

# CVL100:Environmental Science(2-0-0)

## Water and Wastewater Treatment Part Dr. Arun Kumar (Tuesday and Friday)

Email: [arunku@civil.iitd.ac.in](mailto:arunku@civil.iitd.ac.in)

Check IITD course email daily for information



भारतीय प्रौद्योगिकी संस्थान दिल्ली

Indian Institute of Technology Delhi

Hauz Khas, New Delhi-110016 INDIA

# Learning Objectives

- To introduce water contaminants and their health effects
- To decide about treatment need for a given use objective
- To make aware of reading treatment plant schematic and estimating removal efficiency
- To provide basic information on processes for removing contaminants from water

# Water Pollution



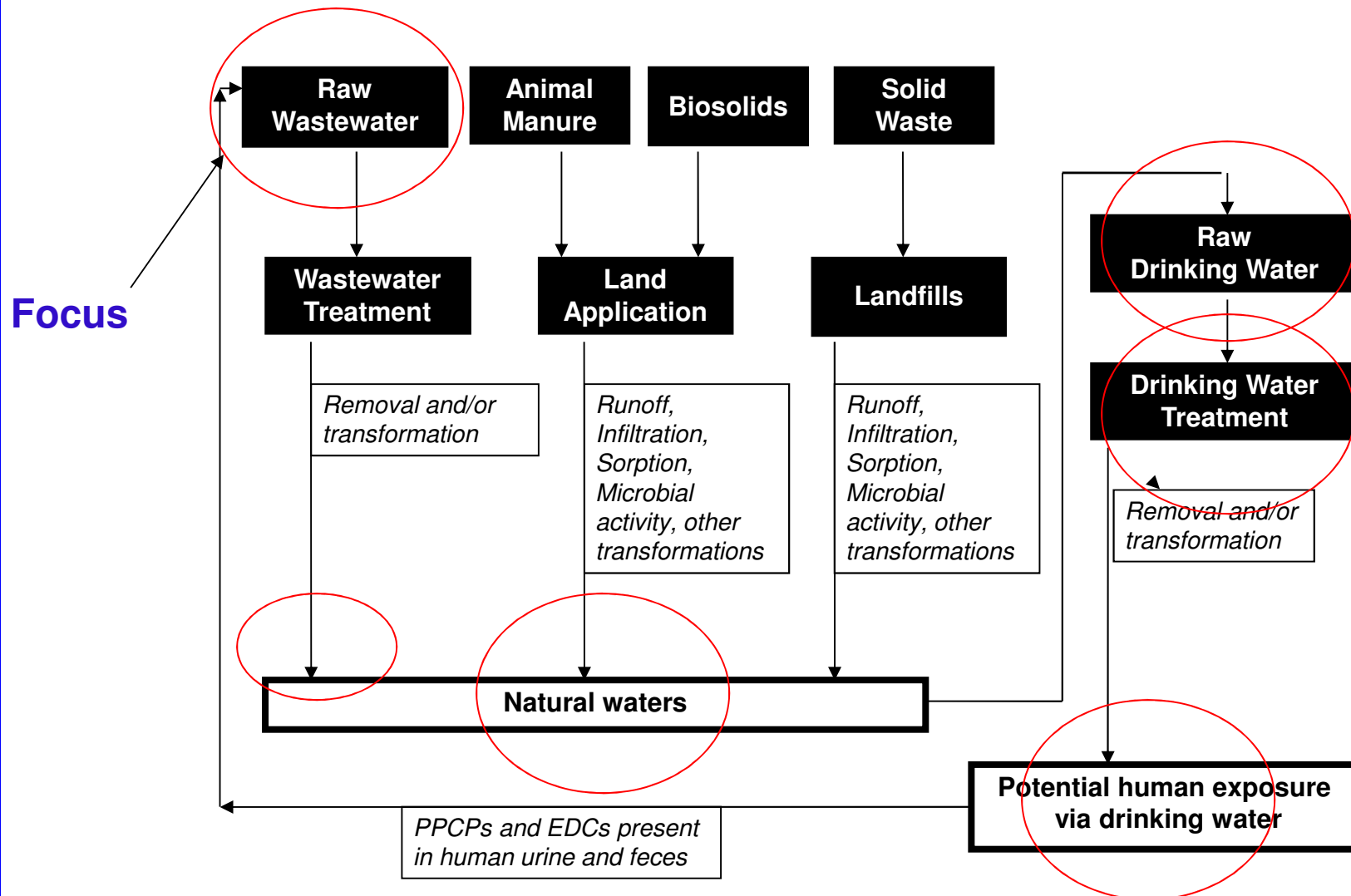
Ben Osborne

(www.benosborne.com)

