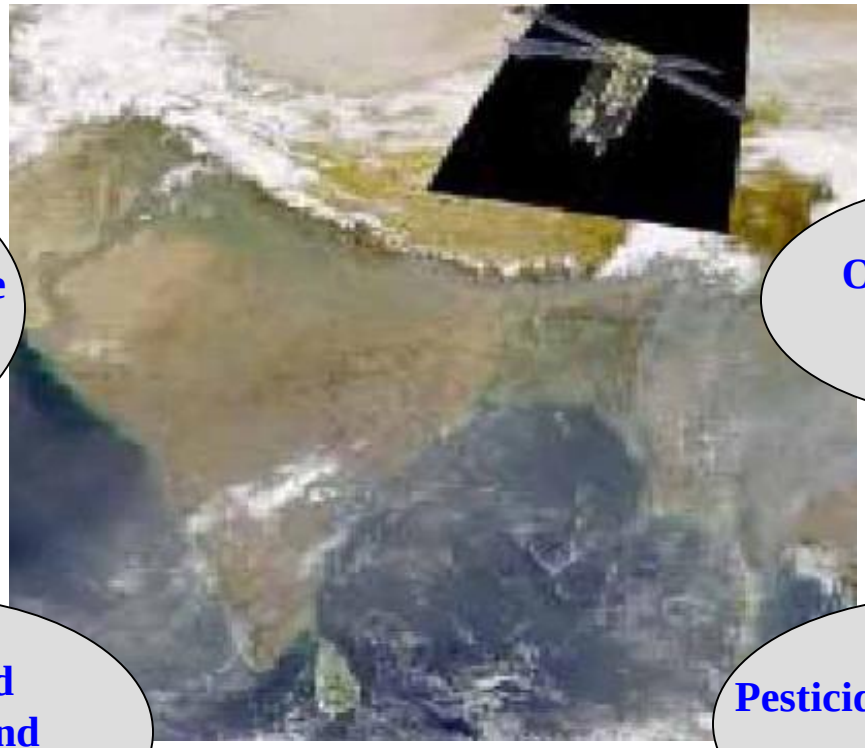
Environmental Chemistry Principles in Site Remediation

