Complex microbial bioremediation of hypereutrophic aquatic environments (COBIOMIC)

Prof. dr hab. Ryszard J. Chróst
Biorem Ekoserwis: Bioremediacja i Monitoring Zbiorników Wodnych

Hypereutrophication

- High concentrations of nutrients (P, N) and organic matter in water column
  - Phosphorus key eutrophication factor in majority of freshwaters
  - Detritus which 50-70% decomposition releases inorganic nutrients and easy utilizable organic substrates into a water column
- Phytoplankton blooms
  - Frequent predomination of cyanobacteria
  - Often production of cyanotoxins
- Deposition of nutrients and organic matter in bottom sediments
  - Anoxic conditions
    - phosphorus release from sediments to water column („internal loading”)
    - H_2S, CH_4, ammonia, and other volatile odor compounds (some very toxic)
  - Aerobic conditions
    - Rapid organic matter mineralization and nutrients release (acceleration of “short circuit metabolism” of planktonic microorganisms)
    - Fast decomposition and production rates of phytoplankton biomass

Visual consequences of hypereutrophication

Toxic cyanobacteria bloom: *Planktothrix agardhii, Aphanizomenon gracile, Aphanizomenon flos-aque, Anabaena planctonica, Microcystis aeruginosa*
(Lake Suskie, August 2014)

How can we control hypereutrophication?

To stop hypereutrophication of aquatic environment must:

- Control and decrease of nutrients influx from a watershed
  - Reduce amount of water usage for human, agriculture, industry, etc. activity (i.e., decrease of wastewater production)
  - Reduce amount and nutrient load in wastewater discharge
  - Reduce amount of fertilizers in agriculture
  - Construct biological barriers in close vicinity of lake
  - Liquidate dispersed points of pollution
- Decrease amount of phosphorus and organic matter in water and sediments
  - Precipitate inorganic orthophosphates and deposit them in insoluble forms in bottom sediments
  - Increase oxygenation of water column and bottom sediments to accelerate transformation and mineralization rates of organic matter

Phosphorus inactivation

Chemical precipitation of phosphorus by means of coagulants (most common)

- Fe^{+3} ($Fe2(SO_4)_3$, $FEClSO_4$, $FeCl_{3)}$ – **PIX**

- Al^{+3} (polyaluminum chloride) – **PAX**

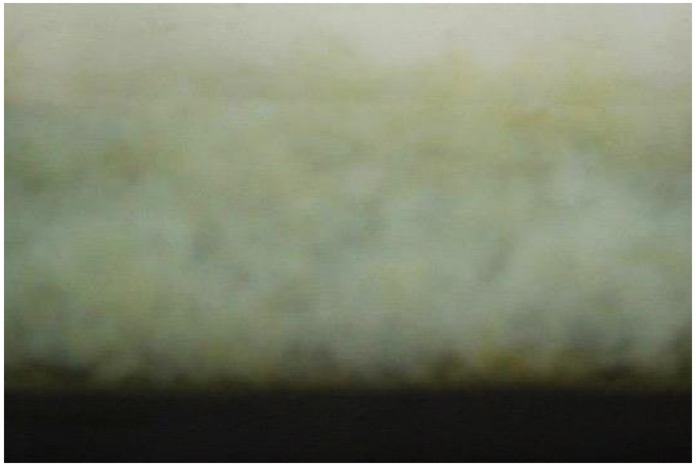


Photo courtesy of prof. R. Wiśniewski
Dept. Applied Limnology, Torun Univ.

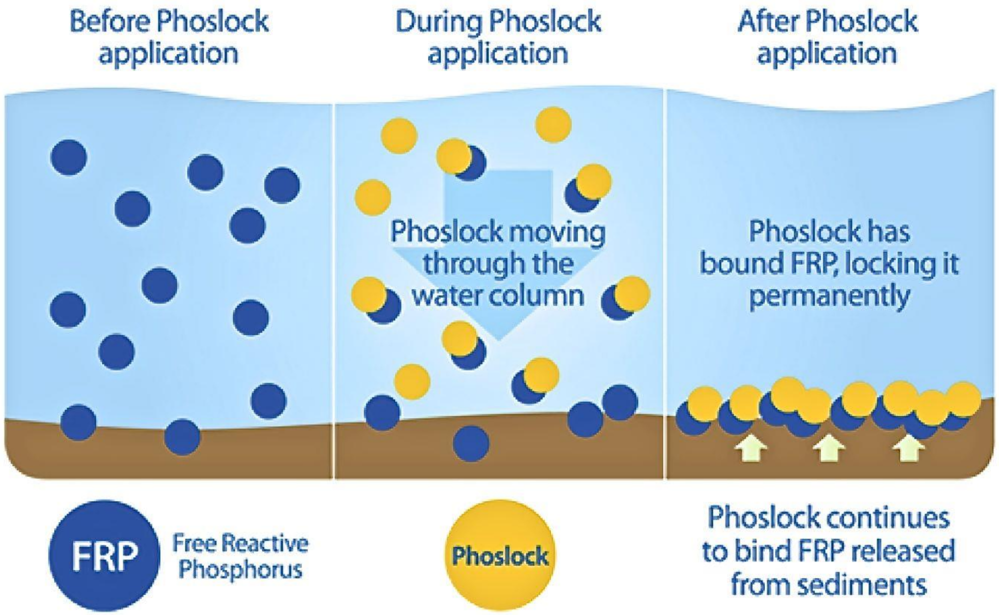
Phosphorus inactivation

Chemical precipitation of phosphorus by PIX and PAX

- P-precipitates are insoluble only under aerobic conditions
- **P-precipitates under anaerobic conditions release P**
- **PAX is toxic for aquatic biota**
- PIX and PAX precipitates form colloidal layer at surface of bottom sediments negatively affecting metabolism of benthic organisms and bottom bacteria (inhibit metabolic activity)

