REFRACTORY SUBSTANCES AND HEAVY METALS IN WATER ENVIRONMENT

Presented by
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Presentation outline

- What is a refractory substance
- What are the heavy metals
- Refractory substances and heavy metals
- Important heavy metals in concern to water environment
- Sources of heavy metal in water bodies
- Ecotoxicity of heavy metals
- Bioaccumulation of heavy metals
- Measurement and analysis of heavy metals
- Mitigation and Remediation of heavy metal pollution in water environment
  - How to control heavy metal pollution in water environment

Definition of refractory substances

A substance that able to resist "high temperatures"

"Hard, heat resistant substances such as fire clay, bricks or blocks. The refractory protects a furnace shell from abrasion, heat and oxidation"

Refractory substances in water environment

The organic material that are resistant to biological degradation

Molecules with exceptionally strong bonds (some of the polysaccharides) and ring structures (benzene) can be referred as REFRACTORY

Source: Environmental Engineering by Peavy H, Rowe D.R., Tchobanoglous
Specific substances that are considered as refractory in water environment

- Organics pesticides
- Organics fertilizers
- Organic insecticides (chlorinated hydrocarbons)- e.g.: aldrin, Dieldrin, endrin, lindane
- Herbicides (chlorinated phenoxyx)
- Industrial chemicals eg: HgCl2
- Hydrocarbon compounds that are combined with chlorine
- DDT
- Phenols
- Many of the organics associated with petroleum and its refining and processing (they mostly contain benzene)

Organics becomes non-biodegradable (refractory) when they become toxic to microorganisms

Some refractory substances present in natural water systems

- Tannic
- Lignic acids
- Cellulose

They degrade very slowly

Problems associated with refractory substances

- Some refractory organics are toxic to aquatic life.
- As refractory substances are resistant to biodegradation or degrade very slowly, they persist in the water environment for long time, which may be undesirable for certain water-quality requirements

  - Water bodies highly contaminated with refractory substances like plastic waste, interfere with the gas exchange process between the water body and atmosphere, also reduces light penetration into the and thus may reduces the self purifying ability of the water body.

  - ABS (alkyl benzene sulfonate) from detergents is substantially nondegradable and frequently leads to a persistence of foam in a watercourse and create problems in water treatment processes.

Alkyl Benzene sulfonate (ABS) used in detergent

Causes frothing and foaming in waste water treatment plants and increases turbidity by stabilizing colloidal suspensions

Alternative

Linear Alkyl sulfonate (LAS)

Biodegradable
Measurement of refractory/non biodegradable organic substances

- COD test
- TOC test

Specific organic compounds can be identified and quantified through analysis by Gas chromatography.

Definition of Heavy Metal

The term “Heavy Metal” is often used as a group name for metals and semimetals (metalloids) that have been associated with contamination and potential toxicity or ecotoxicity.

Out of the 105 elements

- 65 are metals
- Trace metals (metals that occur in < 1000 ppm)
- Light metals
- Heavy metals

Below — Density 5 g/cm³ — Above

Source: A Text Book of Environmental Chemistry and Pollution Control, by S.S. Dara

Essential heavy metals

- Cu
- Co
- Mn
- Mo
- Se
- Zn

Essential for healthy growth

Some toxic Heavy metals

- Hg
- Pb
- Cu
- Cd
- Zn
- Ni
- As
- Sb

Cd, Pb and Hg are the major trace elements posing greatest environmental hazards

- Carcinogenic
- Mutagenic
- Teratogenic

Agricultural chemicals like fertilizers, fungicides, pesticides etc are the major source of heavy metals like Cd, Pb and As

Refractory and heavy metals

Most of the refractory substances like pesticides, fertilizers generally contains toxic heavy metals like Cd, Pb and As

Heavy metals that are of major concern for water environment

- Hg
- Pb
- Cd
- Zn
- As
- Cu
- Cr
Ecotoxicity of heavy metals

Toxicity of essential heavy metals
- Under supply leads to deficiency
- Optimum supply helps in healthy growth
- Over supply leads to toxicity and death

Heavy metal ions acts as enzyme inhibitors

Most of the heavy metals involves in binding to the metabolically active groups like….
- Amino-
- Sulphydryl-
- Carboxyl-
- Phosphoryl-

Toxicity of a metal is mainly determined by factors like
- Solubility
- Stability
- Physical form at the site of its action
- Homeostatic mechanism
The target organ affected by heavy metal pollution

