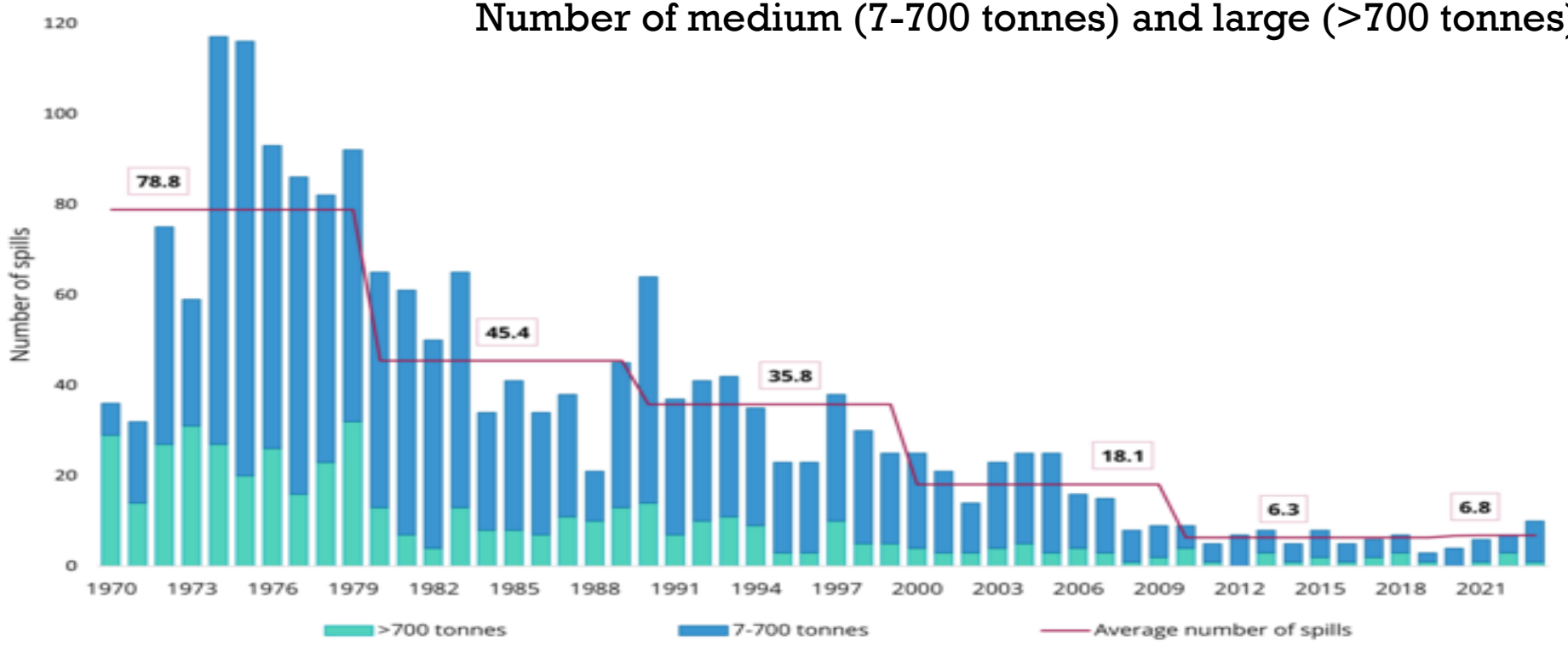
Peck Slip - 1978

Morris J. Berman - 1994

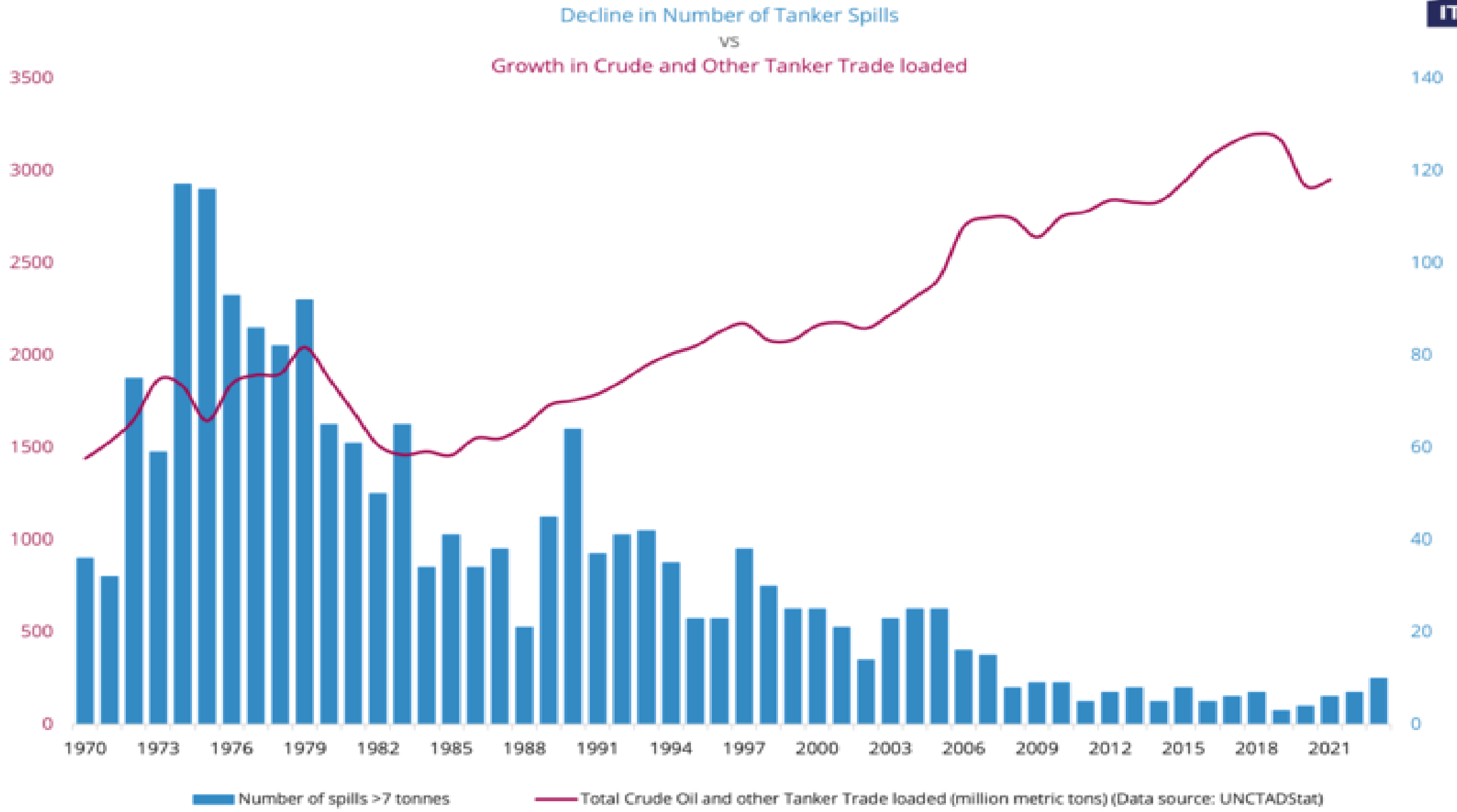
N

ITOPF: Number of oil tanker spills in 1970-2023

Number of medium (7-700 tonnes) and large (>700 tonnes) tanker spills

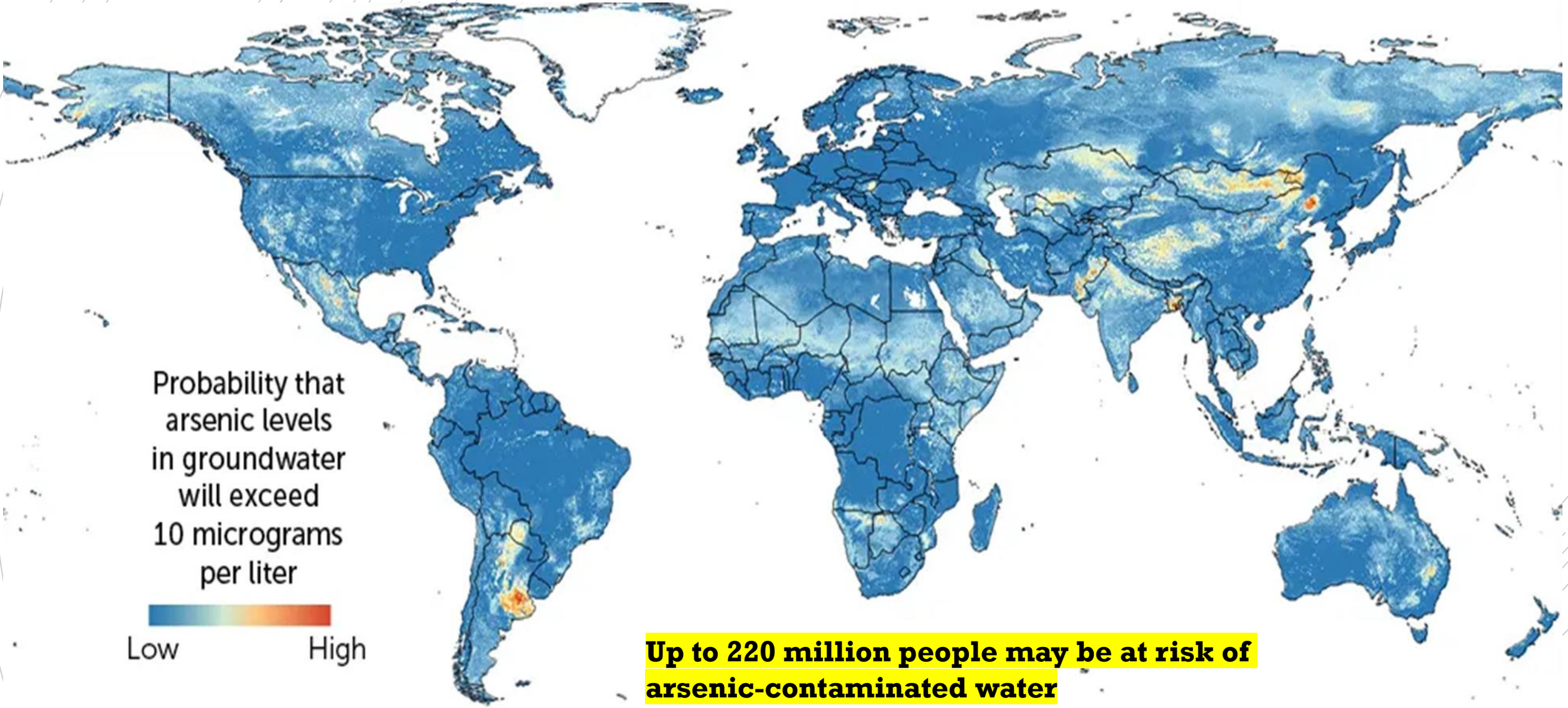


The International Tanker Owners Pollution Federation (ITOPF) issued its oil spill statistics, noting a continuing decrease at the frequency of oil spills from tankers. With one large and two medium oil spills in 2019, the number in 2019 was the lowest in 50 years, ITOPF notes.