Phosphorus inactivation

Phoslock is the best fixative for P in water and sediments



$(La,Ce)PO_4 \bullet (H_2O)$

Rhabdophane-La complexes of P are insoluble in both aerobic and anaerobic conditions

Phosphorus inactivation

PIX, PAX and PHOSLOCK ONLY react with inorganic orthophosphate

Coagulants selectively precipitate only mineral pool of phosphorus in ecosystem !

Blockade of mineral phosphorus limits phytoplankton biomass and primary production

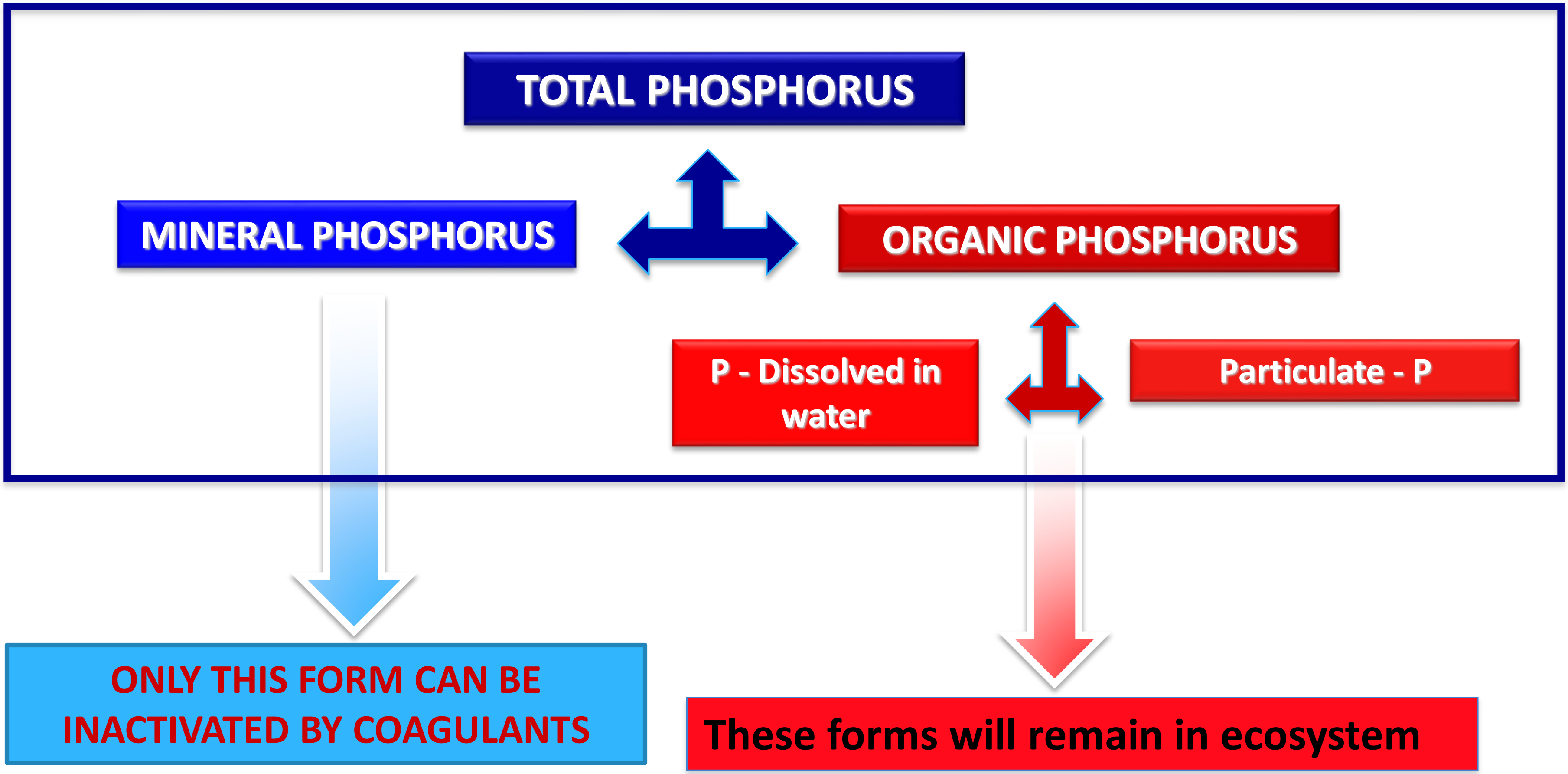
Does inorganic phosphorus inactivation stop lake hypereutrophication?

Inactivation of phosphorus by PIX and PAX coagulants is not highly effective in long-term scale to prevent lake against hypereutrophication. PIX and PAX lake treatment usually improve water quality for 3-4 years then symptoms of eutrophication come back.