<table>
<thead>
<tr>
<th>Heavy metal pollutant</th>
<th>Target organ</th>
</tr>
</thead>
<tbody>
<tr>
<td>(As), Hg, Mo, Se</td>
<td>Liver</td>
</tr>
<tr>
<td>(As), Cd, Hg, Pb</td>
<td>Blood</td>
</tr>
<tr>
<td>(As), Hg, Pb</td>
<td>Brain</td>
</tr>
<tr>
<td>(As), Cd, Hg</td>
<td>Lungs</td>
</tr>
<tr>
<td>(As), Cd, Hg, Pb</td>
<td>Kidney</td>
</tr>
<tr>
<td>Cd, Se</td>
<td>Bones and teeth</td>
</tr>
</tbody>
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Source: A Text Book of Environmental Chemistry and Pollution Control, by S.S. Dara

Some common human health impacts of Heavy metals

- Retardation of growth
- Decrease in longevity
- Neurological disorders
- Physiological illness like Diarrhoea, stomach pain and severe vomiting
- Formation of tumors

Sources of heavy metal in water bodies

- Surface water
  - Industrial effluents: point source
  - Natural weathering process: non point source
  - Runoff from agricultural areas and waste dumping sites: non point source

- Ground water
  - Underground rocks,
  - Seepage from dumping sites

Bioaccumulation of Heavy metals

An increase in the concentration of pollutant in a biological organism over time compared to its natural concentration in the environment

Source: Extension Toxicology Network, 1993
The most important disaster with heavy metal

**Minamata Disease**
In 1953, 52 persons living in fishing villages along the Minamata Bay, Japan died because of eating Shellfish contaminated with Mercury containing effluent from a nearby plastic factory. About 7% of the children born to mothers who ate contaminated fish had neurological problems. Symptoms in these children included uncoordinated movement, abnormal reflexes, seizures and speech problems. Some adults also had neurological problems such as visual disorders, shaking (tremors), weakness, nausea, hearing loss, depression, confusion, loss of appetite and memory problems.

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**Mercury (Hg)**

- Inorganic Mercury \( \text{eg} \ Hg_2Cl_2 \)
- Organic mercurial  
  
  Methyl mercury, Dimethyl mercury  
  
  The biological half life of methyl mercury is about 74 days as compared to 5 days for that of inorganic forms

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**Sources of Mercury in water**

- Chloro alkali industries
- Plastic industries
- Paper and pulp industries
- Pharmaceutical industries
- Fungicides

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**Cadmium (Cd)**

**Sources of Cd in water**

- Sulphide deposits
- Igneous rocks
- Electroplating industry
- Nickel-Cadmium battery industry
- Fertilizers
- Fungicides

Cd in water at 10 ppm level can kill fishes in one day while at 2 ppm they will be killed in 10 days
## Lead (Pb)

### Sources of Pb in water
- Galena (PbS)
- Carbonate ore
- Natural weathering process
- Mining of lead ores

Normal level of Pb in human is very close to the lowest prescribed safety level.

## Chromium (Cr)

### Sources of Cr in water
- Fertilizers
- Effluents from steel industries, paint industries, leather tanning industries etc

Less toxic than Cd, Hg and Pb

Cr (IV) is much more toxic than Cr (III)

## Zinc (Zn)

### Sources of Zn in water
- Sulphide ores
- Silicate minerals
- Steel industries
- Agricultural chemicals

Zn is one of the most essential heavy metal, however toxic effects attributed to Zn may be due to other associating metals like Cd, Pb and As.

Unlike Cd and As effect of Zn is not cumulative.

## Copper (Cu)

### Sources of Cu in water
- Discharge of mine tailings
- Fly as deposits
- Municipal and industrial effluent discharges

Water containing 1 mg/L gives undesirable taste.
Arsenic (As)

Sources of As in water

- Agricultural chemicals such as fertilizers, weedicides, insecticides
- Sulphide deposits
- Underground rocks

As poisoning is mostly occur in ground water

Measurement of Heavy metals in water

ICP
Inductively Coupled Plasma Photometry

AAS
Atomic Absorption Spectrophotometry

Mitigation and Remediation of heavy metal pollution in water environment

As the heavy metals are the natural component of earth crust, it is difficult to prevent entering of a major fraction of heavy metals in the water environment

However proper treatment of industrial effluents can reduce the problem to a great extend

Mitigation and Remediation of heavy metal pollution in water environment

Specific treatment of industrial effluents containing heavy metals like Pb, Cd Hg

- Go for alternatives wherever possible
- Metal recovery, recycling and reuse
- Bioremediation- use of microorganisms capable of consuming heavy metals
Treatment of Heavy Metal Poisoning

Chronic poisoning can be treated by supportive therapy with the use of appropriate metal chelating agents

Eg- Dimercaprol for Mercury poisoning

References

- http://www.mindfully.org/Farm/Toxic-Wastes-Fertilizers.htm
- Environmental Engineering by Beatty H, Rawe D.R., Tchobanoglous
- A Text Book of Environmental Chemistry and Pollution Control, by S.S. Dara
- Extension Toxicology Network, 1993

THANK YOU