River Water Quality

Section **3b**: Anthropogenic Influence on Running water Hydromorphology & Water Quality

Prof. Maria Lazaridou

School of Biology

Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

License

- The educational material subjects to Creative Commons licensing.
- For the educational material, like images, that subjects to other form of licensing, the license is explicitly referred.

Funding

- This educational material has been developed as part of the educational work of the teacher.
- The project "Open Academic Courses at Aristotle University of Thessaloniki" has only fund the remodeling of educational material.
- The project is implemented under the Operational Program "Education and Lifelong Learning" and co-funded by the European Union (European Social Fund) and national resources.

Anthropogenic Influence on Running water Hydromorphology & Water Quality

Types & Sources of Pollution –

Physical Agents & Toxic Pollution

Section Contents

1. Physical Agents
2. Toxic Chemicals
3. Contamination Mechanisms
4. The role of Plankton in Pollutant Fluxes & Transfer

Physical Agents

- Can change the habitat morphology & alter the biota in dramatic ways
- Weathering can brake rocks and erosion carries them away. Water, wind, ice, & waves are the agents of erosion that wear away at the surface of the earth.
- In streams, water is a very powerful erosional agent & erosion happens in 3 different ways:
  - ✓ the hydraulic action of the water itself moves the sediments
  - ✓ water acts to corrode sediments by removing ions & dissolving them
  - ✓ particles in the water strike the bedrock & erode it

Toxic Chemicals

- Short term & long term mortality thresholds of exposure to metallic contaminants for many freshwater creatures are researched (e.g. Crompton 1997)
- Metals have different toxicity, with Hg being the most toxic. Their effect depends on their concentration
- The significance & the effects of different Pollutant Classes are more or less known (e.g. Manahan 1994):
  - ✓ Trace elements affect water biota,
  - ✓ radionuclides are responsible for water toxicity,
  - ✓ inorganic pollutants affect human health & cause alterations in water biota along with eutrophication,
  - ✓ Trace organic pollutants have various biological effects along with aesthetic ones and water toxicity,
  - ✓ chemical carcinogens are responsible for incidences of cancer etc.

Toxic Chemicals cont.

- Substances that are both toxic and persistent are a challenge for management of the enormous loads dispersed in the ecosystems.
- WFD suggests that in order to control & limit pollutants potential impact on ecosystems, their transfer mechanisms & fate must be fully known
- In aquatic ecosystems that have been receiving & conveying industrial pollutants for decades, plankton, due to its high biomass and rapid turnover, makes their potential impact on transfer & fate of contaminants a critical element
- The transfer of xenobiotics in aquatic food webs is a source of human contamination by metals & organ chlorinated compounds through fish consumption & bioaccumulation

Toxic Chemicals cont.

- 3 main classes of potentially hazardous for aquatic environments:
  - ✓ Inorganic ions
  - ✓ Organic pollutants
  - ✓ Organometallic compounds
- These molecules have been shown to be toxic to aquatic organisms (even at low concentrations). Many of them are listed as priority substances
- WFD stipulates that emissions of these substances to the aquatic environment should be progressively stopped
- Amounts already released in the past persist & bioaccumulate.
- Much is the concern for persistently toxic as PCDDs, PCDFs, & PBBs compounds, organochlorinated pesticides & PCBs

Toxic Chemicals cont.

Inorganic Ions

- Most hazardous to aquatic environments are mainly heavy metals: Hg, Cd, Pb, Ni, Zn, Cu, Co & nutrient anions NO_2^-, PO_3^-
- Inorganic anions are natural substances with presence in aquatic ecosystems – deleterious in high concentrations (toxicity and/or eutrophication)
- Their presence in high concentrations derive from human activities (fertilizers, fossil fuels, detergents, mining etc.)

Toxic Chemicals cont.

Organic Pollutants

- Many different types of molecules created by man during the last decades:

✓ Hydrocarbons (non aromatic, ethylene, aromatic & Polycyclic Aromatic Hydrocarbons-PAHs)

✓ Polychlorinated Biphenyls - PCBs (highly degradation-resistant, lipophilic, great accumulation potential)

- ➢ *PCBs can be considered as model molecules for all persistent, lipophilic organic pollutants*

✓ Polychlorinated Dibenzodioxins - PCDDs (dioxins, toxic to mammals, stable & lipophilic)

✓ Polychlorinated Dibenzofurans - PCDFs (similar to PCDD)

✓ Polybrominated Biphenyls - PBBs (fire retardants unreactive, stable, lipophilic)

✓ OrganChlorinated Insecticides (DDT, Lindane, Dieldrin etc. banned since 1990)

Toxic Chemicals cont.