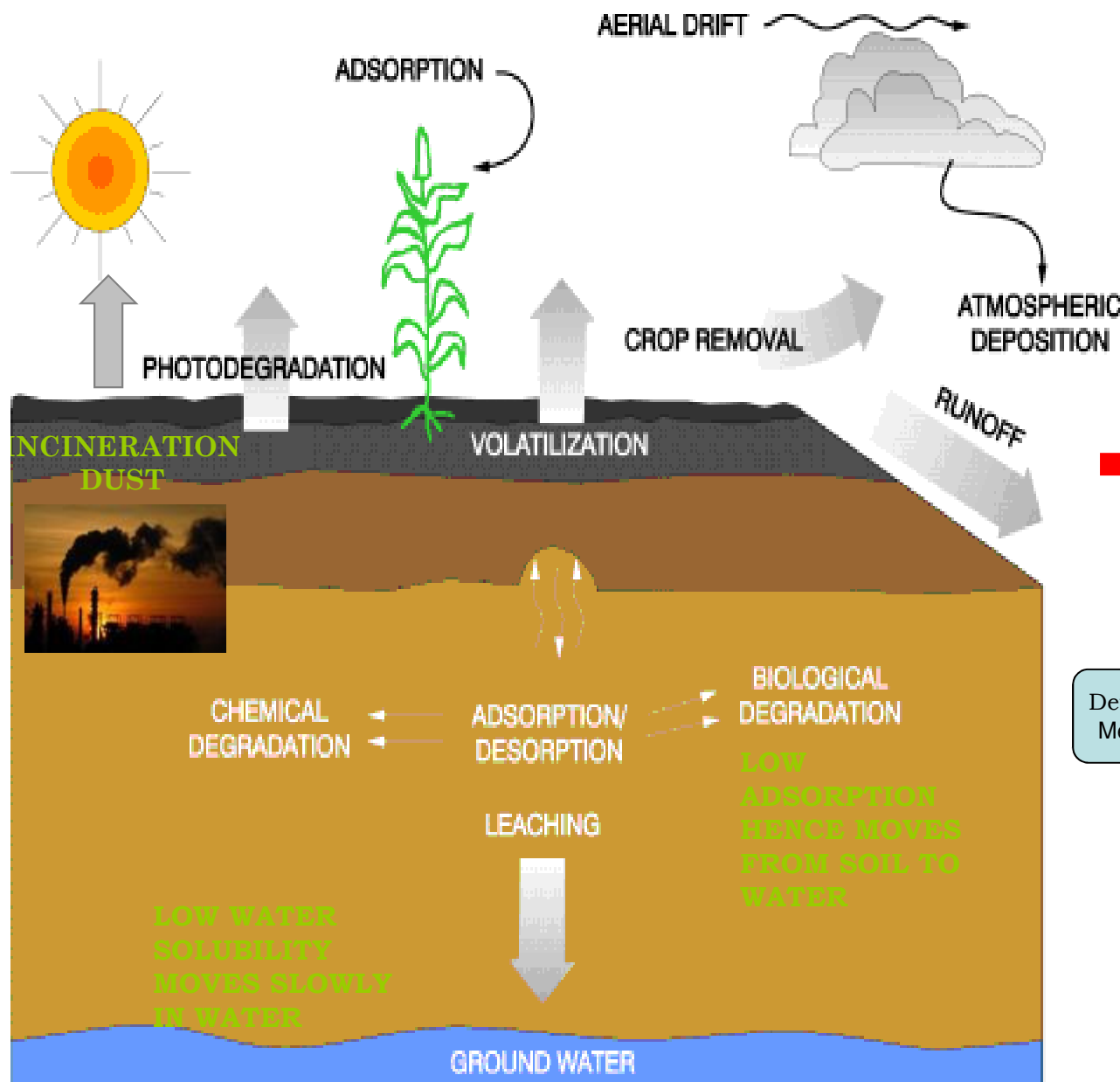


un Ku  
(arunka@civil.mca.com)

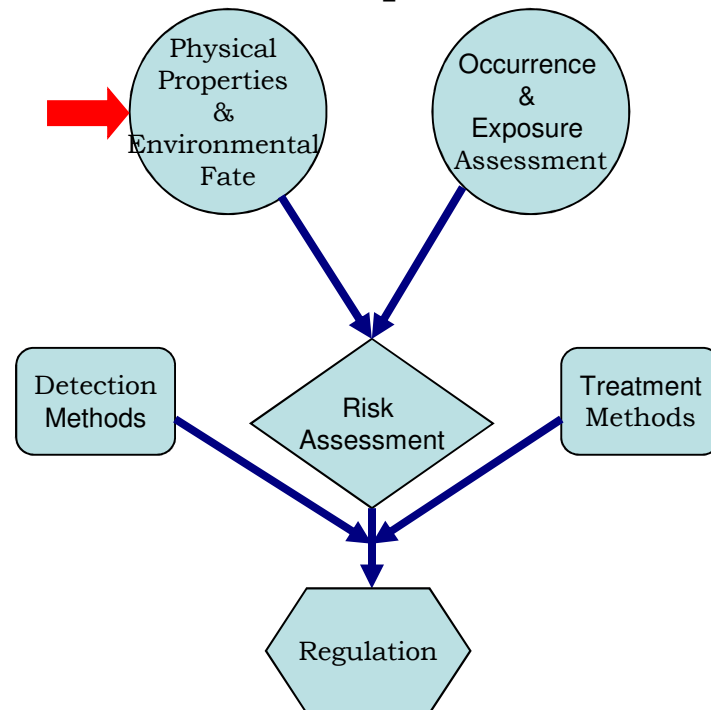
# Emerging Contaminants in Environment



# Physical Properties & Environmental Fate

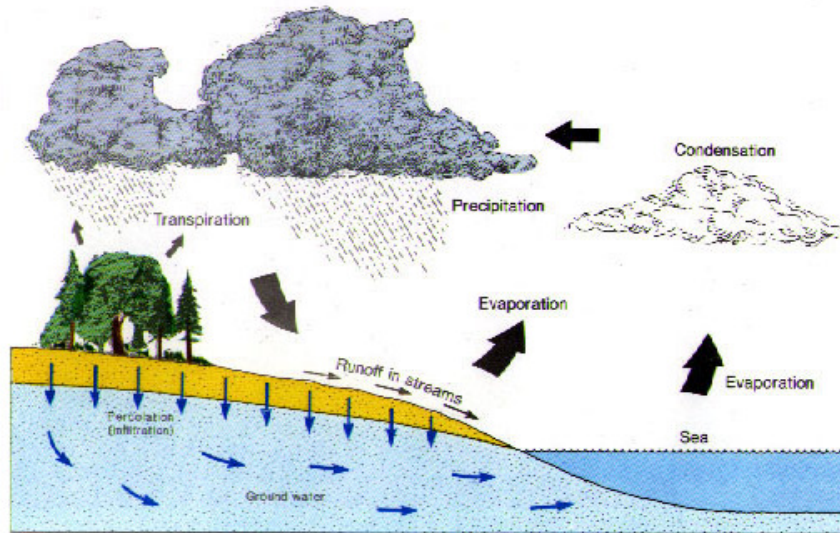


- Water solubility – 32-40 mg/L
- Weakly volatile
- Low sorption to soil





# Transport of Enteric Viruses (Wong, K.; MSU)



- Viruses can contaminate the surface water and groundwater by runoff and infiltration.