Souhail R. Al-Abed

US EPA, NRMRL, Cincinnati, OH

Environmental Challenges for the 21st Century…

Maintaining and Improving Soil, Water, and Air Quality



Emissions of Airborne Gaseous and Particulate Matter

Oil and Chemical Spills

Abandoned Industrial and Mining Sites

Pesticide and Fertilizer Runoff

Environmental Chemistry

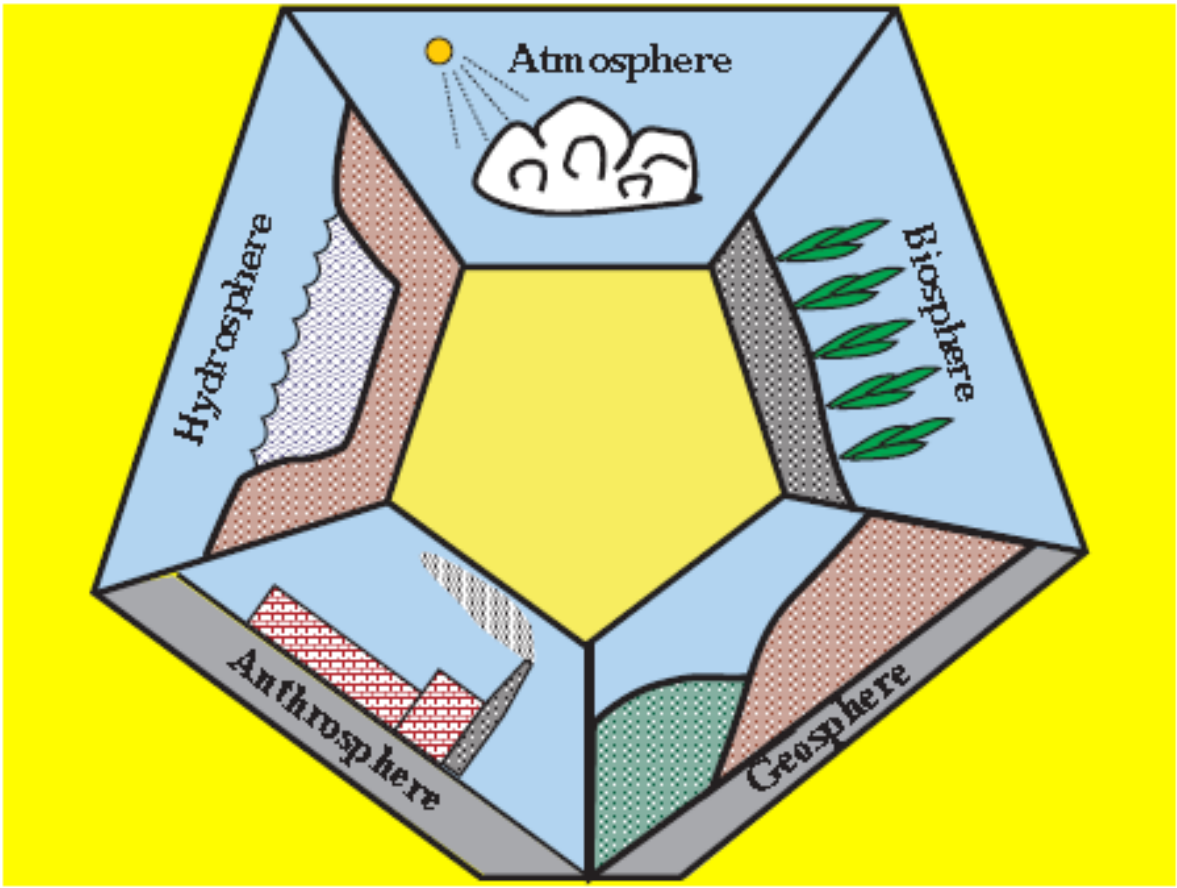
Environmental Chemistry deals with the production, transport, reactions, effects, and fates of chemical species in water, air, terrestrial, and biological system (human and ecosystem).