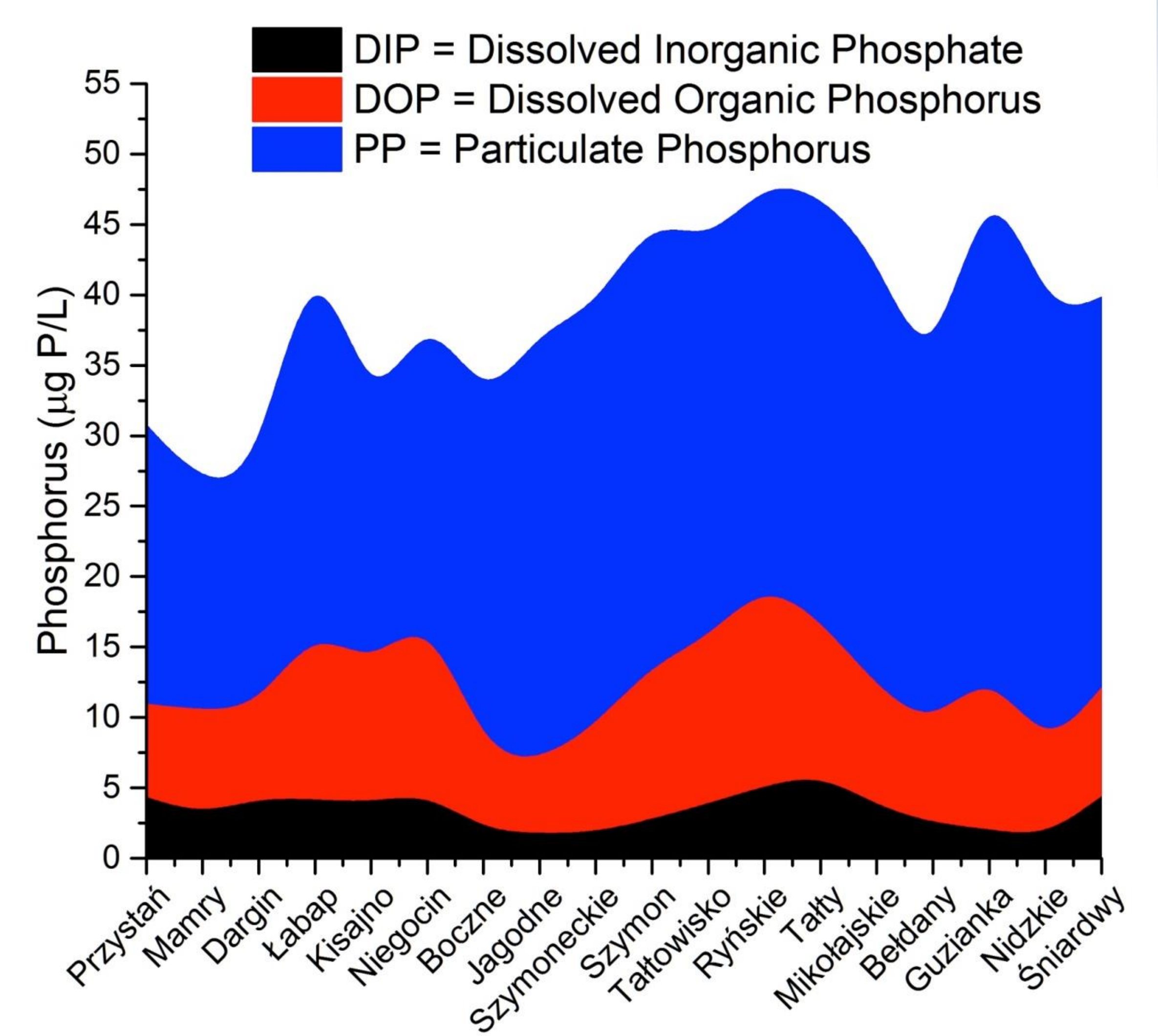
Phoslock inactivation of phosphorus appears to have more prolonged effect of phosphorus limitation for phytoplankton

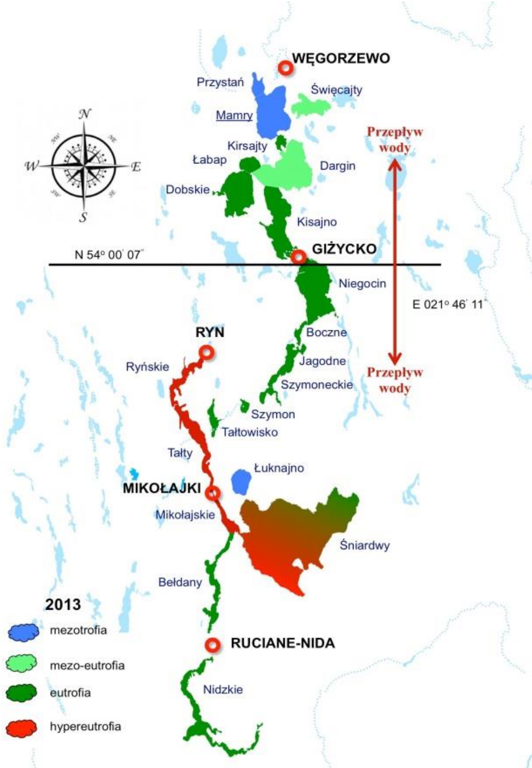
Does inorganic phosphorus inactivation stop lake hypereutrophication?

