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River Water Quality

Section **5**: River Restoration & Self-purification

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Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο
ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
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ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
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Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

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Section Goals

- To show the student what is self purification, under which circumstances it is happening and how in the opposite case restoration may reestablish the healthiness of a system

Section Outcomes

- The student should have considered what a river self purification concerns and how we can restore the hydromorphological characteristics of rivers & streams

Section Contents

1. River Self – Purification
2. River Restoration
3. River Rehabilitation

River Self – Purification

- Rivers & streams receive in their course the anthropogenic influence – pollutants
- Pollution can reduce species diversity & biomass, favoring tolerant species imposing a sterile uniformity
- ALL STREAMS have the capacity to purify themselves! In natural habitats Self-Purification results in substantial decrease of contaminants concentration (unless the waste quantities are too high)
- Does not require any chemical additions & acts fast due to the flowing nature of water
- Geomorphological & hydrological characteristics, physical – chemical & biological interconnected processes affect the purification procedure

River Self – Purification

Geomorphology influences:

- ✓ The hydrodynamic characteristics of the stream
- ✓ Diversity of substrates and consequently biological traits
- ✓ Ground water characteristics
- ✓ Water infiltration and surface runoff

Physical processes that take place are:

- ✓ Solution & dilution of pollutants
- ✓ Export of pollutants to the adjacent land areas (water bodies)
- ✓ Sorption of pollutants onto suspended particles & sedimentation
- ✓ Sorption of pollutants by sediments
- ✓ Evaporation of pollutants
- ✓ Flotation (way of removing pollutants from water body by air bubbles from air dissolved in water & air captured by water)

River Self – Purification

Main chemical processes that take place:

- ✓ Hydrolysis of pollutants
- ✓ Chemical oxidation of pollutants
- ✓ Photochemical transformations
- ✓ Redox-catalytic transformations
- ✓ Transformations including free radicals
- ✓ Binding of pollutants by dissolved organic matter, which may lead to decreasing toxicity

River Self – Purification

Main biological processes that take place:

- ✓ Sorption, uptake & accumulation of pollutants by organisms
- ✓ Biotransformations & mineralization of organic matter
- ✓ Transformation of pollutants by extracellular enzymes
- ✓ Removal pollutants from water column in the processes of water filtering by filter-feeders
- ✓ Sorption of pollutants by pellets excreted by aquatic organisms
- ✓ Uptake of nutrients
- ✓ Biotransformation & sorption of pollutants in soil (removal of nutrients)
- ✓ Network of regulatory processes when certain organisms control or influence other organisms involved in water purification

River Self – Purification

Zonation

A stream receiving excessive amount of sewage exhibits changes, which can be classified into zones:

- ✓ Clean zone – upstream before a point of pollution discharge
- ✓ Zone of recent pollution – the point of discharge when the water has increased turbidity
- ✓ Septic zone – shortly below the discharge point where D.O. decreases sharply (≈0)
- ✓ Recovery zone – where is no further pollution input & self-purification processes are active
- ✓ Clean zone – pollution is discernible but water is clean

- Saprobity = The amount of organic matter and the activity by microbial communities living on it
- Waters are said to have a saprobic level which is calculated by a biotic index of organic pollution

River Self – Purification

Organic matter

Organic Carbon forms in waters: Dissolved organic carbon (DOC), Dead particulate organic carbon (POC) & Living POC (small portion but important for C fluxes)

Detritus: Dead organic matter from any trophic levees - carries most of the energy

The organic matter degradation involves a succession of events:

i. Various invertebrate, vertebrate taxa & erosion effects grind & tear to shreds the organic matter in small particles

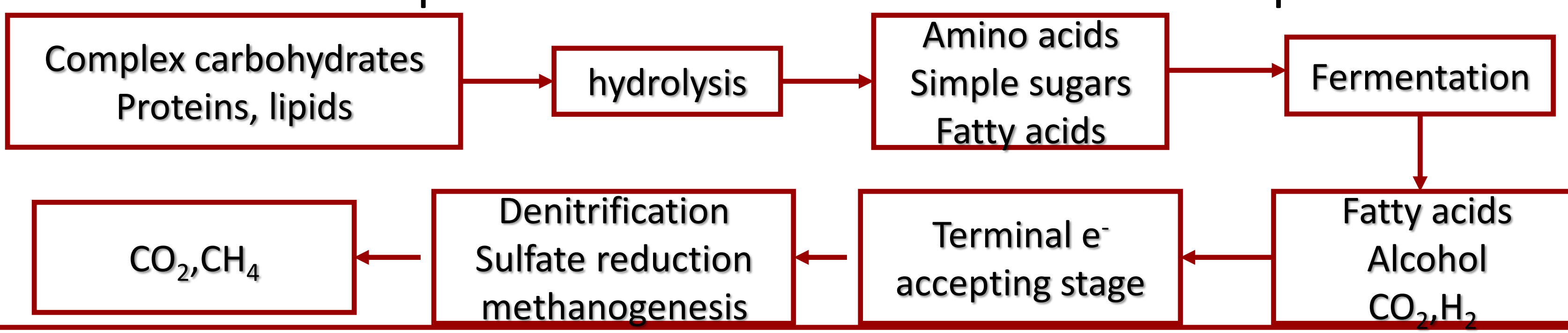
ii. The microorganisms (fungus or bacteria) attack the small particles up to the final decomposition to mineral matter

iii. A chemical degradation by abiotic oxidation or photo-oxidation of the organic matter may also take place (Namour 1999)