Environmental chemistry has developed as a positive force for a clean environment:

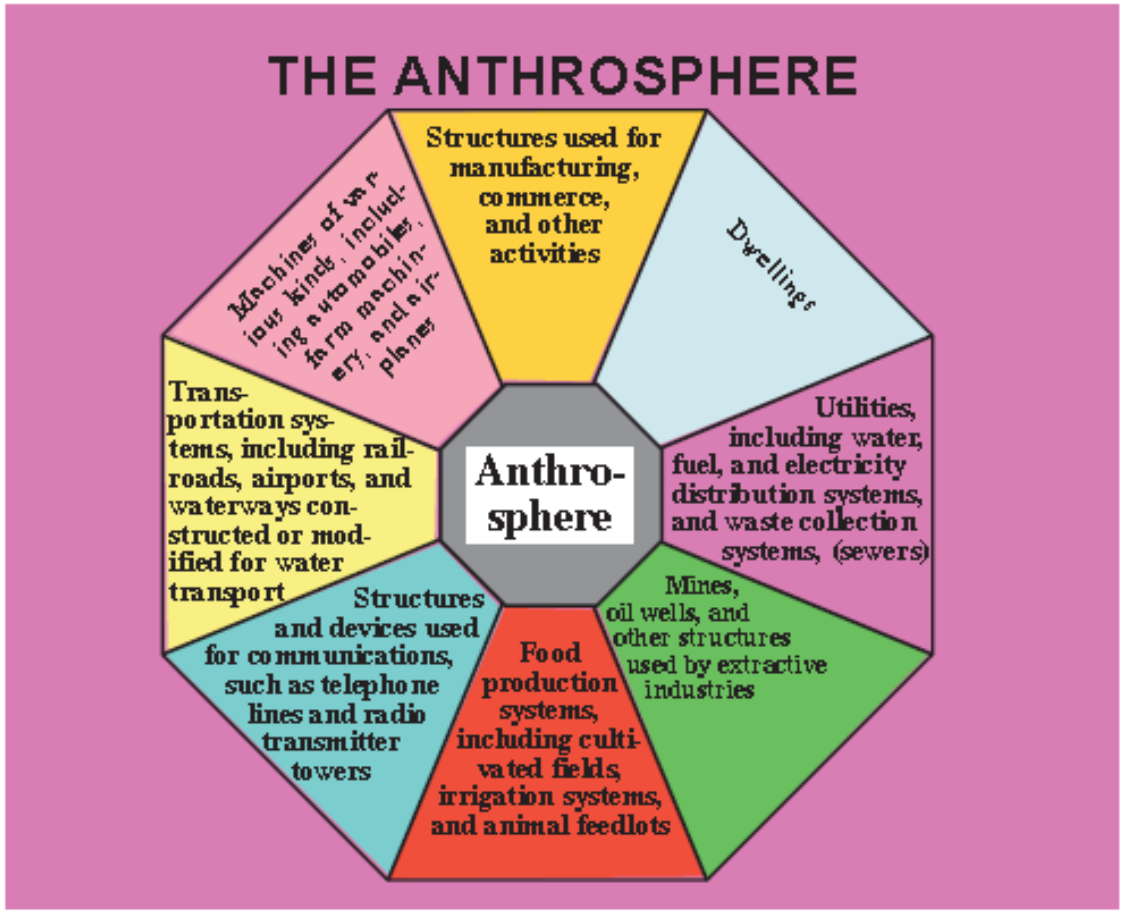
- Revealing the extend of environmental problems
- Measures to control pollution
- Foreseeing environemtal problems before they develop
- Appropriate action to forestall environmental problems
- Support of other disciplines such as industrial ecology and green chemistry employed in environmental improvement