# Harmful Algal Blooms (HABs) (*part of reason on eutrophication*)

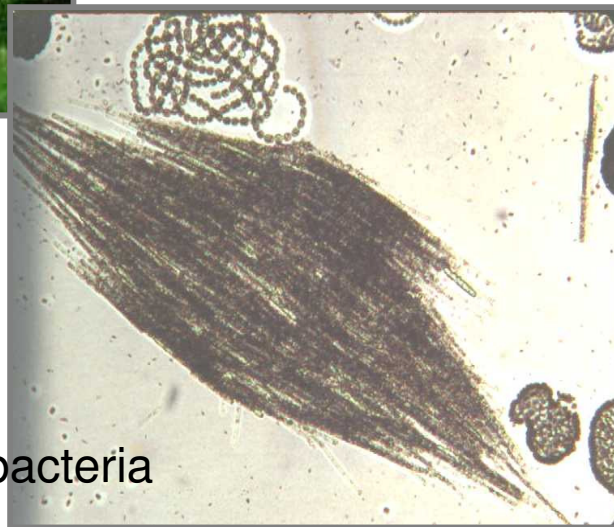
*Microcystis* sp. bloom



HAB



*Anabaenopsis* sp. bloom



mixture of cyanobacteria

October 21, 2021

(arunku@civil.iitd.ac.in)



# Eutrophication



October 21, 2021

Arun Kumar  
([arunku@civil.iitd.ac.in](mailto:arunku@civil.iitd.ac.in))

# Effects on human and environmental components

- **Direct**  
Infections,  
Toxicity,  
Carcinogenesis  
Other disease acute or chronic  
← Effects on HUMANS
- **Indirect**  
Eutrophication,  
Oxygen depletion - Hypoxia,  
Harmful algal bloom formation,  
Aquatic toxicity,  
Accumulation in fish and sediments,  
Bioaccumulation,  
Endocrine disruption,  
Antibiotic resistance development  
← Effects on ECOSYSTEMS

# Exercise 1

- List names of 3 water pollutants for your city and find out their standards for drinking water and for discharging in surface water.
- Spots: river, lake, nallah, sea
- Man made pollution (domestic, industrial)
- Accidental water pollution (oil spill situation)

# Water Contaminants

- Heavy metals
- Pathogens (not indicator organisms such as fecal coliform and total coliforms)
- Organic compounds (pesticides, antibiotics, endocrine-disrupting chemicals, etc.)
- Nanoparticles

# Water Pollutants

## TYPES:

- **Biological:**
  - Viruses
  - Bacteria
  - Parasites
  - Helminths
  - Bacterial Toxins
- **Chemical:**
  - Inorganic
  - Organic

## EFFECTS:

- **To Humans:**
  - Infections
  - Toxicity
  - Carcinogenesis
- **To Ecosystems:**
  - Oxygen Depletion
  - Environmental Toxicity
  - Accumulation in fish and sediments

*Courtesy: Dr. Irene Xagorarakis, MSU (USA)*



# Pollutants that cause ecological damage

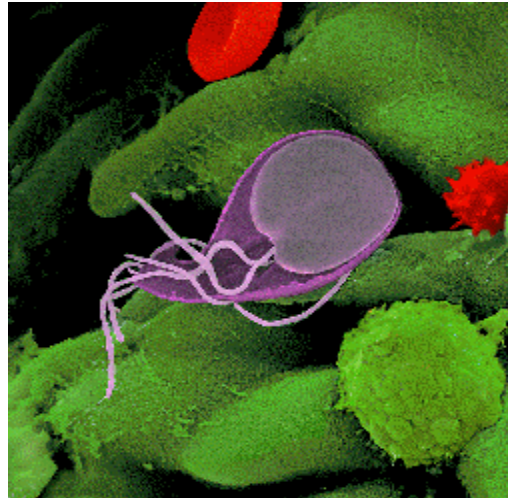
- Oxygen demanding wastes (hypoxia, eutrophication)
- Excess nutrients (hypoxia, eutrophication)
- Salts (fresh water population damaged)
- Suspended solids (settling)
- Toxicants (aquatic toxicity)
- Antibiotics (antibiotic resistance bacteria)
- Pharmaceuticals and personal care products (endocrine disruption)