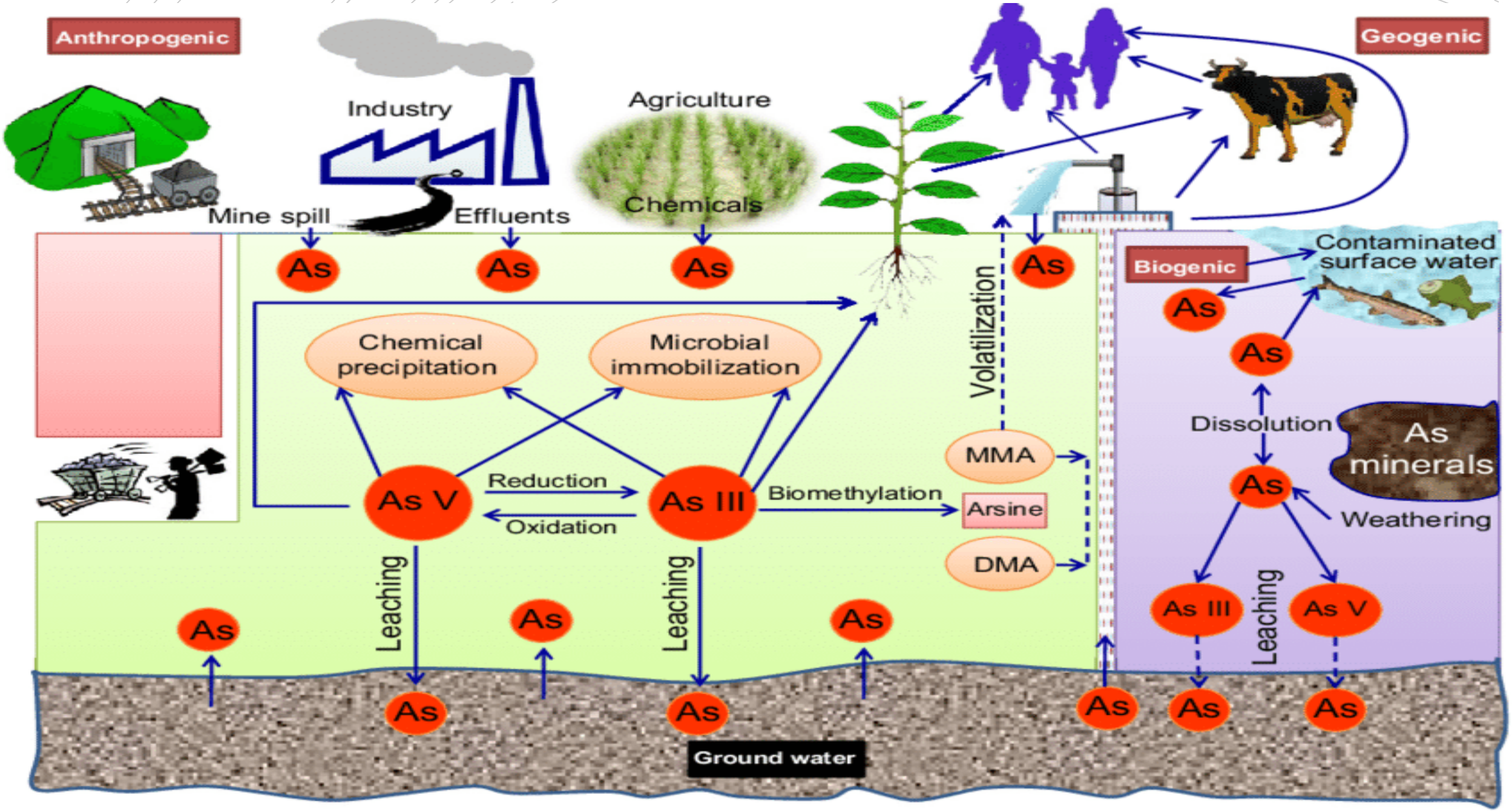

Decline in Number of Tanker Spills
vs
Growth in Crude and Other Tanker Trade loaded
3500
3000
2500
2000
1500
1000
500
0
140
120
100
80
60
40
20
0
1970
1973
1976
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012
2015
2018
2021
Number of spills >7 tonnes
Total Crude Oil and other Tanker Trade loaded (million metric tons) (Data source: UNCTADStat)

2. Arsenic – occurs naturally in Earth's crust (mining), can dissolve into groundwater (leading into drinking water)

Arsenic drinking water standards is 10mg/L



Up to 220 million people may be at risk of arsenic-contaminated water


Anthropogenic
Geogenic
Industry
Agriculture
Chemicals
Mine spill
Effluents
As
Chemical precipitation
Microbial immobilization
Volatilization
Biogenic
Contaminated surface water
Dissolution
As minerals
Weathering
As V
Reduction
Oxidation
As III
Biomethylation
MMA
Arsine
DMA
Leaching
Ground water

Heavy Metals & Other Substances that can threaten human Health and the Environment

1. **Lead** – sources of drinking water

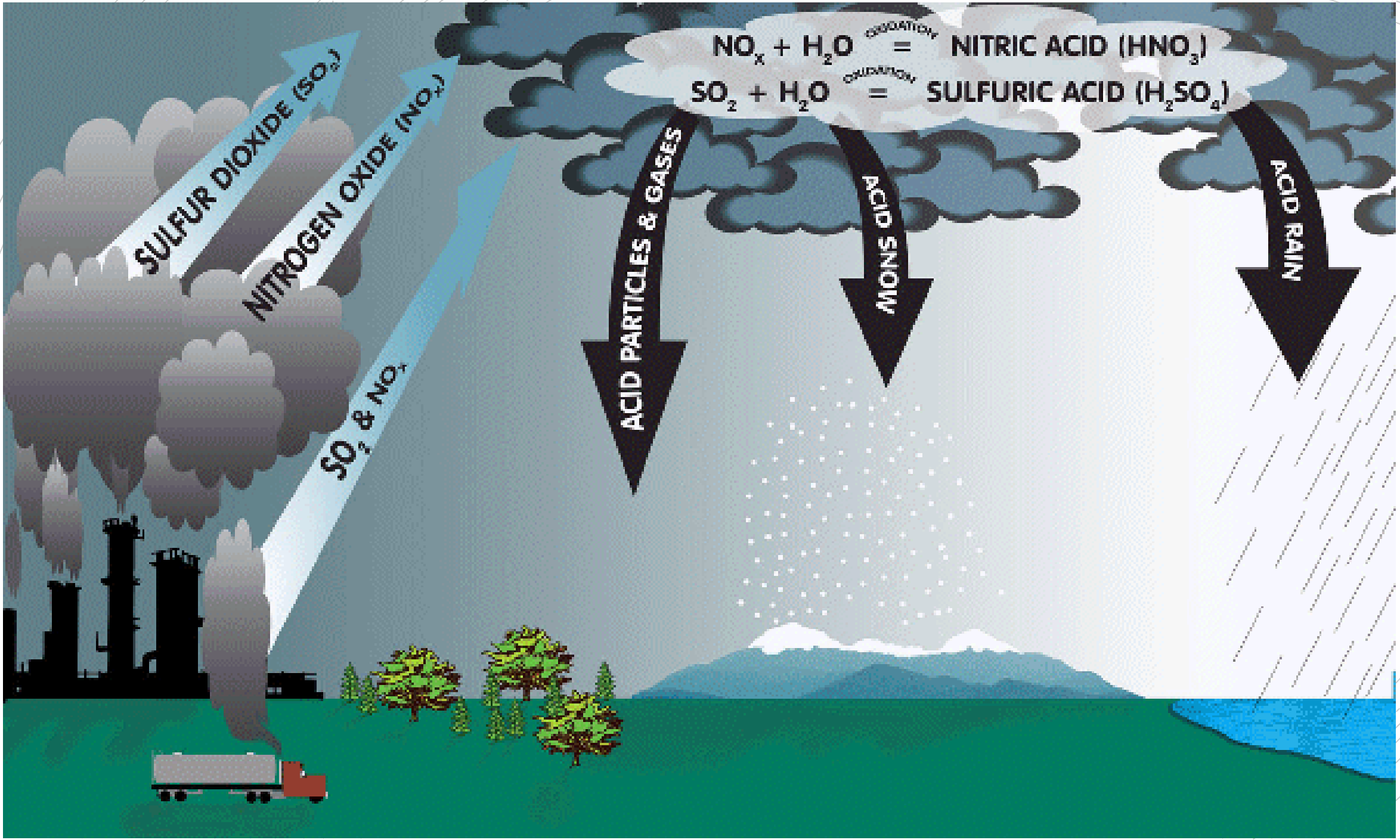
2. Mercury – naturally occurring in water, human activities such as burning fossil coal, incineration of garbage, hazardous waste &/or medical/dental supplies

3. **Nitrogen & phosphorus** cause environmental problems by overfertilizing the water

(Algal Bloom –BOD – dead zones)

"Biochemical oxygen demand"

3. Acids – industrial plants burning coal & releasing Sulfur dioxide & nitrogen dioxide into air causing forests, lakes, streams and some bodies of water to become more acidic (altering pH balance… buffers = acid rain)


$NO_x + H_2O$ OXIDATION = NITRIC ACID (HNO_3)
$SO_2 + H_2O$ OXIDATION = SULFURIC ACID (H_2SO_4)
SULFUR DIOXIDE (SO_2)
NITROGEN OXIDE (NO_x)
SO_2 & NO_x
ACID PARTICLES & GASES
ACID SNOW
ACID RAIN

4. **Synthetic compounds (pesticides "DDT", military/industrial "PCB" chemical compounds, pharmaceuticals, and hormones)** – toxic, carcinogens, genetic defect, interfere with growth & sexual development (reproduction – survival of the fittest) found in the water, soil, and agricultural