FORMS OF PHOSPHORUS IN AQUATIC SYSTEMS

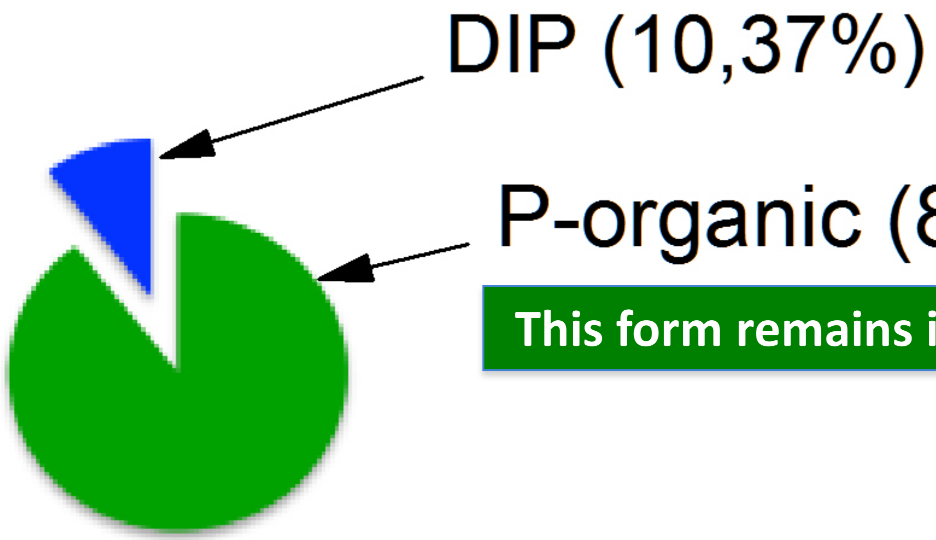


Forms of phosphorus in Mazurian lakes





Forms of phosphorus in Mazurian lakes

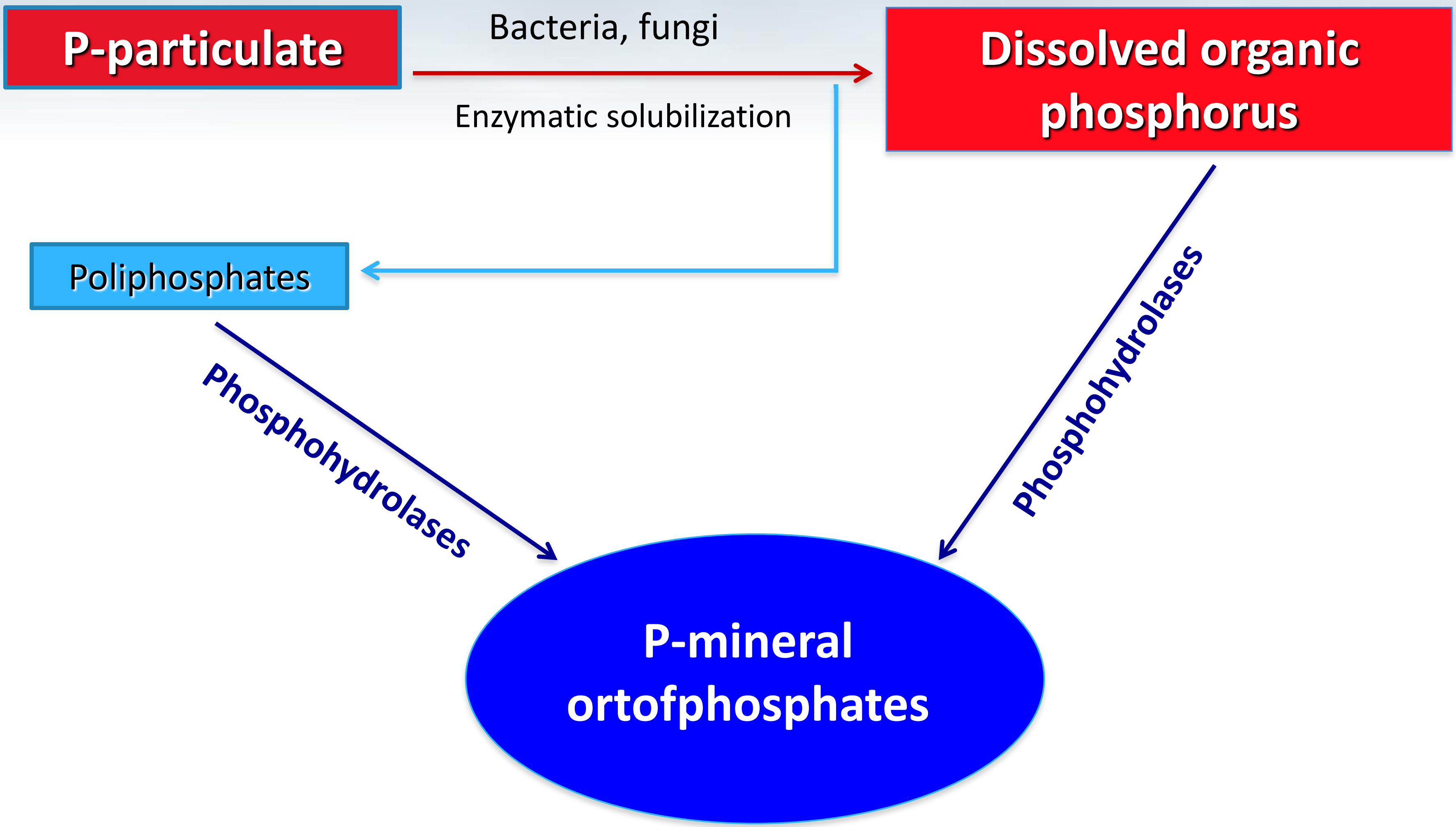


ONLY this form can be inactivated by coagulants

This form remains in water and sediments

DIP = Dissolved Inorganic Phosphorus, av. % of total P in lake water
P-organic av. % pf total P in lake water