# Pathogenic Microorganisms in Water

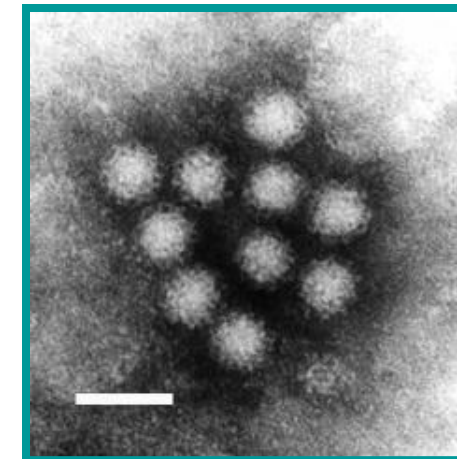
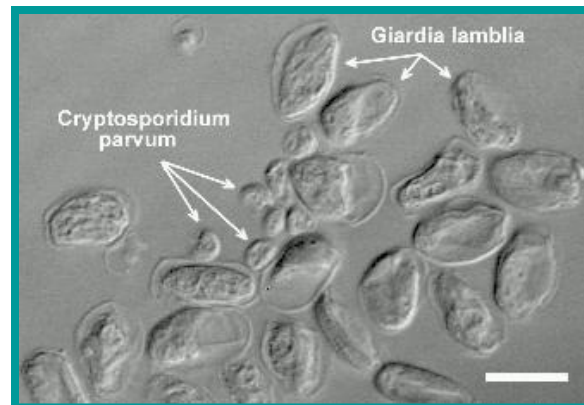
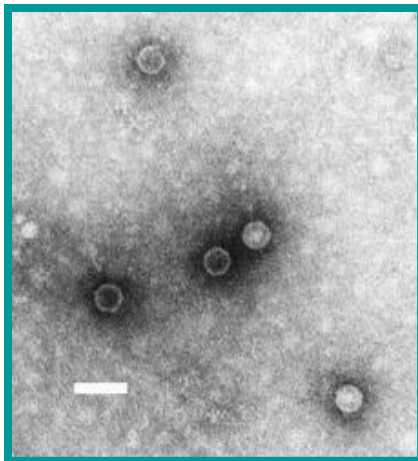
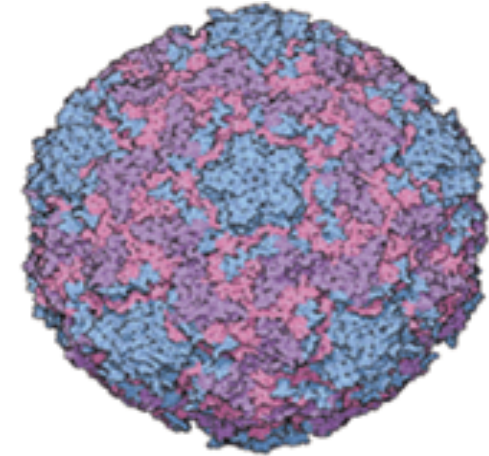
## Bacteria



## Parasites



## Viruses

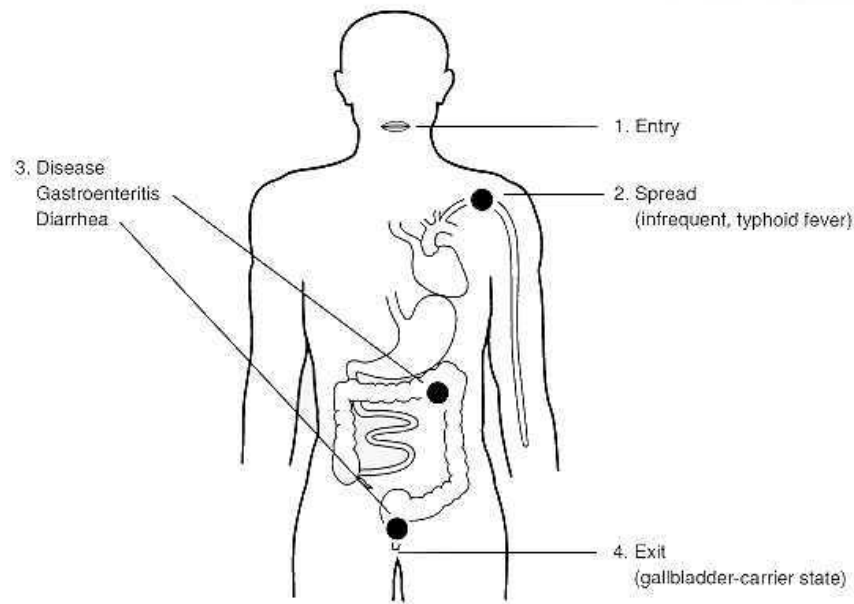


October 21, 2021 Poliovirus

Arun Kumar  
(arunku@civil.iitd.ac.in)

Norwalk virus (norovirus)

# Enteric Pathogens



- Exposure is via ingestion
- Primary site of infection is gastrointestinal tract
- Gastroenteritis symptoms
  - Nausea
  - Vomiting
  - Diarrhea
  - Fever
- May spread to other sites (blood, liver, nervous system)
- Shed in fecal material
- “Fecal-oral” route of transmission

# Pathogenic Microorganisms

## Typical Pathogens Excreted In Human Feces

Pathogen Group and Name	Associated Diseases
<b>Virus</b>	
Adenoviruses	Respiratory, eye infections
Enteroviruses	
Polioviruses	Aseptic meningitis, poliomyelitis
Echoviruses	Aseptic meningitis, diarrhea, respiratory infections
Coxsackie viruses	Aseptic meningitis, herpangina, myocarditis
Hepatitis A virus	Infectious hepatitis
Reoviruses	Not well known
Other viruses	Gastroenteritis, diarrhea
<b>Bacterium</b>	
<i>Salmonella typhi</i>	Typhoid fever
<i>Salmonella paratyphi</i>	Paratyphoid fever
Other salmonellae	Gastroenteritis
<i>Shigella</i> species	Bacillary dysentery
<i>Vibrio cholerae</i>	Cholera
Other vibrios	Diarrhea
<i>Yersinia enterocolitica</i>	Gastroenteritis

# Pathogenic Microorganisms

---

## Protozoan

---

<i>Entamoeba histolytica</i>	Amoebic dysentery
<i>Giardia lamblia</i>	Diarrhea
<i>Cryptosporidium</i> species	Diarrhea