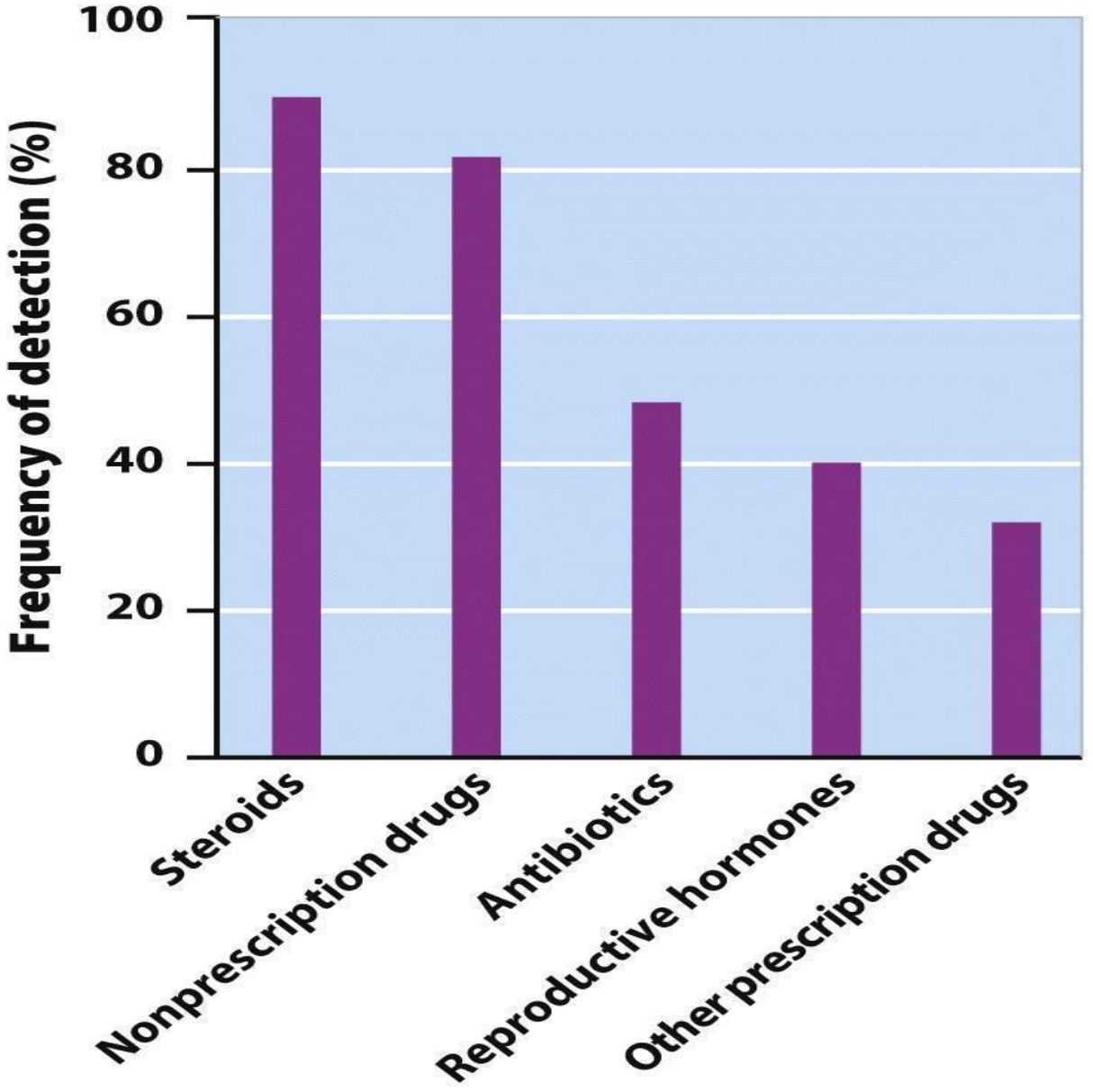
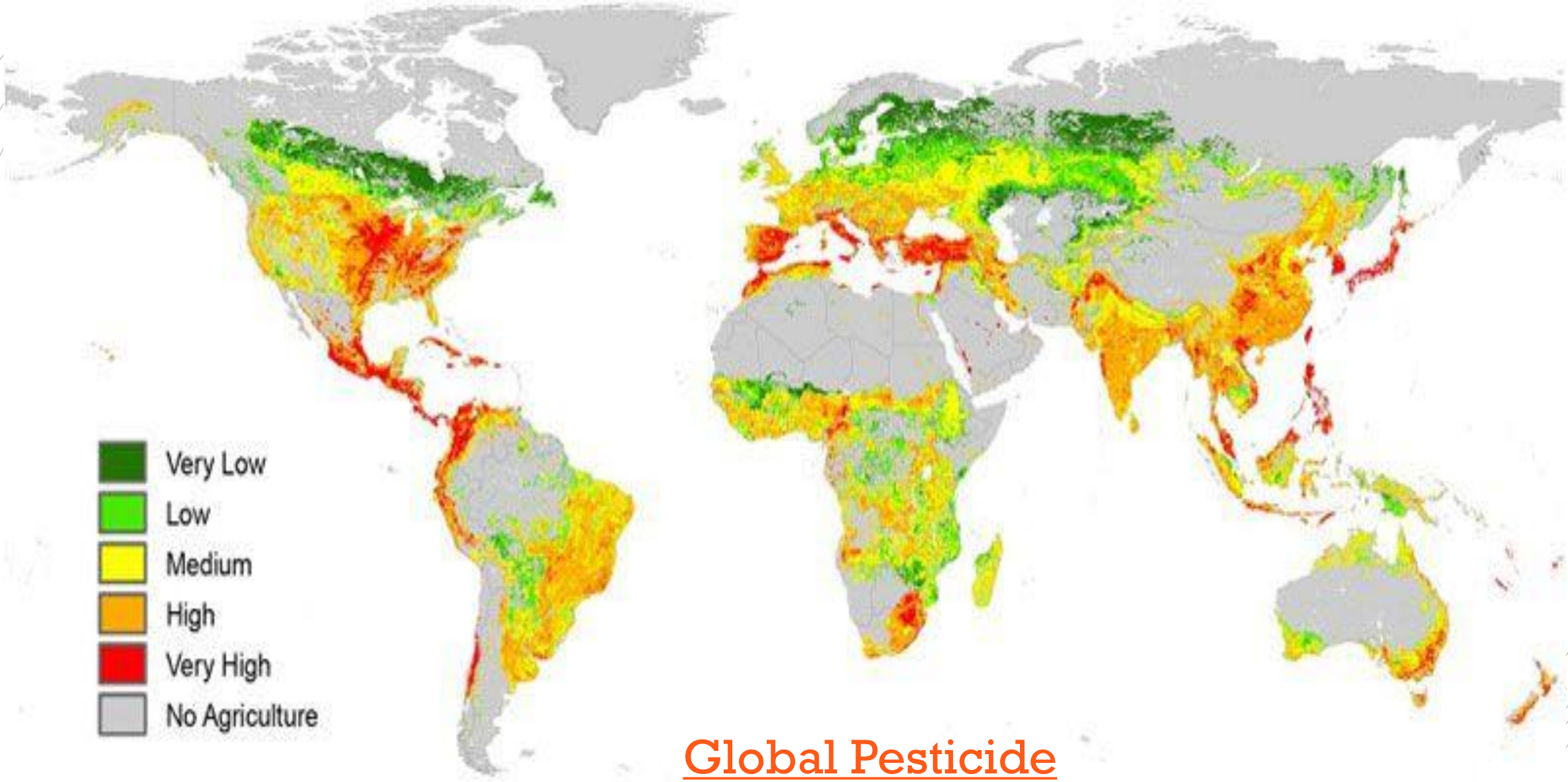
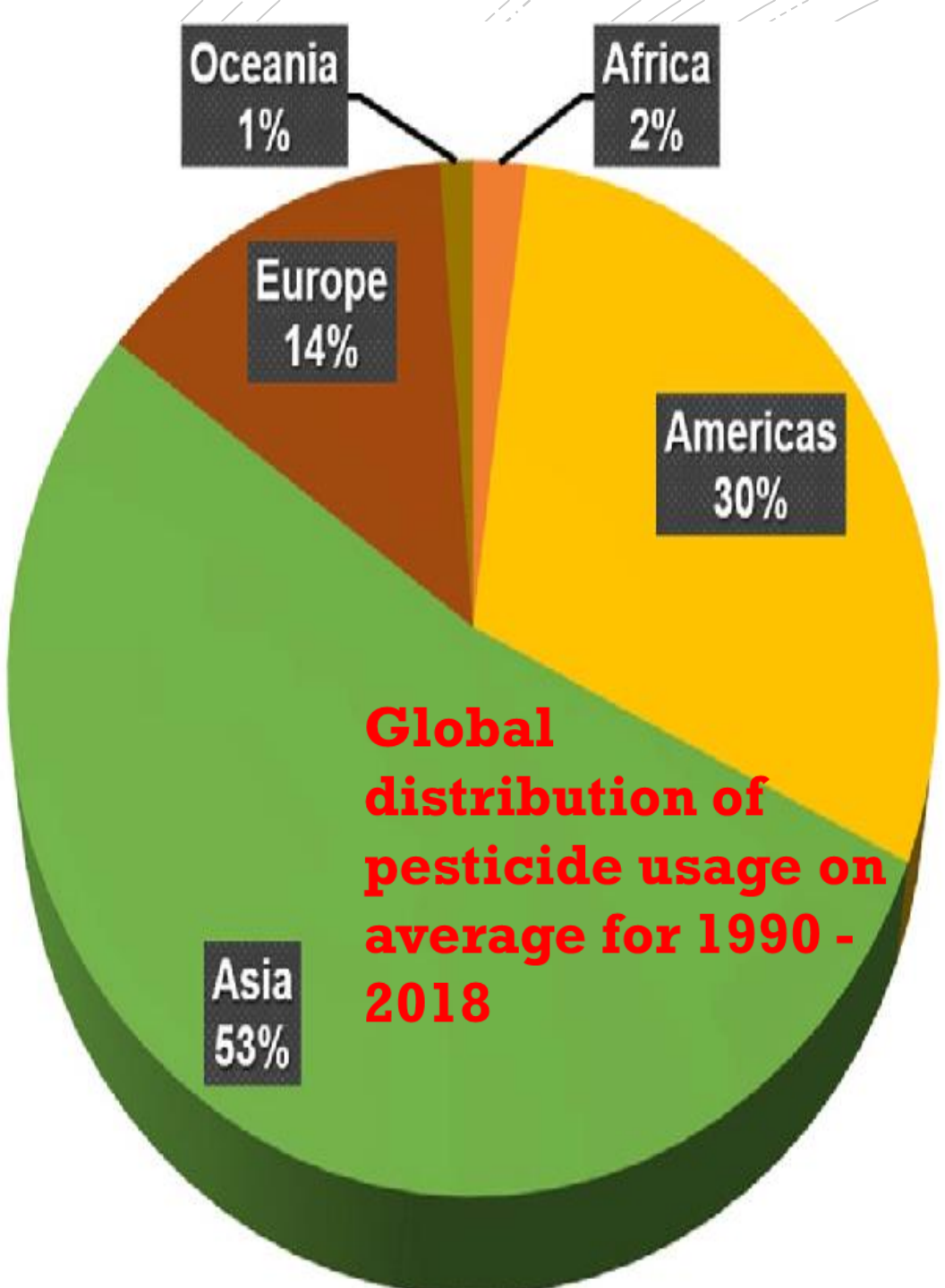
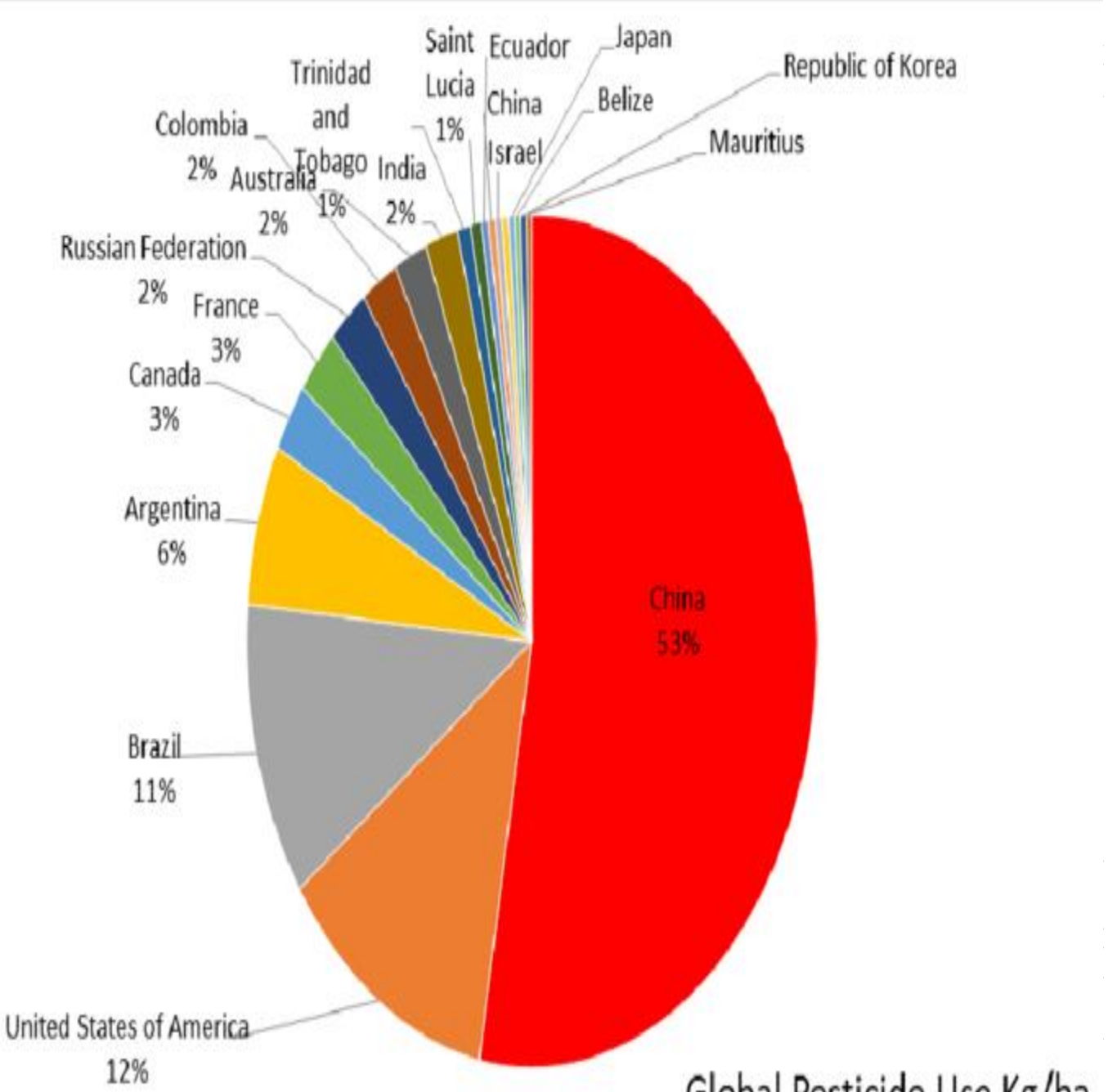