Microbial metabolism of organic phosphorus

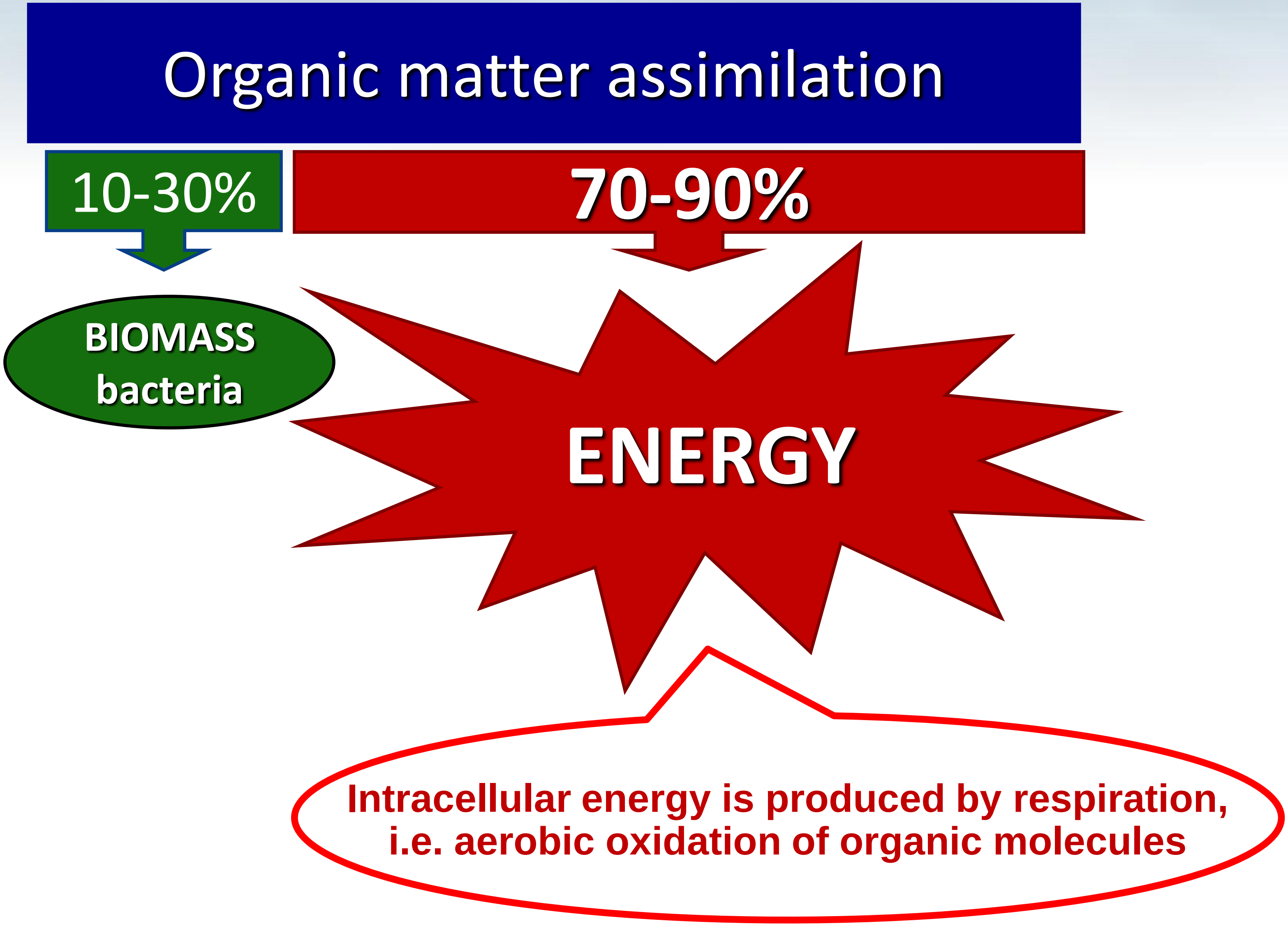


Inactivation of phosphorus

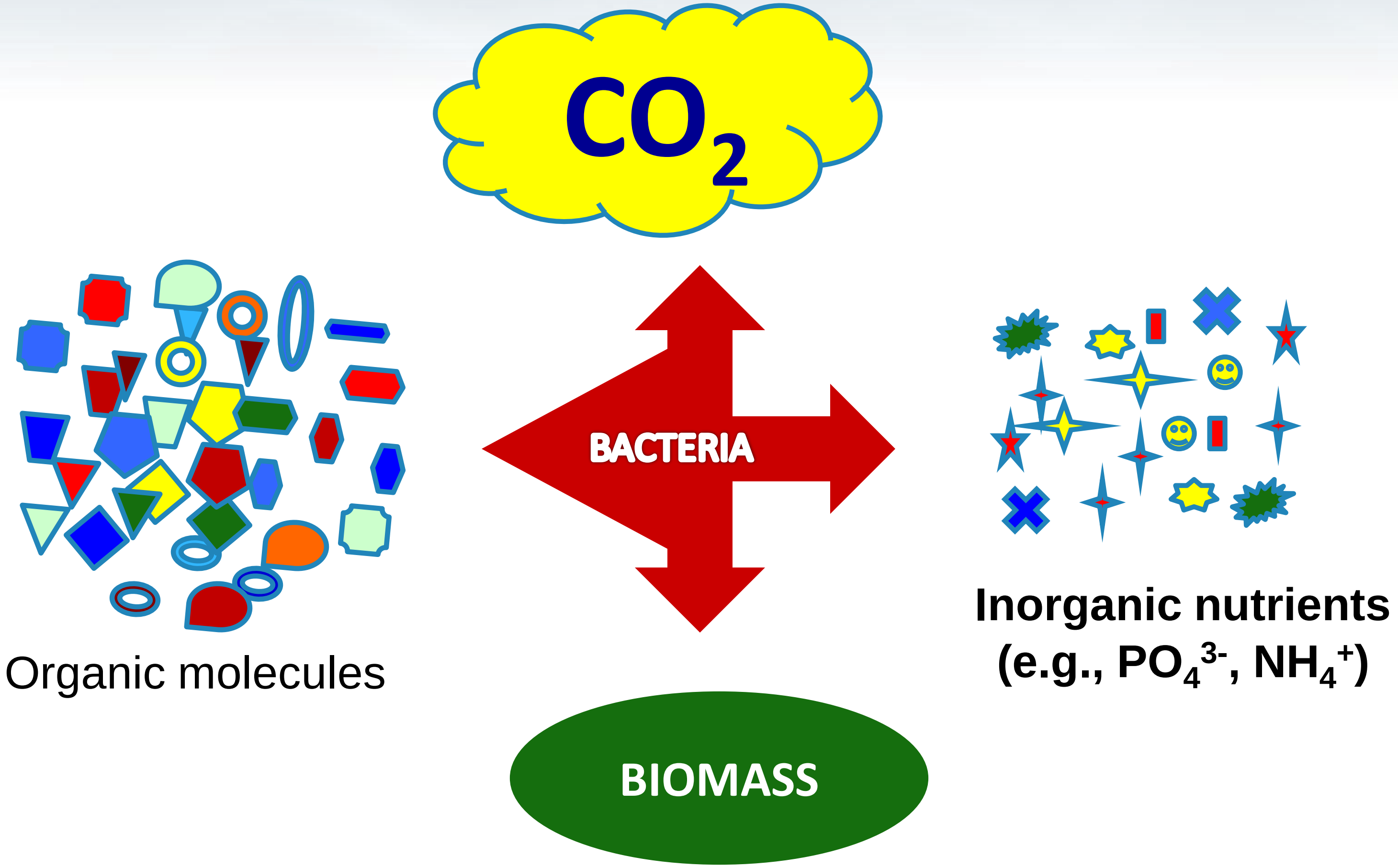
Inactivation of phosphorus as a single major treatment is not highly effective in de-eutrophication of aquatic systems!

- Coagulants inactivate only inorganic phosphate, i.e., a minor portion of total phosphorus in ecosystem
- Organic forms of P-remaining in water and sediments will be continuously dephosphorylated by microorganisms and will release inorganic orthophosphate which will fuel phytoplankton development