---

## Helminth

---

<i>Ancylostoma duodenale</i> (hookworm)	Hookworm
<i>Ascaris lumbricoides</i> (roundworm)	Ascariasis
<i>Hymenolepis nana</i> (dwarf tapeworm)	Hymenolepiasis
<i>Necator americanus</i> (hookworm)	Hookworm
<i>Strongyloides stercoralis</i> (threadworm)	Strongyloidiasis
<i>Trichuris trichiura</i> (whipworm)	Trichuriasis

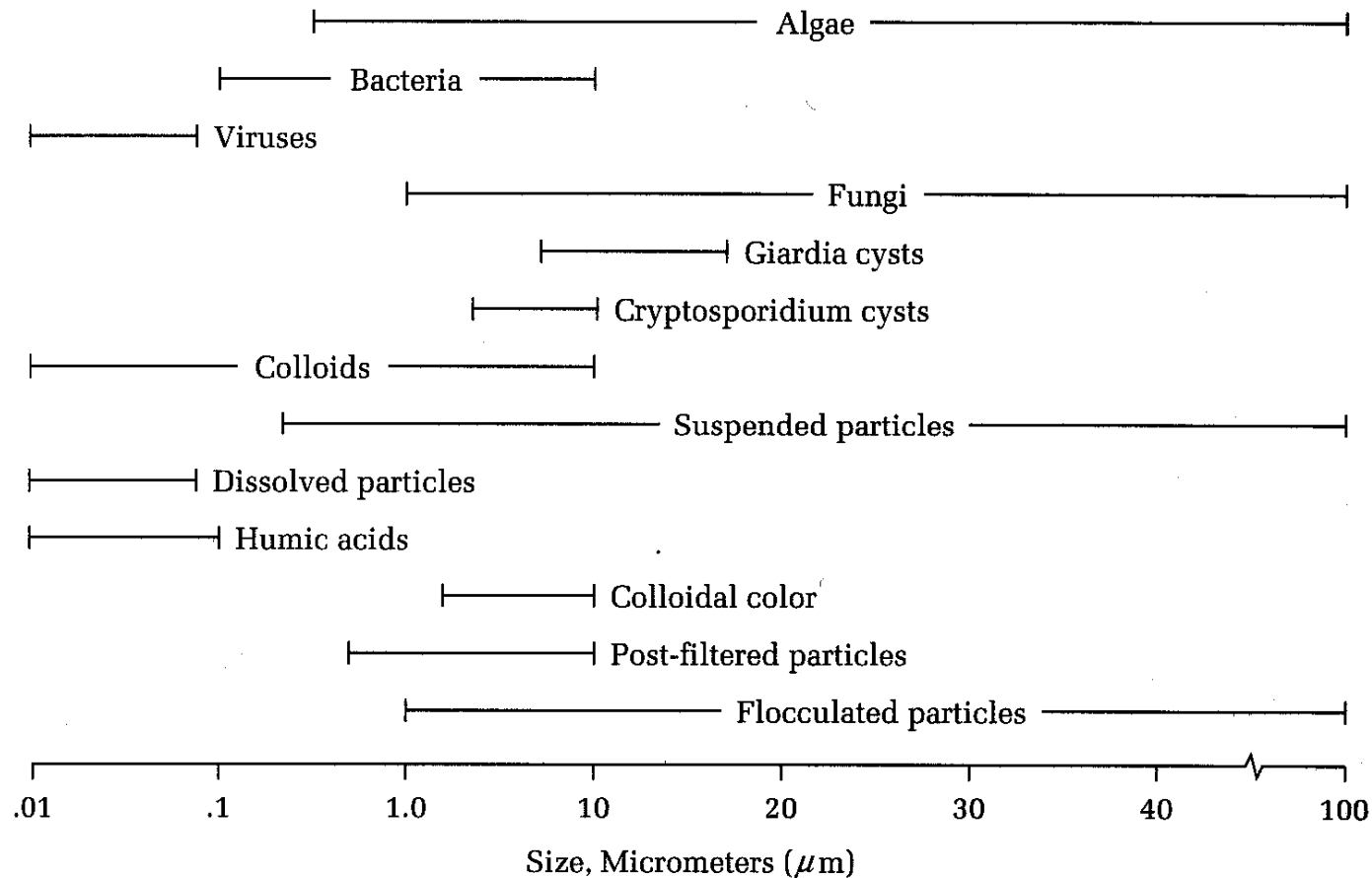
---

Q: Can you list sources which might give you exposure of pathogenic microorganisms?

Source: Hammer and Hammer, 1996.