Figure 14.12
Environmental Science



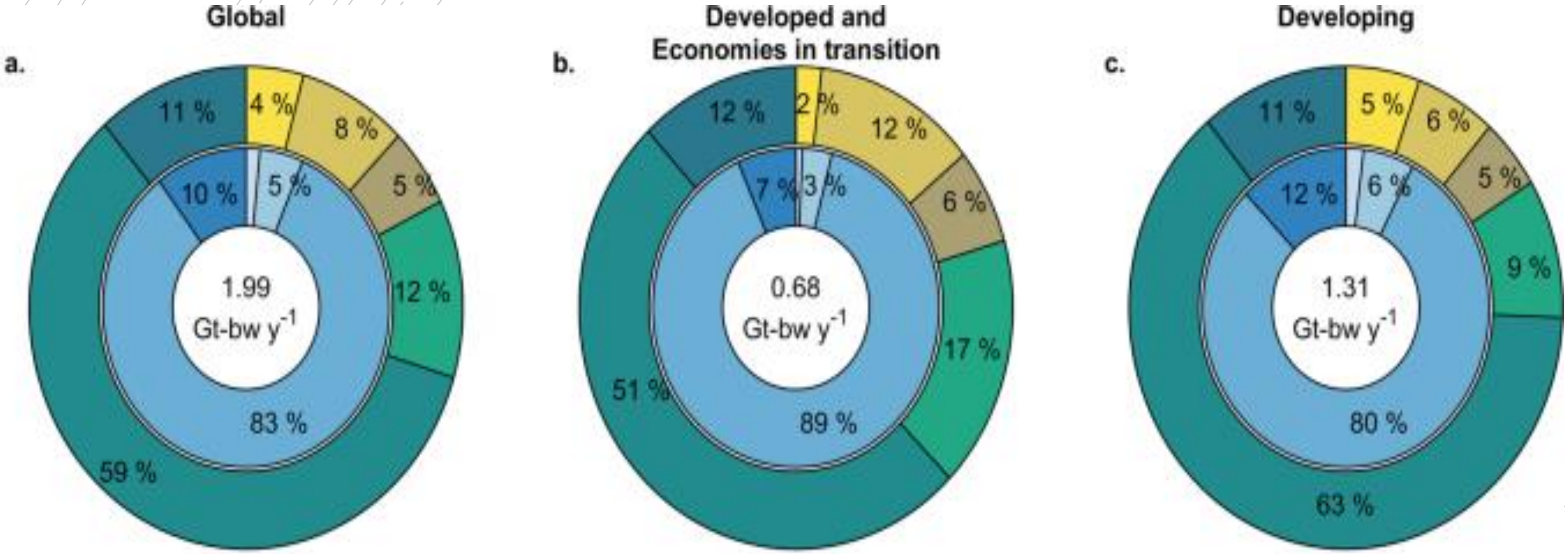
Global Pesticide


Oceania
1%
Africa
2%
Europe
14%
Americas
30%
Asia
53%
Global distribution of pesticide usage on average for 1990 - 2018


Saint Lucia 1%
Ecuador
Japan
Republic of Korea
Trinidad and Tobago 1%
China
Belize
Colombia 2%
Israel
Mauritius
Australia 2%
India 2%
Russian Federation 2%
France 3%
Canada 3%
Argentina 6%
China 53%
Brazil 11%
United States of America 12%
Global Pesticide Use Kg/ha
2023

Insecticides are the largest contributors to the **global pesticide footprints**, contributing **more than 80%,** followed by **herbicides** that contribute about **10%** of the total footprints.

Plant-based foods bear the largest portion of the global pesticide footprints



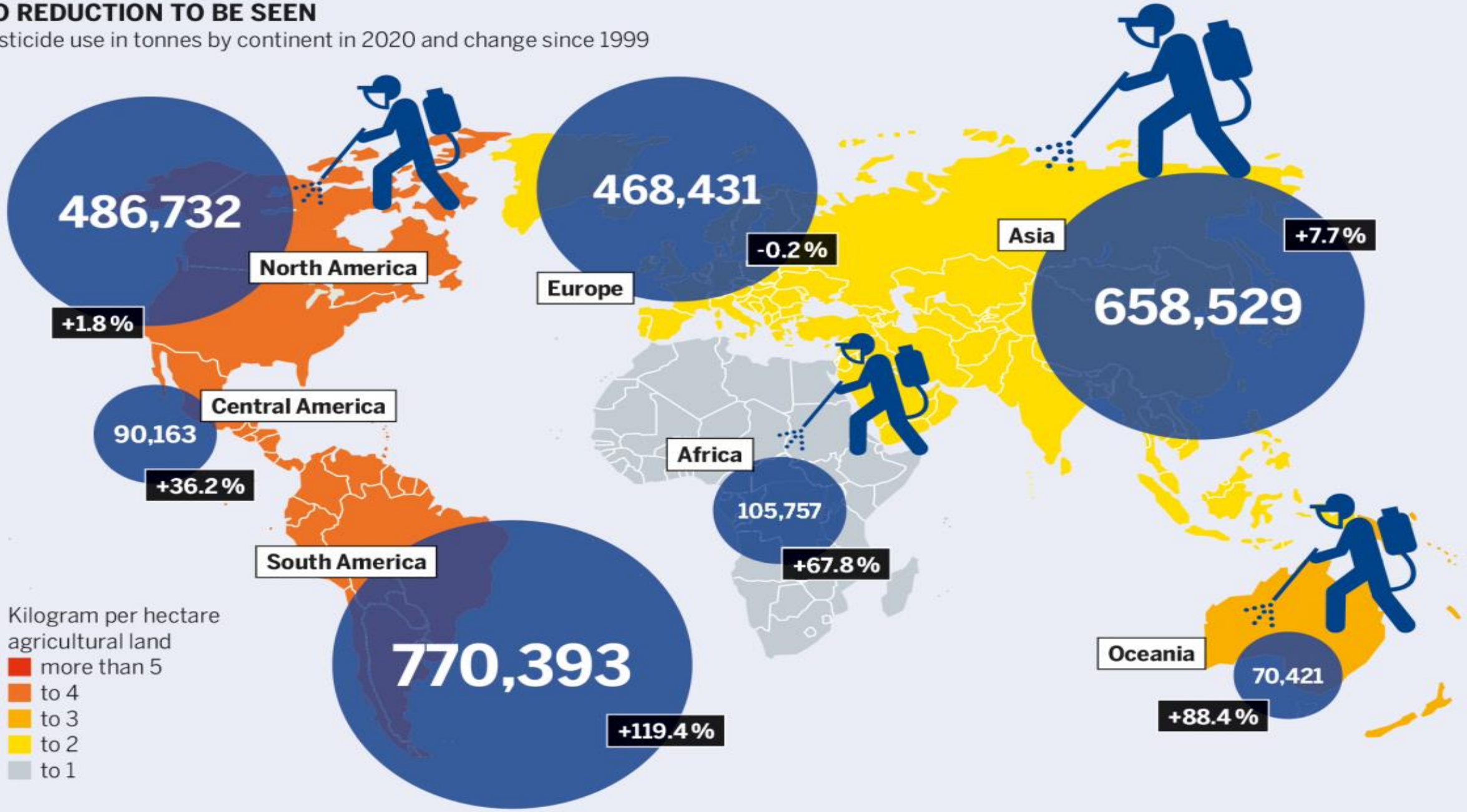
Empty calorie food products such as soft drinks, alcoholic drinks, chocolates, ice-creams, and sugars

Outer ring: Animal-based food; Plant-based food; Empty-calorie food; Textile, rubber, fibre; Services; Other

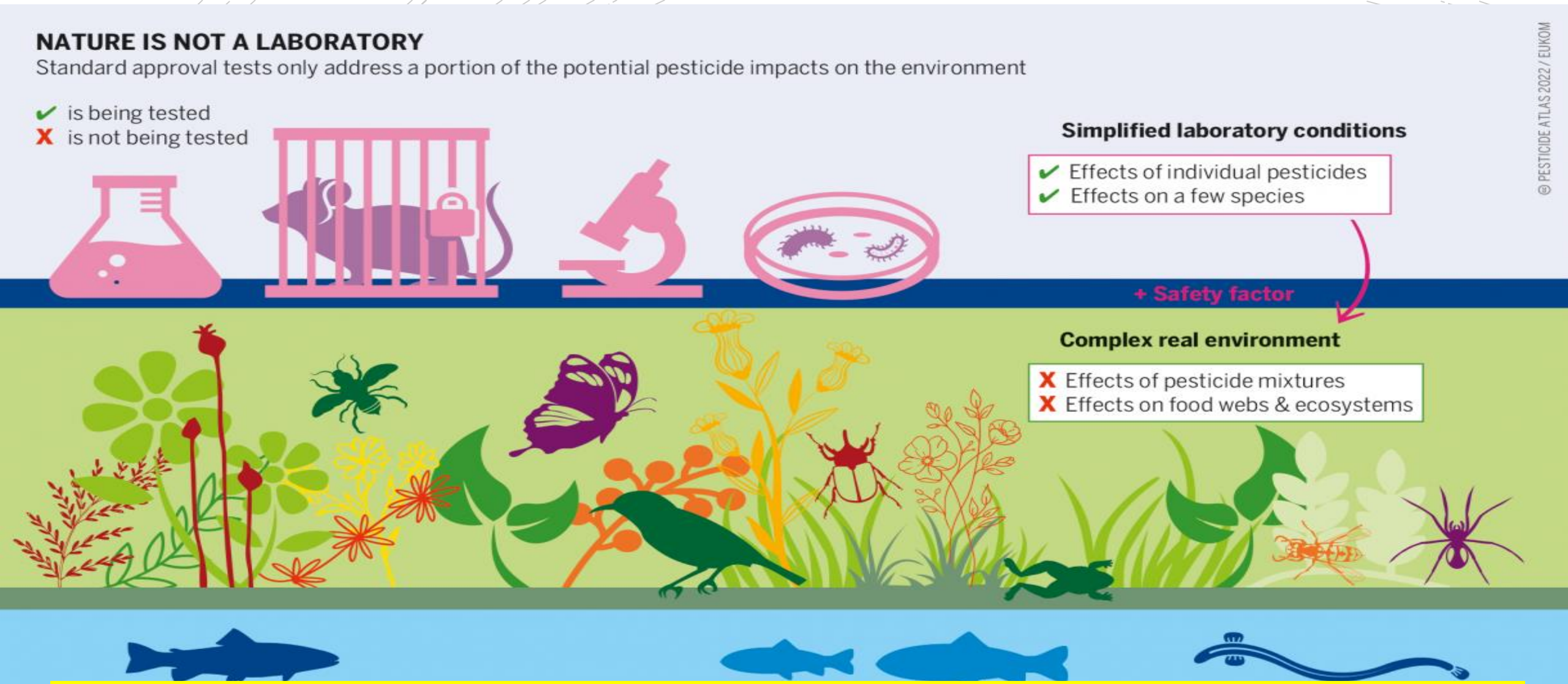
Inner ring: Herbicides; Insecticides; Fungicides; Multi-purpose pesticides