River Self – Purification

Organic matter

- Most of detrital metabolism takes place in benthic region. The organic matter must be immobilized on the river bottom (in accordance with sediment permeability). Metabolism is microbial, heterotrophic & anaerobic.
- Benthic organisms are mainly involved in organic matter degradation. The water column is not a major site of self-purification (suspended bacteria correspond to a very small percentage)
- Anaerobic decomposition in sediments include decomposition of:



River Self – Purification

Organic matter

- The abiotic adsorption delays the degradation of the organic matter inside the sediment
- Sediment conserves the soluble organic matter & transforms it , but into organic particles, available for invertebrates consumption
- There are 4 different kinds of filtration in a river (Namour 1999) that act together: mechanical, physical, chemical & biochemical, which influence differently the self-purification process
  - Sediment constitutes a temporary reservoir of soluble organic matter. Accumulates soluble & thin organic matter when contributions are significant & provides the aquatic biocenose when contributions are minor (Namour 1999)

River Self – Purification

Inorganic Carbon

- Most of the carbon is found in equilibrium products of carbonic acid (H_2CO_3) : HCO_3^-, CO_3^{2-}
- Hydrogen cations H^+ are neutralized by OH^-
- The pH remains essentially the same as before, unless the supply of HCO_3^- & CO_3^{2-} is exhausted

River Self – Purification

Nitrogen

- Found as: N_2, NH_4^+, NO_2^- , NO_3^- & organic compounds
- Losses of nitrogen could be due to outflow from the basin, reduction of nitrates (to N_2) by bacterial denitrification & sedimentation of inorganic and organic compounds
- Nitrate assimilation & amination happens into organic nitrogenous compounds within organisms (algae & macrophytes)

✓ *Bacterial nitrification:* oxidation of NH_4^+ to NO_2^- (e.g. Nitrosomonas & methane-oxidizing bacteria) & oxidation of NO_2^- to NO_3^- (Nitrobacter)

✓ *Bacterial denitrification:* biochemical reduction of oxidized N^- (NO_3^- > NO_2^- > N_2O > N_2), simultaneously with organic matter oxidation (e.g. Pseudomonas, Achromobacter). Occurs in anaerobic environment

River Self – Purification

Phosphorus

- Organophosphates (PO_4^{3-}) is the only directly utilizable form of soluble inorganic P
- P- Losses can occur by: interactions with cations (Fe, Ca), sedimentation due to adsorption by inorganic colloids & particulate compounds, & precipitation out of water.
- Bacterial metabolism is the primary mechanism of organic P converting to phosphate in sediments.
- Remobilizing P from sediments depends on physical turbulence & biota (e.g. angiosperms, Pseudomonas, Bacterium)
- Rapid increase of algal productivity is the response of P addition in waters

River Self – Purification

Sulfur

- 2 main form depending on oxygenation: Sulfate (oxic waters) & Hydrogen sulfide (H_2S) (anoxic waters)
- Sulfate reduction: anaerobic bacteria can reduce sulfate (SO_4^{2-}), sulfite (SO_3^{2-}), thiosulfate ($S_2O_3^{2-}$), hyposufite & sulfur (S) to H_2S
- Sulfur oxidization:

✓ colorless chemosynthetic aerobic bacteria oxidize reduced S compounds & elementar S to sulfate intra- & inter- cellular (e.g. Thiothrix,& Thiobacillus respectively)

✓ colored photosynthetic anaerobic bacteria use S compounds as electron donors in photosynthetic reduction of CO2. Such are the green thiobacteria (Thiorhodaceae) & purple non thiobacteria (Athiorhodaceae)

River Self – Purification

Silica

- Occurs mostly as dissolved silica acid or particulate Si, assimilated mostly by diatom algae (Bacillariophyceae), some macrophytes (Equisetum) & silicone sponges

Essential micronutrients

- Availability of micronutrients (Fe, Mn, Zn, Cu, Co, Mo, V, Se) is governed by redox conditions & the extent of complexing with dissolved organic compounds & other inorganic ions. Inputs of many trace elements are higher as a result of pollution.