# Sizes of Microorganisms and Other Particles *(size influences removal through filtration method)*



# Inorganic Pollutants

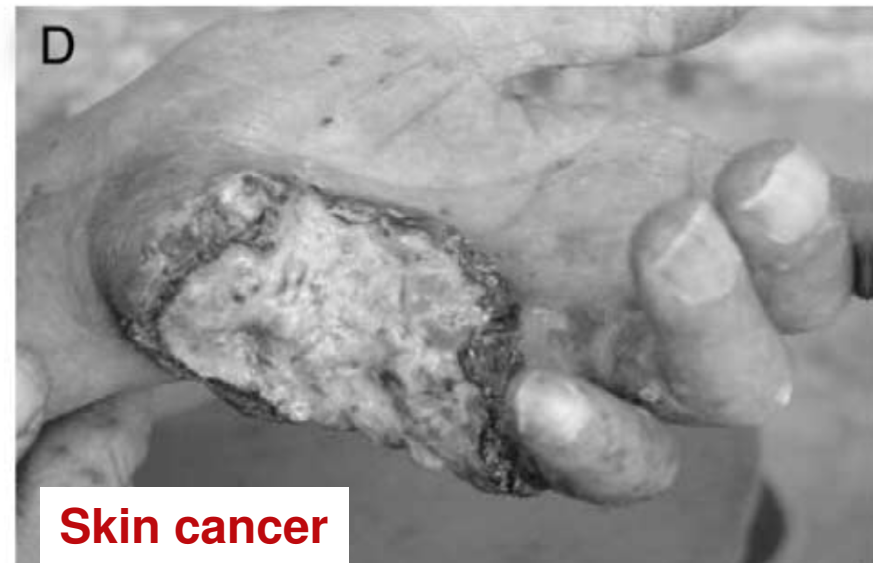
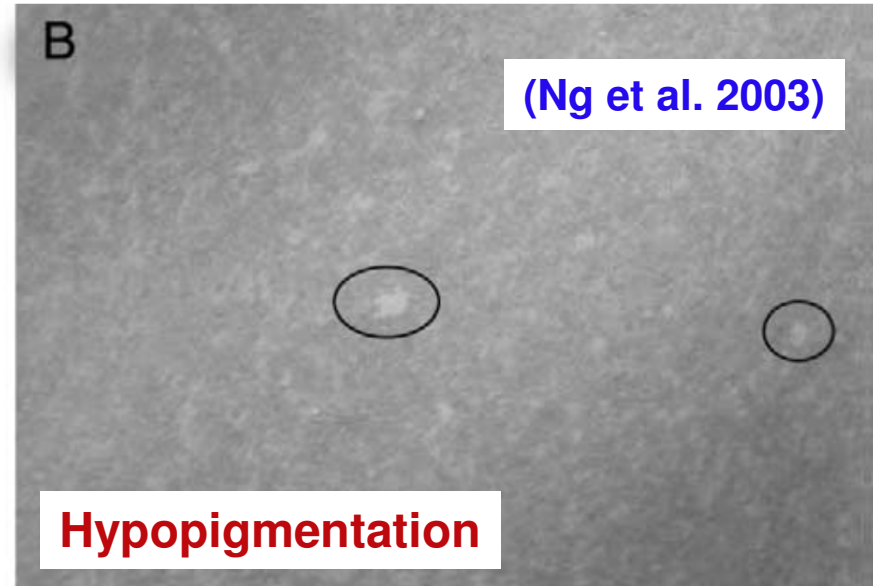
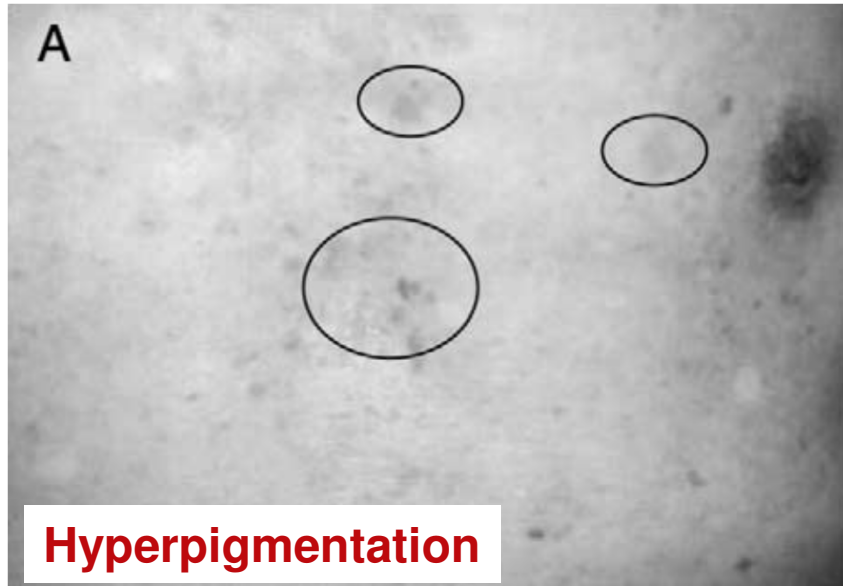
- Heavy Metals
- Arsenic
- Nitrates
- chromium
- Asbestos
- Other?

Effect = f(valency type, concentration)