NO REDUCTION TO BE SEEN

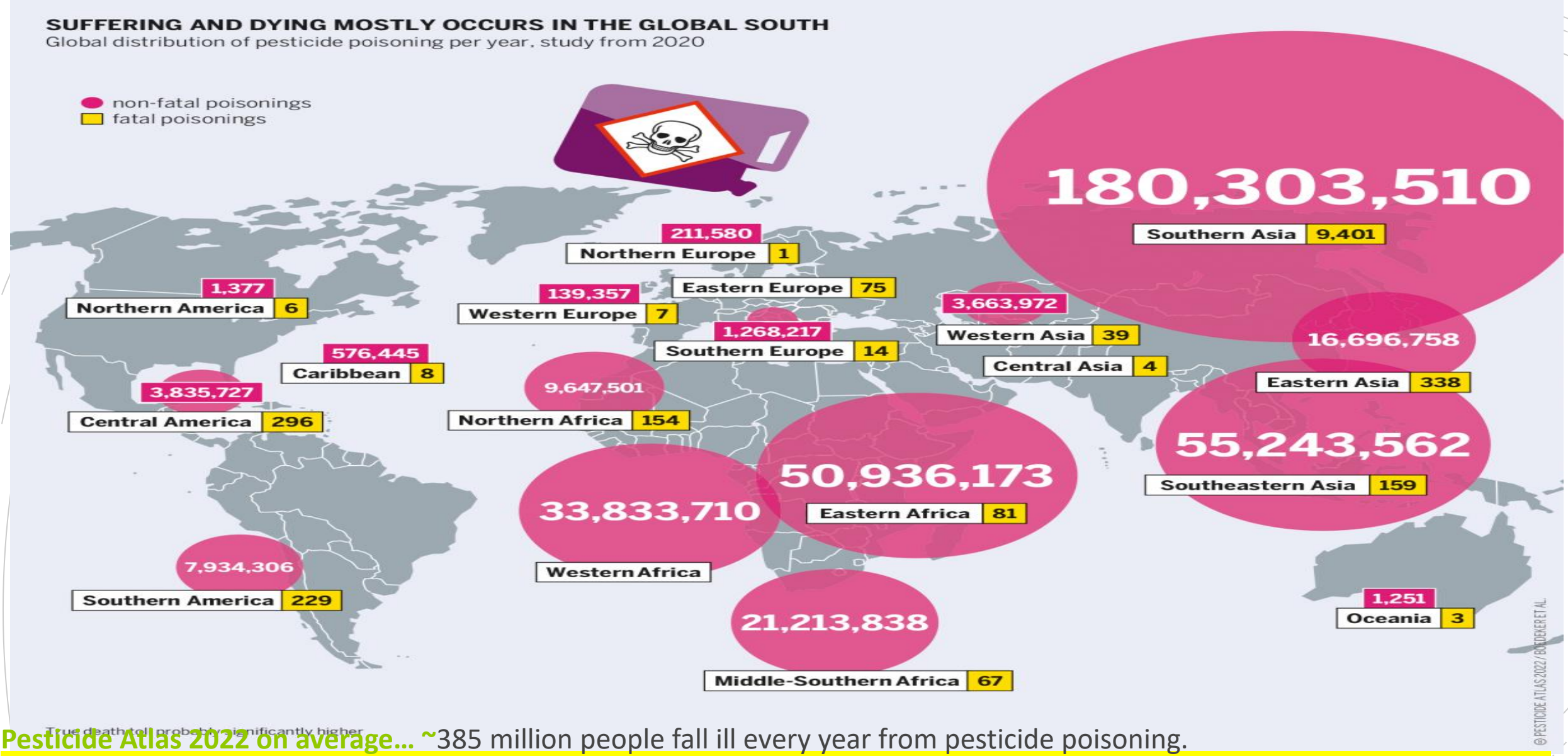
Pesticide use in tonnes by continent in 2020 and change since 1999



According to United Nations. Mere volumes do not reflect toxicity



The results from approval tests with only a few species are subject to uncertainties. To compensate for these uncertainties, safety factors are supposed to help. Before they are put on the market, pesticides go through an approval process in which their impacts on human health and the environment are tested. But their indirect effects **on food chains and biodiversity receive little attention, neither do the effects of pesticide mixtures that are hard to predict.**

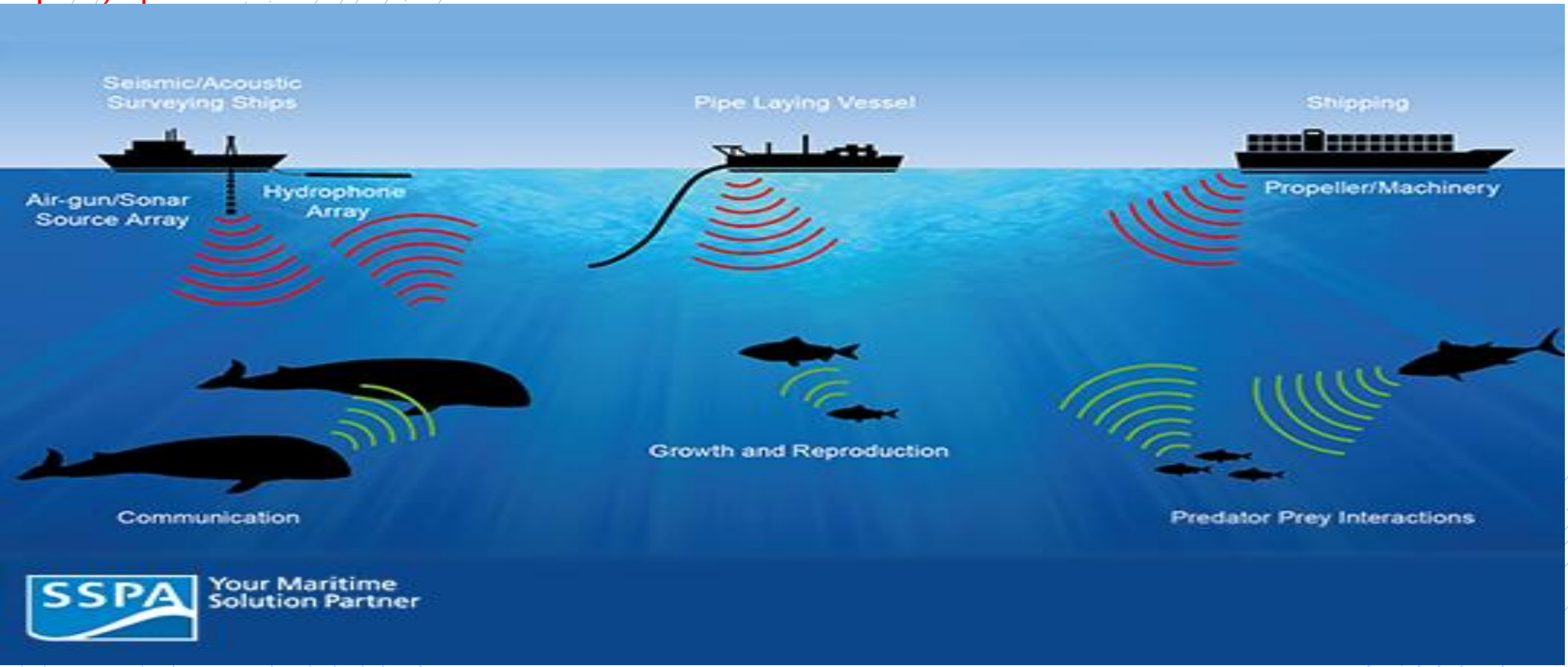


Pesticide Atlas 2022 on average… ~385 million people fall ill every year from pesticide poisoning.

People can be unintentionally exposed to pesticides in various situations: on the field, in the forest, through food or drinking water…Farmers are at a higher risk of getting exposed to pesticides, but the substances can also pose risks to people outside the agricultural sector as pesticides are mobile and difficult to control. They often contaminate the environment and end up in our food.

Other Water Pollutants (*Non-Chemical Based*)

1. Noise pollution (receives least amt. of attention) Sound emitted by ships & submarines can interfere with animal communication, growth & reproduction, & prey/predator.

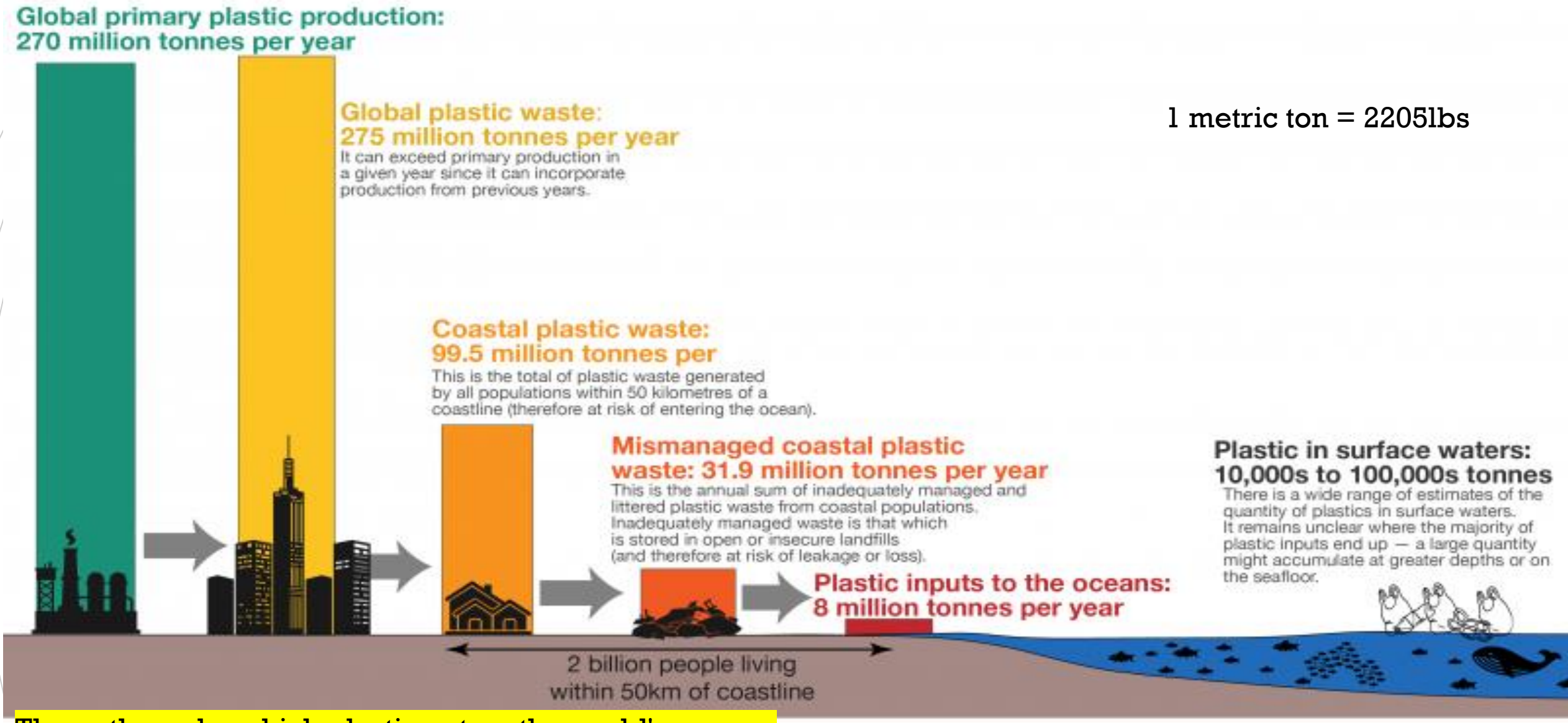


2. Solid waste pollution (*garbage, mostly plastic, coal ash/slag)* do not pose any toxic hazard, generally disposed in landfills, but some cases ends up in bodies of water.