Organic Pollutants

- ✓ Organ Phosphorus insecticides – OPs (more polar & less resistant to degradation than organ chlorinated insecticides)
- ✓ Pyrethroid insecticides (biodegradable esters that can bind to suspended particles & sediment & become persistent)
- ✓ Phenoxy herbicides (plant growth regulators that disrupt growth of unwanted dicotyledonous, environmentally hazard- phytotoxicity)
- ✓ Anticoagulant rodenticides (warfarin-compensate for the resistance observed in rodents, persistent in vertebrates liver)
- ✓ Detergents (for cleaning or in pesticides – priority substance because they degrade in endocrine disruptors)
- ✓ Poly-Chlorinated Phenols – PCPs (wood preservatives & paper mills effluents, tendency to form PCDDs-dioxins)
- ✓ Organ metallic compounds (metallic ions bound to organic ligands, used as pesticides or antifouling agents on boats – toxic to biota)

Contamination Mechanisms

- In the environment there exist a number of synthetic pollutants that are absorbed through diffusion on the surface of particles & matrixes
- Phytoplankton & Bacteria uptake pollutants dissolved in the water column directly **&** indirectly by xenobiotics absorption onto the surface of organisms and then through diffusion
- In phytoplankton organisms, equilibrium between pollutants concentrations in the water column and the organisms is reached within hours or days
- There can be no contamination if growth is too intensive, the xenobiotic is hydrophobic or the species cell wall hinder the absorption & lipid composition is low (Stange & Swackhamer 1994, Skoglund et al. 1996)
- Bio concentration factors are linked to hydrophobicity of the substance expressed as linear relationship – log K_{OW} (coefficient between octanol & water) & log BCF (bio concentration factor, when log K_{OW} <6)

Contamination Mechanisms cont.

Bacteria:

- their surface to volume ratio is so high that uptake mainly consists in surface adsorption rather than through absorption into inner cell compartments
- Is almost instantaneous for lipophilic toxicants (like PCBs) (Del Vento & Dachs 2002)

Zooplankton:

- Uptake of pollutants dissolved in the water column
- Indirect or trophic pathway when they ingest contaminated food
- Lipophilic pollutants taken up directly from the water column get accumulated into the lipids of their tissues
- Not certain the contaminant accumulation through ingestion of contaminated food as in vertebrates

Contamination Mechanisms cont.

In rivers

- Rotifers & Cladocerans (especially small) display high grazing activity on phytoplankton => there could be a link between pollutants accumulated in phytoplankton & higher trophic levels
- Similar contamination kinetics occur by both the direct & trophic pathways
- Particularly, at environmental PCB concentrations, both phenomena occur. Accumulation of PCBs in plankton is a fast phenomenon with no seasonal variation
- Contamination is lower when blooms occur due to pollutants dilution in increased biomass & lower lipid content of plankton. In oligotrophic systems, heavy metal & pollutant accumulation in fish can be larger

Contamination Mechanisms cont.

Bio-magnification or bio-amplification

- Accumulation of pollutants in plankton can impact aquatic ecosystems through the contamination of higher trophic levels
- Zooplankton is contaminated at same or lower level than their food
- Biomagnification can occur with xenobiotics with a high affinity for lipids
- Higher contamination levels can be reflecting the higher lipid content of the animals (invertebrates or vertebrates)
- The efflux rate of metals can be very high depending on the uptake pathway

The role of Plankton in Pollutant Fluxes & Transfer

- Major impact of plankton on toxic pollution in freshwater ecosystems concerns fluxes of persistent pollutants
- Freshwater systems are exposed to pollutants used in the continents
- The sediment acts as a storage compartment where contaminants are fixed for a certain period of time depending on their degradation rates and the type of water body
- Bacterioplankton & phytoplankton, have been shown to play a significant role in the decontamination of the PCBs accumulated in sediments of the river
- Their high number & high surface to volume ratio makes them a considerable bio surface where PCBs adsorb & accumulate

The role of Plankton in Pollutant Fluxes & Transfer cont.

- 36% to 64% of the PCBs accumulated by plankton will be transported downstream of the river. The rest remains and recirculate with the ingestion of contaminated algae & then returns (altered or intact) to the water column.
- When bacteria consume POC/DOC, as they are already saturated with PCBs accumulated by adsorption & absorption from the water column, PCBs bound to the consumed POC/DOC will not follow the carbon flux & will return to water column.
- PCB fluxes transition through plankton at the ecosystem level are important
- Contamination levels in sediments have indeed decreased over the last decades:
  - ✓ Prediction that maximum inputs from the river basin & atmospheric deposition are lower than PCB uptake by plankton=> plankton “pumps” the transportation