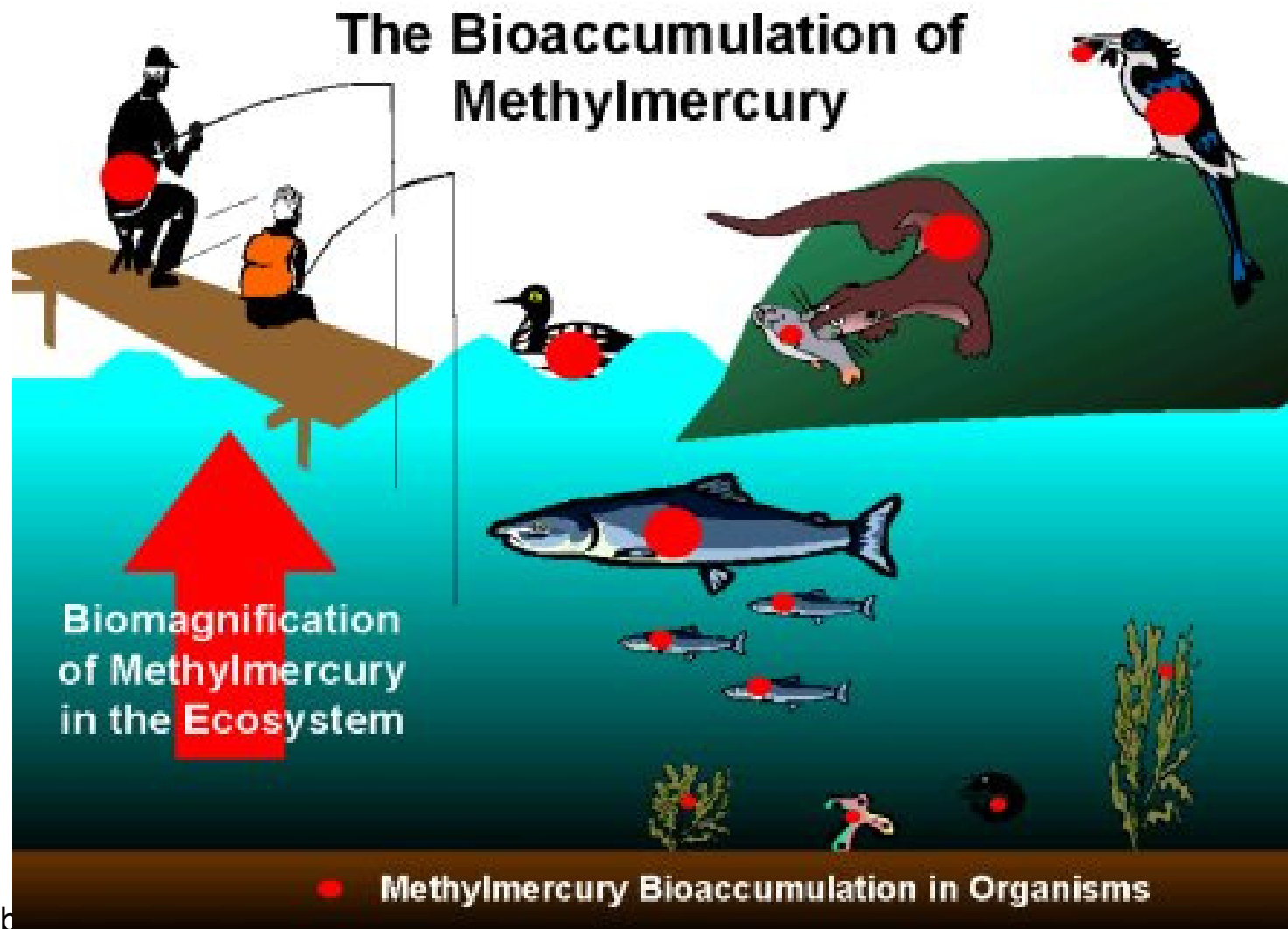
For example: toxic effects of arsenate(AsIV)) and arsenite (As(III)) might be different.

Q: Can you list sources which might give you exposure of these inorganic pollutants?

# Arsenic



# Mercury in water and then exposure to human beings through fish consumption



# Pharmaceutical compounds

<https://www.sciencedirect.com/journal/journal-of-hazardous-materials>

## RESEARCH ARTICLE



### Antibiotics and antibiotic-resistant bacteria in waters associated with a hospital in Ujjain

Vishal Diwan<sup>\*1,2</sup>, Ashok J Tamhankar<sup>3,4</sup>, Rakesh K Khandal<sup>5</sup>, Shanta Sen<sup>5</sup>, Manjeet Aggarwal<sup>6</sup>, Rama V Iyer<sup>6</sup>, Karin Sundblad-Tonderski<sup>7</sup> and Cecilia Stålsby-Lundborg<sup>1</sup>



Contents lists available at ScienceDirect

#### Ecotoxicology and Environmental Safety

journal homepage: [www.elsevier.com/locate/ecoenv](http://www.elsevier.com/locate/ecoenv)



### Mutagenicity and genotoxicity of tannery effluents used for irrigation at Kanpur, India

Mohammad Zubair Alam<sup>a,\*</sup>, Shamim Ahmad<sup>a</sup>



Contents lists available

#### Food and Chemical Toxicology

journal homepage: [www.elsevier.com/locate/foodchemtox](http://www.elsevier.com/locate/foodchemtox)

Available online at [www.sciencedirect.com](http://www.sciencedirect.com)



Journal of Hazardous Materials 148 (2007) 751–755

[www.elsevier.com](http://www.elsevier.com)

Short communication

### Effluent from drug manufactures contains extremely high levels of pharmaceuticals

D.G. Joakim Larsson<sup>a,\*</sup>, Cecilia de Pedro<sup>a</sup>, Nicklas Paxeus<sup>b</sup>



### Sperm motility in the fishes of pesticide exposed and from polluted rivers of Gomti and Ganga of north India

Pratap B. Singh<sup>\*</sup>, Vikash Sahu, Vandana Singh, Santosh K. Nigam, Hement K. Singh

Department of Zoology, Tilak Dhari College, Jaunpur 222002, India

October 21, 2021

23

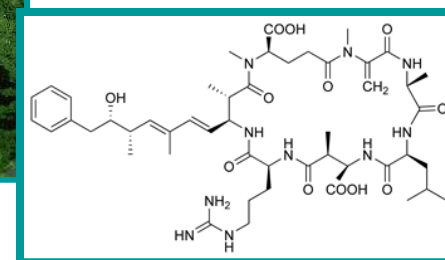


# Pesticides (hydrophobic organic compounds)

- **Organochlorine Insecticides:** were commonly used in the past (e.g. DDT and chlordane).
- **Organophosphate Pesticides:** most are insecticides, some are very poisonous (they were used in World War II as nerve agents)
- **Carbamate Pesticides:** affect the nervous system
- **Pyrethroid Pesticides:** were developed as a synthetic version of the naturally occurring pesticide pyrethrin, which is found in chrysanthemums

# Other Organic Pollutants

- Fertilizers
- Surfactants
- Explosives, propellants
- Chlorination By-Products (e.g. trihalomethanes)
- Antibiotics
- Pharmaceuticals
- Personal care products
- Cyanobacterial toxins
- nanomaterials