The pathway by which plastic enters the world's oceans

Our World in Data

Estimates of global plastics entering the oceans from land-based sources in 2010 based on the pathway from primary production through to marine plastic inputs.



1 metric ton = 2205lbs

The pathway by which plastic enters the world's oceans.
(Results were analyzed by Our World in Data (accessed on 18 June 2023)

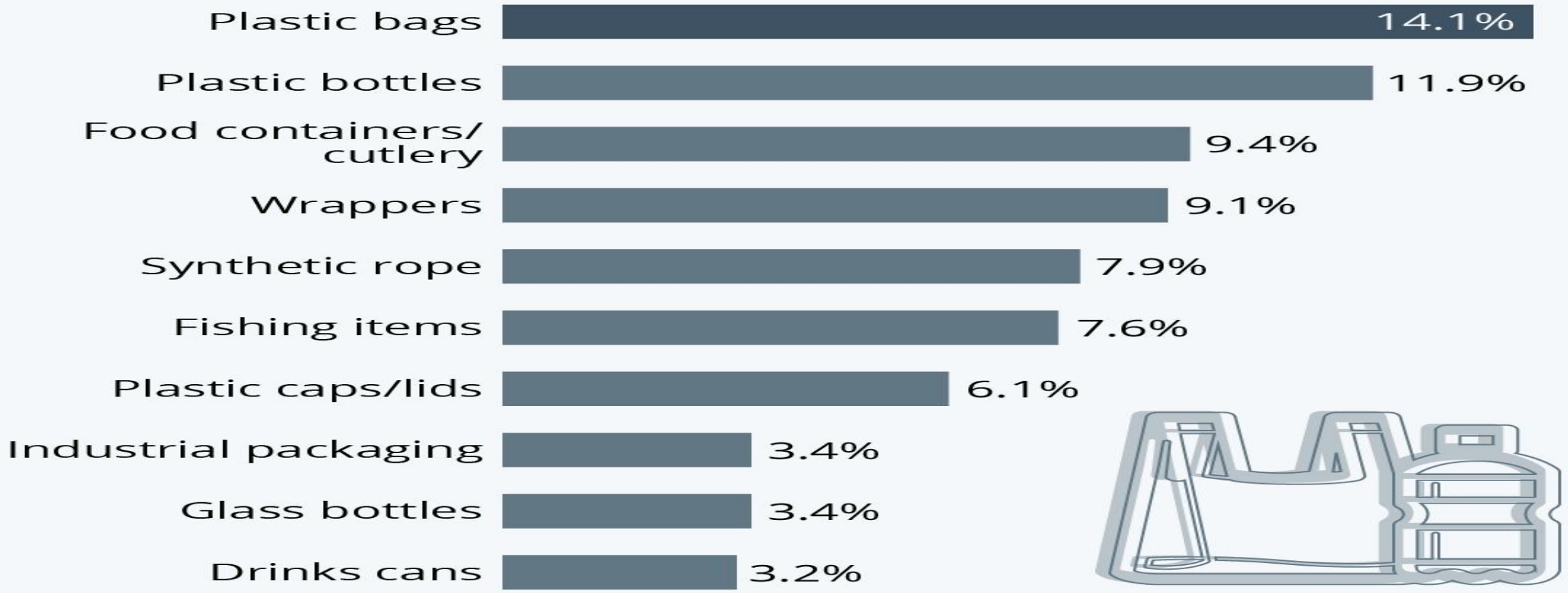
d waste management practices by country

Due to **circular ocean currents** (global trade winds and forces created by the Earth's rotation) and **weather conditions** Disproportionately large amounts of marine debris have been found in these areas, including the North Atlantic and Great Pacific garbage patches

www.MarineDebris.noaa.gov

Plastic Items Dominate Ocean Garbage

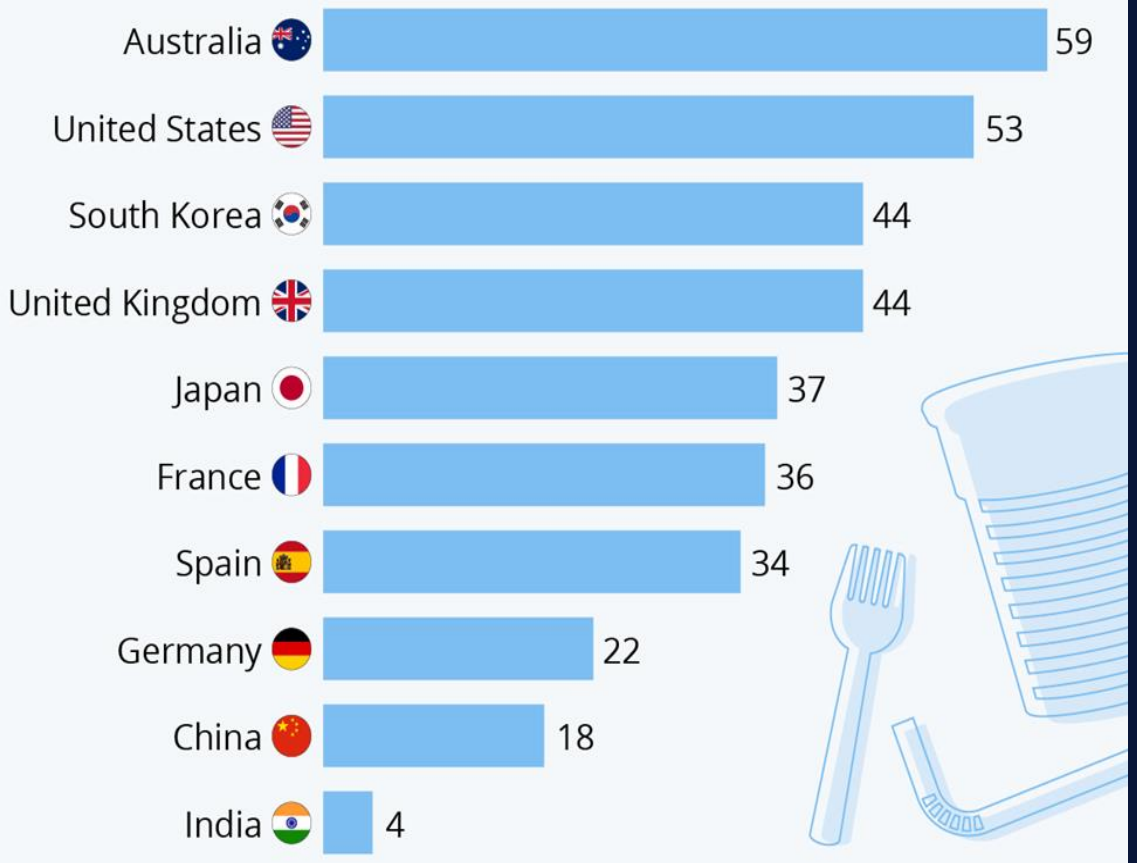
The 10 most widespread waste items polluting the world's oceans*



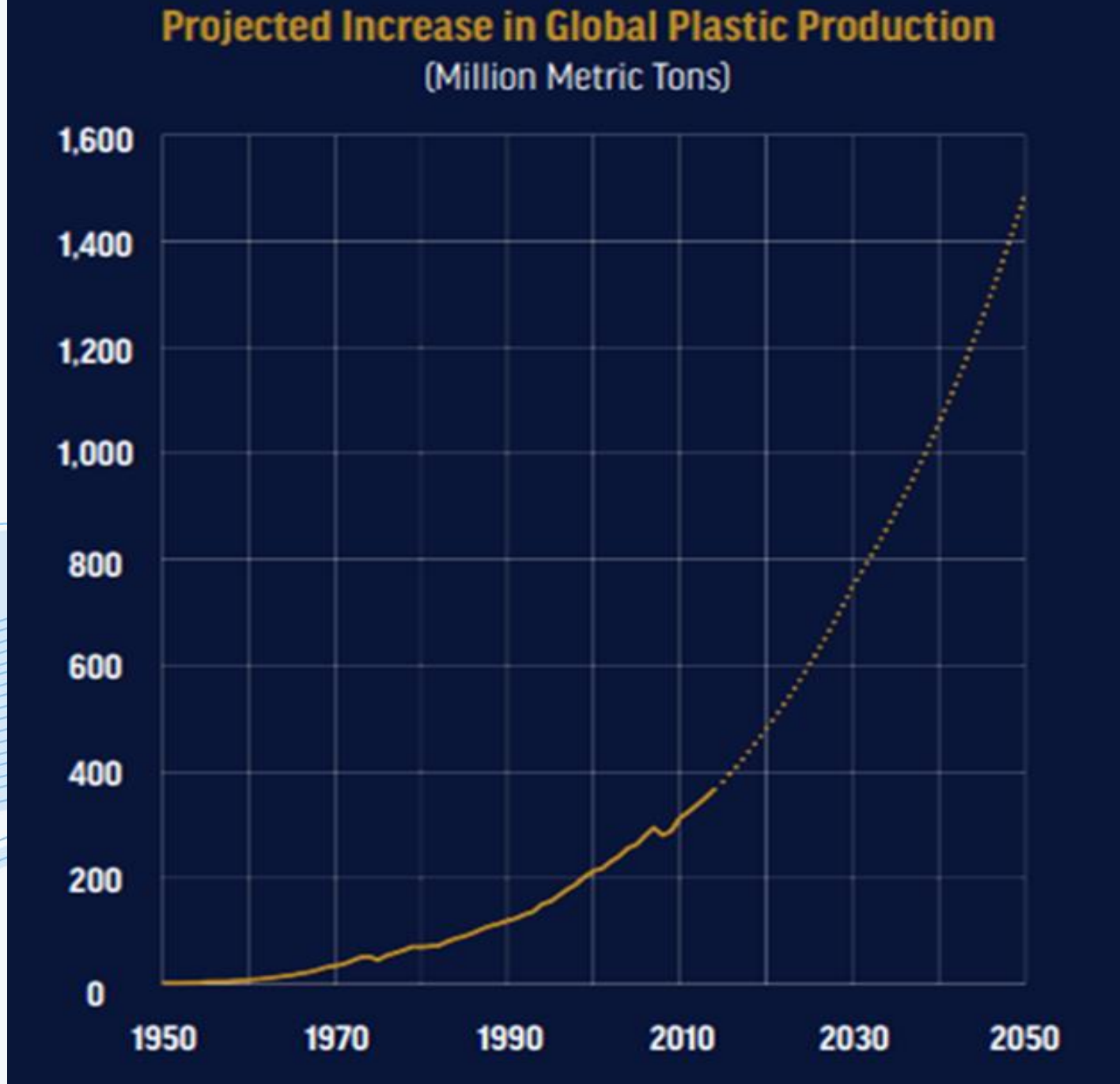
* Based on waste items found in seven aquatic ecosystems globally.
Source: Carmen Morales-Caselles et al. (2021)

How Much Single-Use Plastic Waste Do Countries Generate?