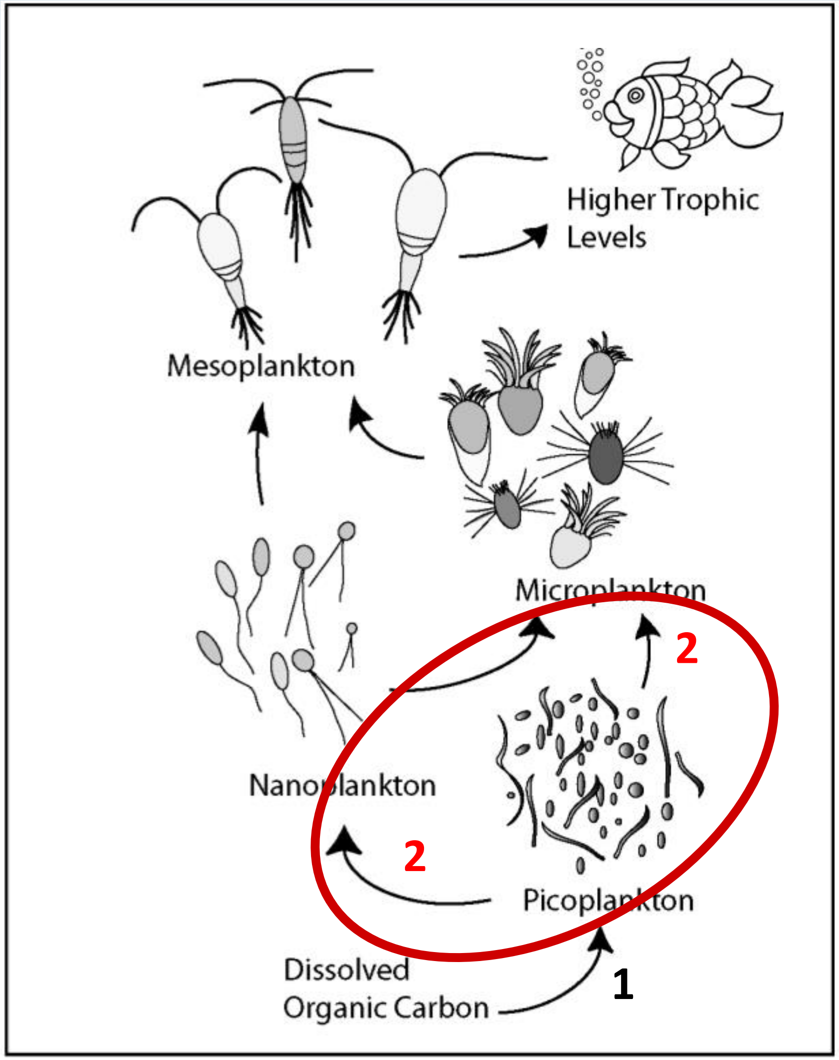
Bacterial metabolism of organic matter in lakes



How do bacteria act in lake water?

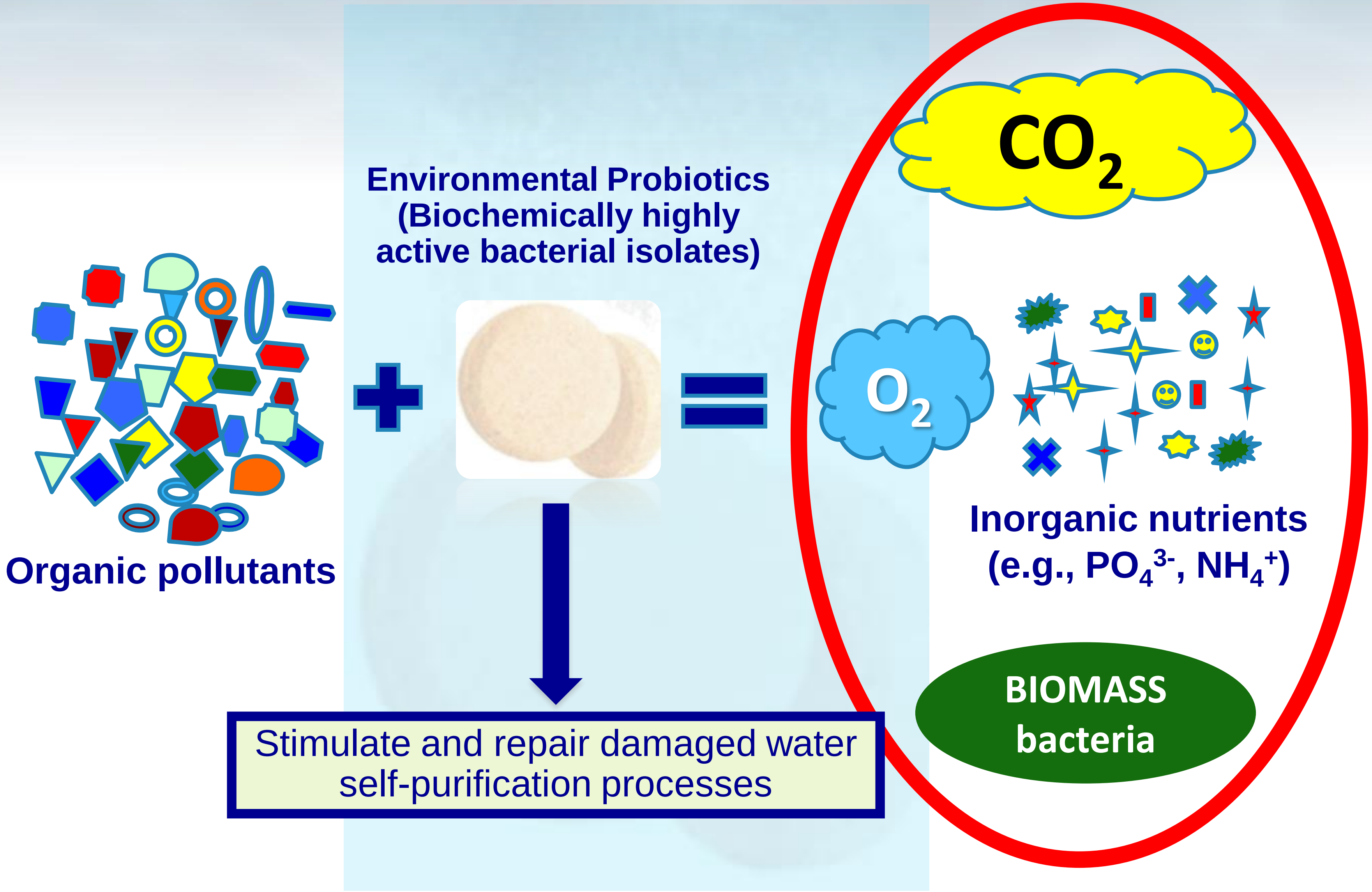


Fate of biomass in aquatic systems



1. Bacterial assimilation of DOC converts dissolved organic molecules into organic particles (i.e., bacterial cells = bacterial biomass)
2. Bacterial cells are consumed by bacterivorous nanoflagellates and cilliates and produce protistan biomass