Major categories of Environmental Chemistry

- ***Aquatic Chemistry*** **deals with chemical phenomena in the hydrosphere:**
  - Biochemical processes are particularly important
- ***Atmospheric chemistry*** **deals with chemical processes in the atmosphere:**
  - Many of these are photochemical
- ***Geochemistry*** **and** ***soil chemistry***
- ***Toxicological chemistry*****.**



Stanley E. Manahan, *Fundamentals of Environmental Chemistry, 3rd ed., Taylor & Francis/CRC Press, 2009*

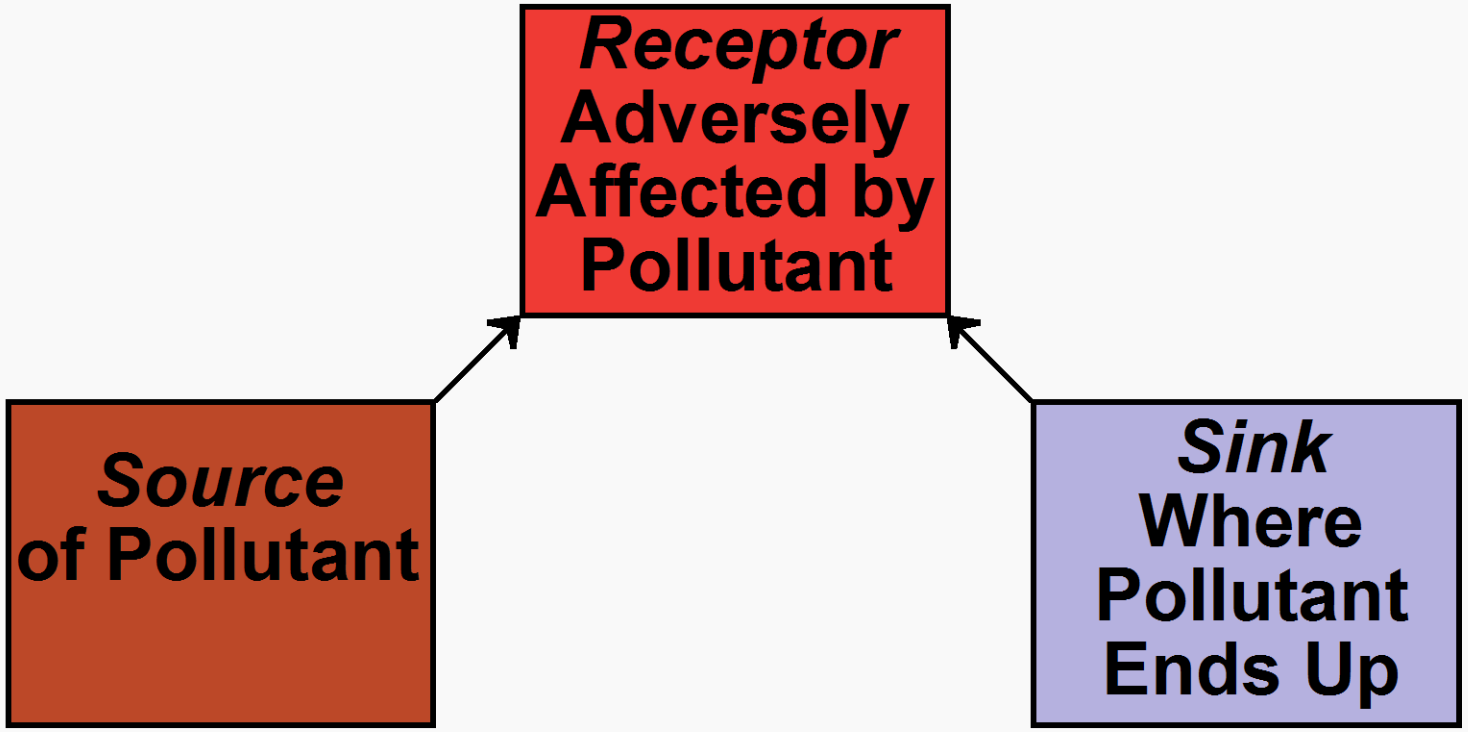


Stanley E. Manahan, *Fundamentals of Environmental Chemistry, 3rd ed., Taylor & Francis/CRC Press, 2009*

Human impacts and contamination

Pollutant: **Substance in greater than natural concentration and detrimental to health or environment;**

Contaminants **cause deviations from normal concentration but are not pollutants unless they have adverse effects.**



Contamination

A hazardous substance is a material that may pose a danger to living organisms, materials, structures, or environment by:

Explosion, Fire hazards, Corrosion, Toxicity, Other detrimental effects

A hazardous waste is a hazardous substance that has been:

Discarded, Abandoned, Neglected, Released, Designated as waste, May interact with other

substances to be hazardous

By around 1900 greatly increased amounts of wastes :

- Spent steel pickling liquor
- Lead battery wastes
- Chromic wastes
- Petroleum refinery wastes
- Radium wastes
- Fluoride wastes from aluminum ore

Metal Contamiantion

- **Trace elements (harmful at a few parts per million or less);**
- **Heavy metals** are among most harmful:
  - Cadmium - highly toxic, chemically very similar to zinc, from mining and industrial wastes (especially metal plating)
  - Mercury- highly toxic, Minimata Bay incident, mobilized by bacterial methylation—$HgCH_3^+$, $Hg(CH_3)_2$
  - Lead - widely used and distributed in past, plumbing (lead pipe, solder) was once a major source, uses (such as in gasoline) have been greatly curtailed.
- **Most are sulfur seekers;**
- **Metalloids may be significant water and sediments pollutants;**
  - Most important is arsenic - from coal combustion, occurs with phosphate minerals, byproduct of copper, gold, lead refining, natural occurrence in some groundwaters, formerly in pesticides: $Pb_3(AsO_4)_2$, Na_3AsO_3, $Cu_3(AsO_3)_2$, Bangladesh tube well poisonings may have affected millions;
  - Selenium and antimony can also be harmful .

Inorganic species (continued)

- **Hydrogen sulfide, H_2S:**
  - From industrial sources, decay of organosulfur compounds, geochemical sources;
  - Foul odor, very detrimental to water and sediments quality, very toxic;
  - Precipitates heavy metals.
- **Nitrite ion, NO_2^-, intermediate in reduction of NO_3^-:**
  - Very toxic, but rare water and sediments pollutant.
- **Sulfite ion, SO_3^{2-} :**
  - Added as O_2 scavenger.
- **Perchlorate ion, ClO_4^- :**
  - Industrial pollutant in some cases;
  - Recognized as a pollutant fairly recently.
- **Asbestos:**
  - Causes cancer when inhaled;
  - Asbestos-like fibers in Lake Superior, Reserve Mining.