Single-use plastic waste generated per person in selected countries in 2019 (in kilograms)



Source: The Plastic Waste Makers Index by The Mindaroo Foundation



The Countries Polluting The Oceans The Most 2013

Annual metric tons of mismanaged plastic waste in global waters*

53kg = .053m ton

Mismanaged waste (plastic) (littered or inadequately disposed 'not fully contained') could eventually enter the ocean via inland waterways, wastewater outflows and transport by wind or tides

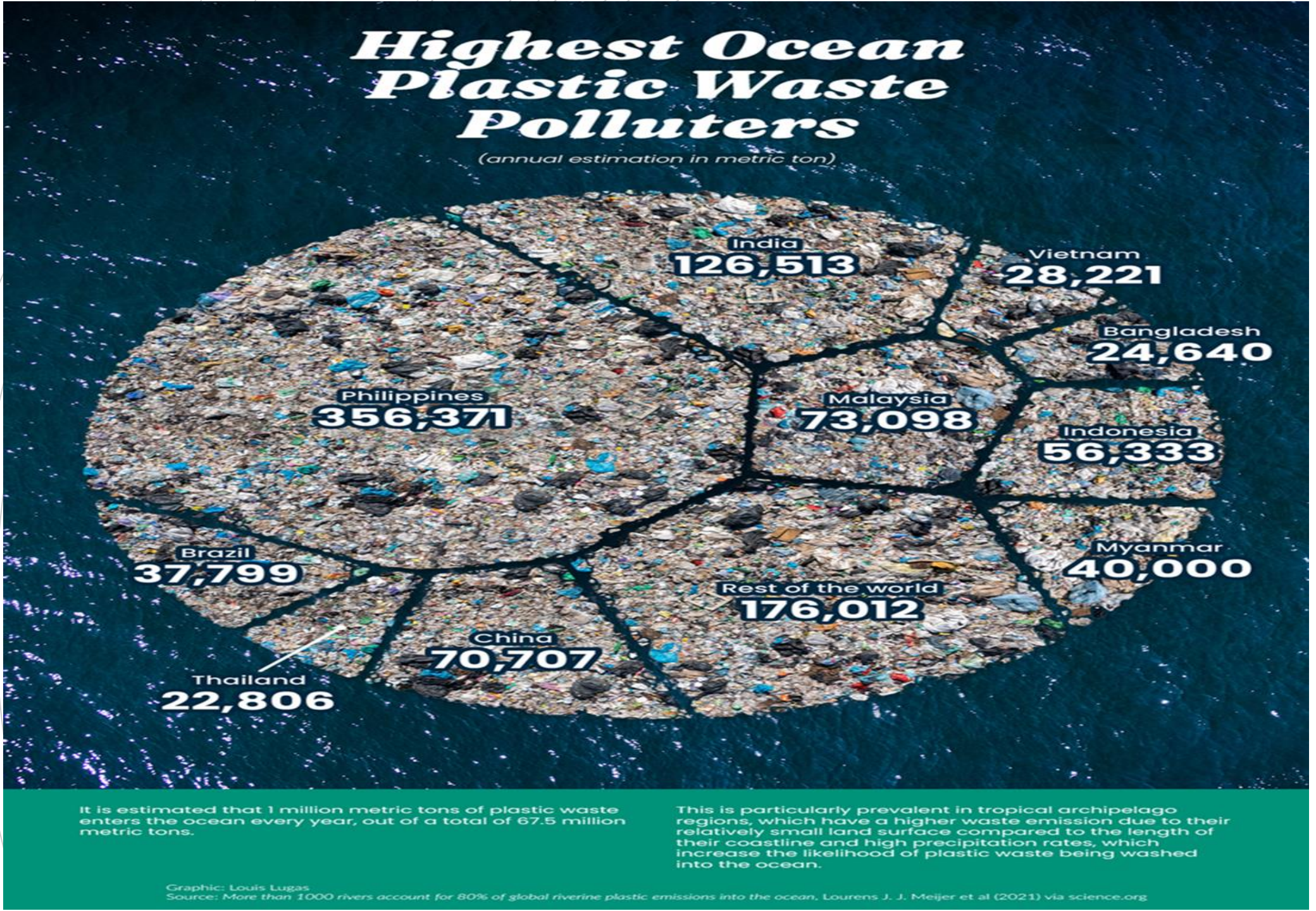
1 ton = 1000 kg = 2205lb

statista

For example, **China** generates 10 times the plastic waste that Malaysia does. However, 9% of Malaysia's total plastic waste is estimated to reach the ocean, in comparison to China's 0.6%.

Rank	Country	Annual Ocean Plastic Waste (Metric tons)
#1	Philippines	356,371
#2	India	126,513
#3	Malaysia	73,098
#4	China	70,707
#5	Indonesia	56,333
#6	Myanmar	40,000
#7	Brazil	37,799
#8	Vietnam	28,221
#9	Bangladesh	24,640
#10	Thailand	22,806
	Rest of the World	176,012
	Total	1,012,500

According to a 2023 study, countries with a smaller geographical area, longer coastlines, high rainfall, and poor waste management systems are more likely to wash plastics into the sea.



What to do about…

Figure 14.18
Environmental Science

3. Sediment pollution *(sand, silt and clay)* carried by moving water in streams and rivers to another location where water is slow moving *(natural process but humans can increase the amt. by sprawling – erosion wind/rain)*

Solution

1. cooling towers that release the excess heat into the atmosphere instead of water.
2. Closed system that cool the hot water in the tower and recycle the water to be reheated (no extraction from natural water bodies)

4. Thermal pollution- *human activities* causes substantial change in temp. of water.

Most common cause occurs when cold water is removed from a natural supply, used to absorb heat *(part of industrial process)* then returned as heated water *(thermal shock* to organisms, kills organisms due to lack of oxygen-warmer water does not carry as much as colder water)

5. Human Wastewater

Figure 14.2
Environmental Science

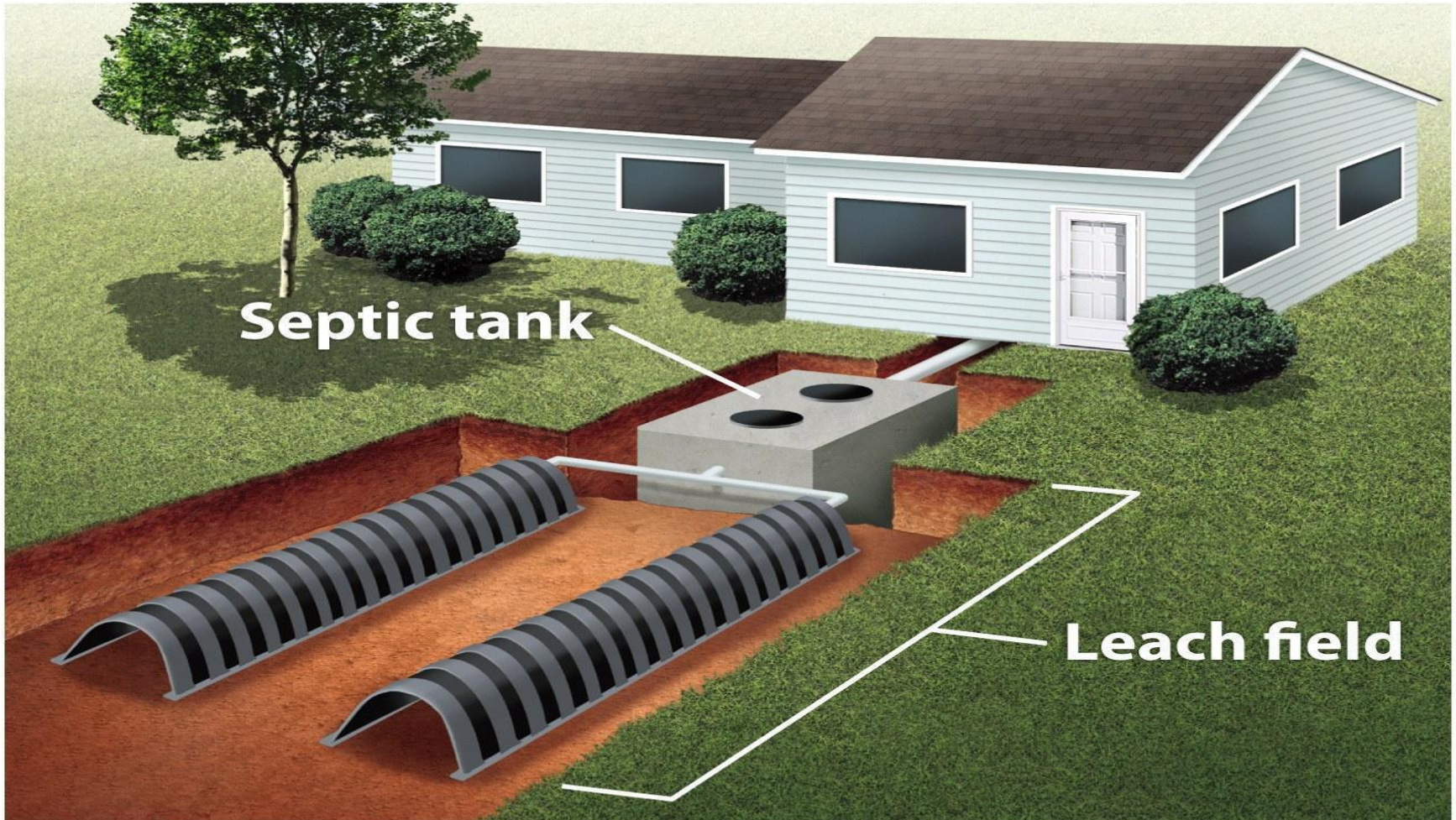
Water produced by human activities such as human sewage from toilets and gray water from bathing and washing clothes or dishes.

Nutrients from wastewater decomposition & leached from agricultural lands during periods of precipitation

Treatments for Human Wastewater:

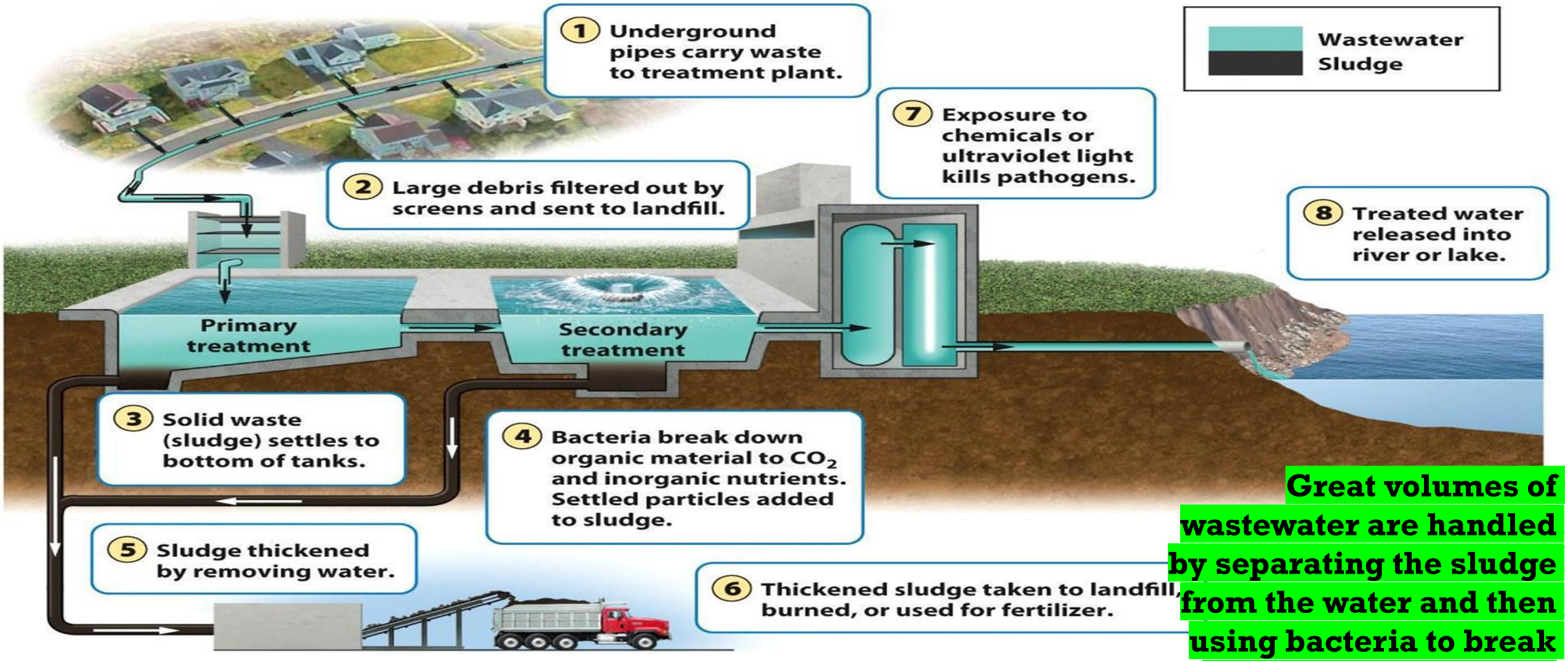
2 systems for treating human waste are…

1. **Septic systems-** a large container that receives wastewater from the house.