River Self – Purification

Oxygen:

- Water flow aids the water oxygenation & generates a partial suspension input for the benthic colonies. Necessary for aerobic degradation

Temperature:

- Affects positively the speed of biological reactions but negatively the D.O. concentration. Extreme values of temperature may influence the degradation capacity

River Restoration

"Return of a river at reference conditions" – Utopia ?

" Return of a river or basin in conditions that mitigate the human pressure and help the natural variability" – Feasible?

- **Restoration** is defined as the collective efforts for returning *ecosystems to their* original, unimpaired condition (Bradshaw 1996, Roni 2005). This could be done using **active** & **passive** measures:
  - ✓ Active restoration includes direct structural measures to obtain the original ecological functional capability
  - ✓ Passive restoration excludes all anthropogenic activities responsible for degradation

River Restoration

- "Does not create a single, stable state, but enables the system to express a range of conditions dictated by the biological & physical characteristics of the watershed & its natural disturbance regime" (Frissell and Ralph 1998)
- 2 main targets for restoration:

i. The functionality of habitats

ii. The river connectivity

- Requirements: River basin approach, Accepting that recovery can be achieved artificially due to the river modification, Acknowledging the time consuming nature of maintaining the functionality of habitats

River Restoration

- Should be focused on the river's natural assets:
  - ✓ These can be identified by comparing the stream under management with another of high quality
  - ✓ These stream elements should be similar to the one with high-quality, or else should be restored
  - ✓ Can be artificially made
  - ✓ Can be rated in importance value (eg high, medium, low)
  - ✓ May be considered to be 'safe' or 'under threat'

- Series of actions to be done before:

i. Problem identification (erosion, problematic flow, riparian vegetation etc.)
ii. Goals setting (bank stabilization, flow modification, vegetation removal etc.)
iii. Priorities setting (can follow principles described in literature, e.g. Rutherfurd et al. 2000) (connectivity, water quality, sediment transport, habitat reconstruction)
iv. Selecting target species to measure restoration process

River Rehabilitation

Rehabilitation:

- improves important aspects of an ecosystem, but does not return it to an original condition (Bradshaw 1996)
- recreates essential key processes and elements and improves the degraded condition of a habitat. The objective of the measure is not to remedy the symptoms of an impaired system (e.g. reduced fish density), but to eliminate their causes (e.g. reduced habitat diversity, reduced connectivity)

- The main difference between Restoration & Rehabilitation is their target: the first tends to return the ecosystem to their original condition, whilst the second tends to fix aspects & guide the ecosystem closer to the original condition
- Remediation recognizes the stream has changed so much that the original condition is no longer relevant & aims for an entirely new condition (Rutherfurd *et al.* 1999)

References

Bradshaw, A.D. 1996: Underlying principles of restoration. Can. J. Fish. Aquat. Sci. 53 (Suppl. 1), pp. 3–9

Cowx, I.G. & Welcomme, R. L. 1998: Rehabilitation of rivers for fish. Fishing News Books 260 p.

De Waal, L.C., A.R.G. Large & P.M. Wade, 2000. Rehabilitation of rivers. Principles and implementation. John Wiley & Sons 331p

Edward, T.R., Meyer, J.L., Findlay, S.E.G. 1990: The relative contribution of benthic and suspended bacteria to system biomass, production and metabolism in a low-gradient blackwater river. *Journal of the North American Benthological Society,* 9, pp.216-228.

Fiebig, D.M. & Marxsen, J. 1992: Immobilization and mineralization of dissolved free amino acids by streambed biofilms. *Freshwater Biology*, 28, pp.129-140.

Fontvieille, D. & Cazelles, B. 1990: Changes in biologically controlled carbon fluxes in a small stream following continuous supply of excess organic load. *Hydrobiologia,* 192, pp.123-141.

Namour, P. 1999: Auto-épuration des rejets organiques domestiques. Nature de la matière organique résiduaire et son effet en rivière. *Thesis,* University of Lyon*,* 161 p.

Ostroumov, S.A., 2002: System of principles for protecting the biogeocenotic function and biodiversity of filter-feeders, Doklady Akademii Nauk, 383 (5), pp. 710-713.

Reynoldson, T.B. 1982: A preliminary model for predicting instream impacts from municipal sewage in wastes and Prairie water quality. *Water Studies institute Symposium,* 8, Saskatoon, Saskatchewan.

Ruthefurd, I.D., Jerie, K., Marsh, N. 2000: A Rehabilitation Manual for Australian Streams. Vol.1 Cooperative Research Centre for Catchment Hydrology, Land and Water Resources Research and Development Corporation (pubs). pp 109, 110

Spellman, F.R. 1996: Stream Ecology and Self-purification. An Introduction for wastewater and water specialists.Technomic Publishing Co. NC, Lancaster.

Wuhrmann, K. 1972: Stream purification. *Water pollution microbiology.* Under the guidance of Mitchell R., Wiley Interscience, New York, pp.119-151.

End of Section 5

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