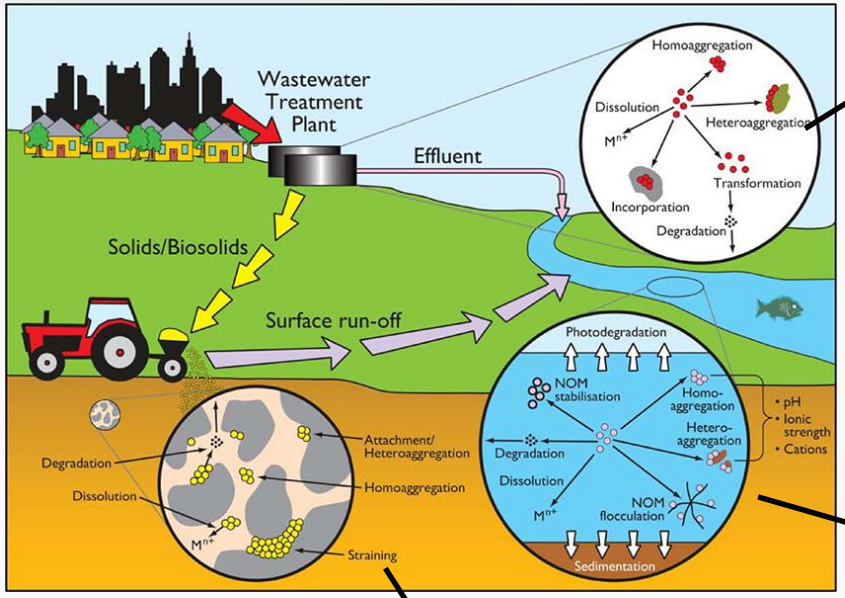
Biorefractory Organic Contaminants

- Poorly biodegradable organics;
- Also called persistent organic pollutants, POP;
- Include prominently chlorinated hydrocarbons;
- Examples are benzene, chloroform, tetrachloroethylene.

Biorefractory compounds are not well removed by conventional biological treatment and may require physical means such as carbon adsorption and other chemical treatment.

Environmental Fate

Source:
- Prioritization
- Characterization
- Release during
  - Production
  - Use
  - Disposal

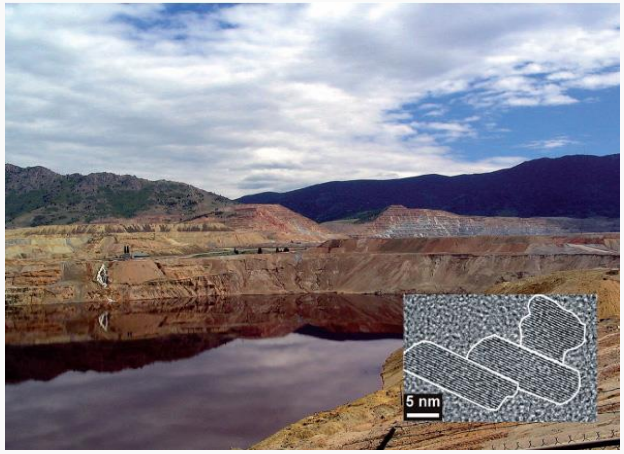


Engineered Systems:
- Transport
- Transformation
- Aggregation
- Dissolution

Aquatic and Sediments:
- Transport
- Transformation
- Aggregation
- Dissolution

Tools:
- Characterization techniques
- Environmental sampling
- Detection in environmental matrices

Soils:
- Transport
- Transformation
- Aggregation
- Dissolution



Batley, G. E., J. K. Kirby, et al. (2012), Accounts of Chemical Research

Summary

- Knowledge of chemical principles is essential in site remediation and reducing human and ecosystem exposure.
- Understanding site chemistry can lead in determining the processes governing proper estimation of fate and degradation of chemicals will help in determining the best treatment, storage, and disposal activities on the site.

THANK YOU!

Questions?