Solids settle at bottle of tank & bacteria breaks down the sewage. The liquid moves through the filtered pipes that distribute the water through a leach field.

2. Sewage Treatment Plants– centralized plants in areas with large populations that receive wastewater via a network of underground pipes (*primary & secondary treatments).*



Great volumes of wastewater are handled by separating the sludge from the water and then using bacteria to break down the components.

Figure 14.6
Environmental Science

Treatments for waste from large livestock operation

Animal Wastewater

3. **Manure lagoons-** large, human-made ponds line with rubber to prevent the manure from leaking into the groundwater. After the manure is *broken down by bacteria*, it is **spread onto fields as fertilizers.**

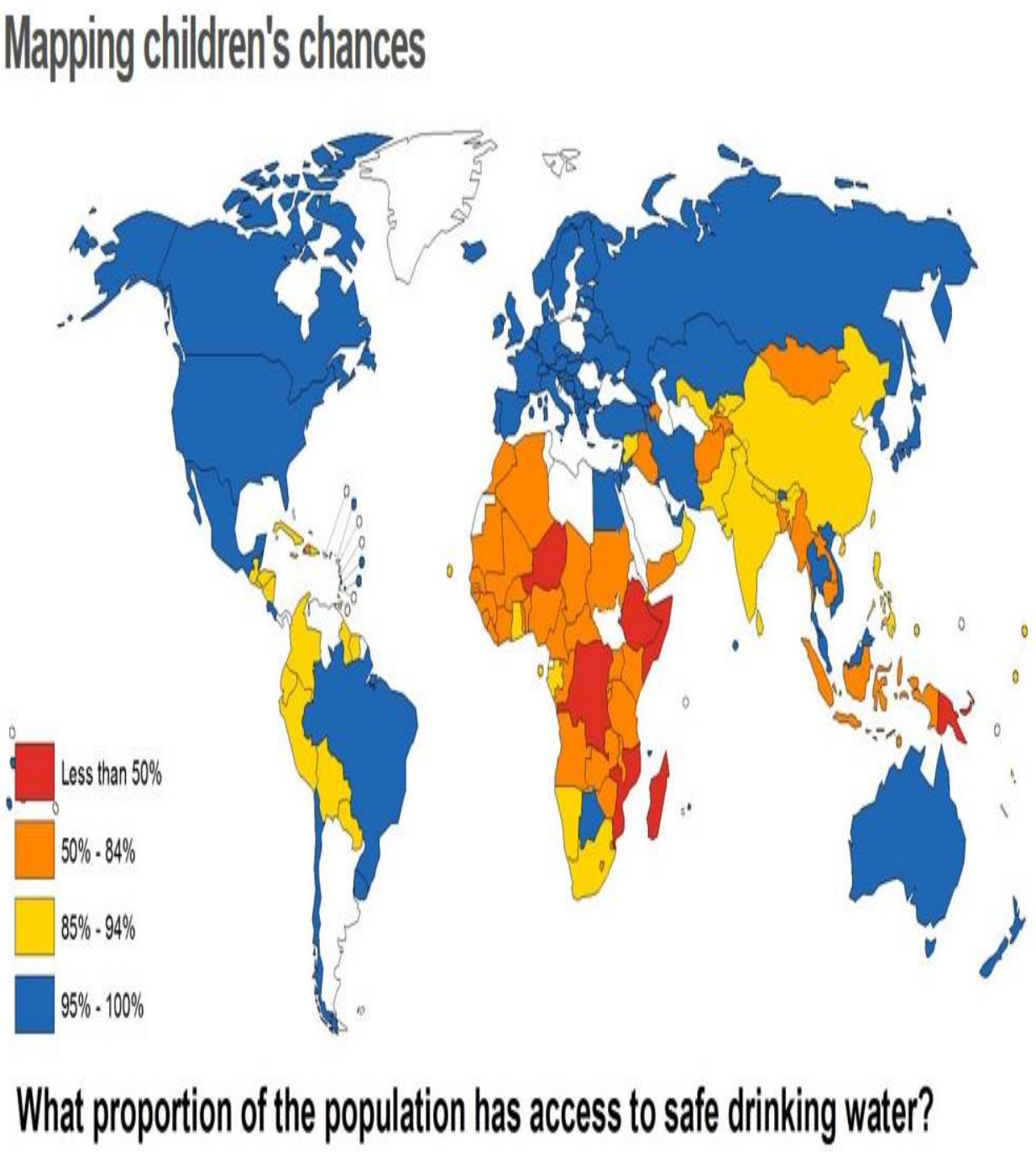
Figure 14.7
Environmental Science

Similar to human waste contamination, manure from the feeding lot operations not only contain **digested animal foods, but also variety of hormones and antibiotics….a leak in the liner can seep into the underlying groundwater and/or overflow into nearby bodies of water (contamination)**

Water Laws

- **Clean Water Act-** (1972) supports the "protection and propagation (breeding) of fish, shellfish, and wildlife and recreation in and on the water".
  - This is done by maintaining and, when necessary, *restoring the chemical, physical, & biological properties of natural waters.* (does not protect groundwater)
  - Issued water quality standards that defined *acceptable limits of various pollutants* in U.S. waterways.
  - This act allows **EPA & state governments** to issue permits to control how much pollution industries can discharge into the water *(pay to pollute)*

- **Safe Drinking Water Act-** (1974, 1986, 1996) sets the *national standards* for safe drinking water.
  - EPA is responsible for establishing **Maximum Contaminant Levels (MCL)** for 77 different elements or substances *(microorganisms, disinfectants, organic & inorganic chemicals)* in both surface water and groundwater.



In 2020, **74%** of the world population had access to a safely managed water source (as of 2000 was 61%) In 2022, 771 million (**1 in 10~26%**) people do not have access to safe water.

As of 2023, around 2 billion ppl around the world do not have access to clean and safe drinking water.

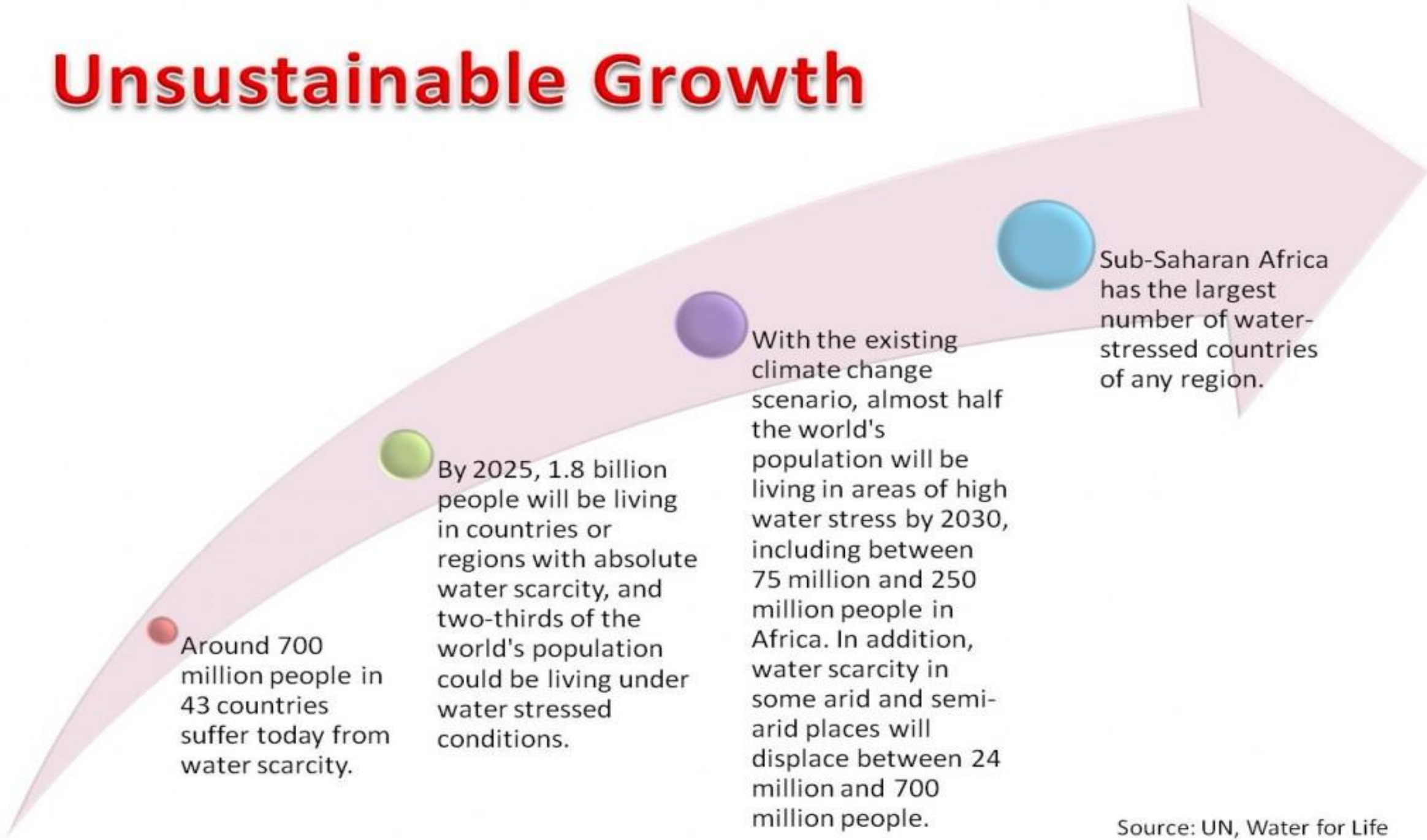
Approximately 3.6 billion people – 46% of the world's population – lack adequate sanitation services, according to a new United Nations World Water Development Report 2023

Furthermore, about 4 billion people, representing nearly **one-half of the world** population, experience severe water scarcity during at least one month of the year

Developed vs. Developing Nations

- **Developed countries** experienced industrialization for many decades and widely polluted their air & water
- **Developing countries** are in the process of industrializing (benefit economically from additional jobs), have less restrictive environmental laws, & have less money to fund water-quality improvements and resources.
- *In some cases, contaminating industries move from developed countries to developing (cycle)*
- **Solutions? Technology? Petition?** (Brazilian river polluted, government regulated the pollution, cleaner today) **Money??**
  - 100% PFAS removal & zero impact on our environment. (doing it in large scale in New York)

Unsustainable Growth



Source: UN, Water for Life