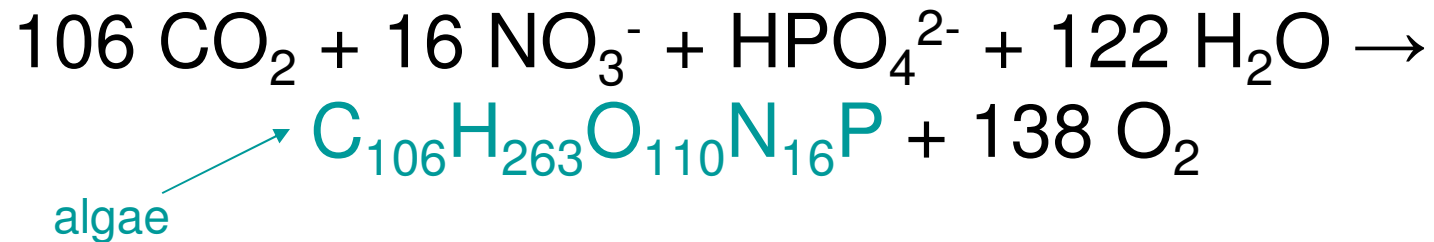


Microcystin-LR  
(hepatotoxin)

# Excess Nutrients

- Nitrogen and phosphorus are nutrients required by all living organisms. They are considered pollutants when they are in excess.
- Excessive nutrients often lead to large growths of algae which in turn become oxygen-demanding material when they die and settle.

## Excess Nutrients



Nitrogen and phosphorus are typically the limiting factors

# Phosphorus

- Phosphorus is typically the limiting nutrient in lakes, and algae growth is linked to phosphorus inputs.
- P Sources
  - fertilizers
  - detergents
  - wastewater
- P can exist in a variety of chemical forms

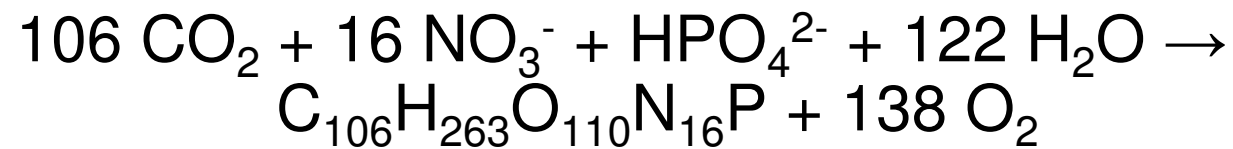


# Nitrogen

- Nitrogen is often the limiting nutrient in ocean waters and some streams
- Nitrogen can exist in numerous forms, but nitrate ( $\text{NO}_3^-$ ), nitrite ( $\text{NO}_2^-$ ), ammonia ( $\text{NH}_3$ ) are most commonly measured
- Sources are primarily from fertilizers and acid deposition

# Factors Controlling Eutrophication

- Stoichiometry of photosynthesis (C,N,P, O & H)



$$\frac{\text{N}}{\text{P}} = \frac{16 \times 14}{1 \times 31} = 7.2$$

It takes ~ 7 times more N than P to produce a given mass of algae

- *Liebig's law of the minimum* – growth will be limited by the availability of the nutrient that is least available relative to the need
- Most fresh water systems are phosphorus limited

# Salts

- Dissolved solids, or salts, may be present as any number of ions
  - cations:  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Ca}^{2+}$
  - anions:  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{HCO}_3^-$
- Typically measures as *total dissolved solids* (TDS)
- Water classification
  - freshwater <1500 mg/L TDS
  - brackish water 1500 – 5000 mg/L
  - saline water >5000 mg/L
  - sea water 30-34 g/L

# Salts

- Sources
  - industrial discharges
  - deicing
  - evaporative losses
  - minerals
  - sea water intrusion
- Effects
  - natural fresh water population threatened
  - limits use for drinking
  - crop damage/soil poisoning (cannot use for irrigation)

# Suspended Solids

- Organic and inorganic particles in water are termed suspended solids
- May be distinguished from colloids, particles that do not settle readily

- Sources

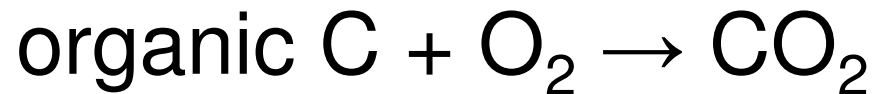
- storm water
- wastes
- erosion

- Problems

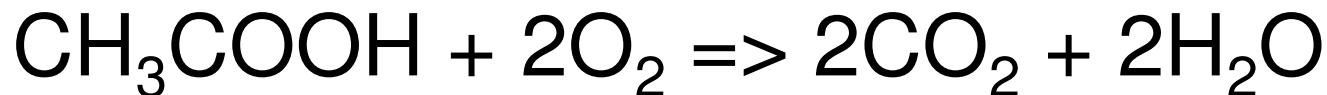
- sedimentation
- may exert oxygen demand
- primary transport mechanism for many metals, organics and pathogens
- aesthetic
- complicates drinking water treatment

# Oxygen-Demanding Wastes

- When organic substances are broken down in water, oxygen is consumed



- For example:



# Oxygen-Demanding Wastes

- High oxygen levels necessary for healthy stream ecology.
- For example:
  - trout require 5-8 mg/L dissolved oxygen (DO)
  - carp require 3 mg/L DO



# Oxygen Demanding Wastes- measurement/estimation

- Estimated stoichiometrically by theoretical oxygen demand (ThOD)
- Measured by oxygen demand potential
  - biochemical oxygen demand (BOD)
  - Nitrogenous oxygen demand (NBOD)
  - chemical oxygen demand (COD)