Microbial bioremediation



Preliminary steps necessary before lake reclamation by COBIOMIC technology

Identification and definition of external sources of nutrients and pollutants flowing into the water reservoir

↓

Analysis of the dynamics of seasonal changes of basic physico-chemical, biological and microbiological parameters of water and bottom sediments

↓

Calibration of reservoir in microcosm scale in order to optimize COBIOMIC

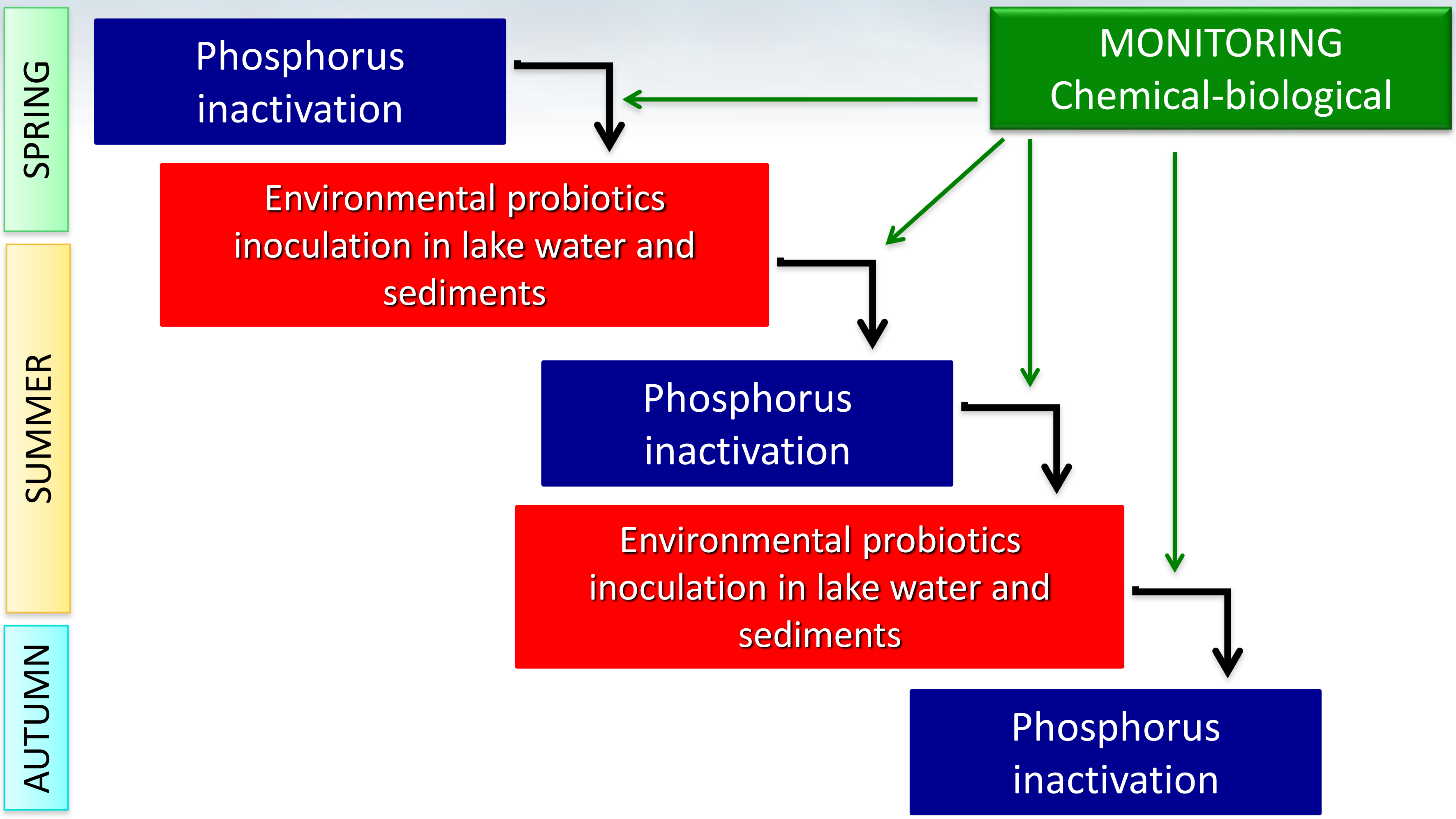
Complex Microbial Bioremediation Concept - COBIOMIC

1. **Because majority of phosphorus in lake water and sediments exists in an organic form, which can not be inactivated by coagulants or Phoslock it is necessary to convert P-organic into inorganic orthphosphate**

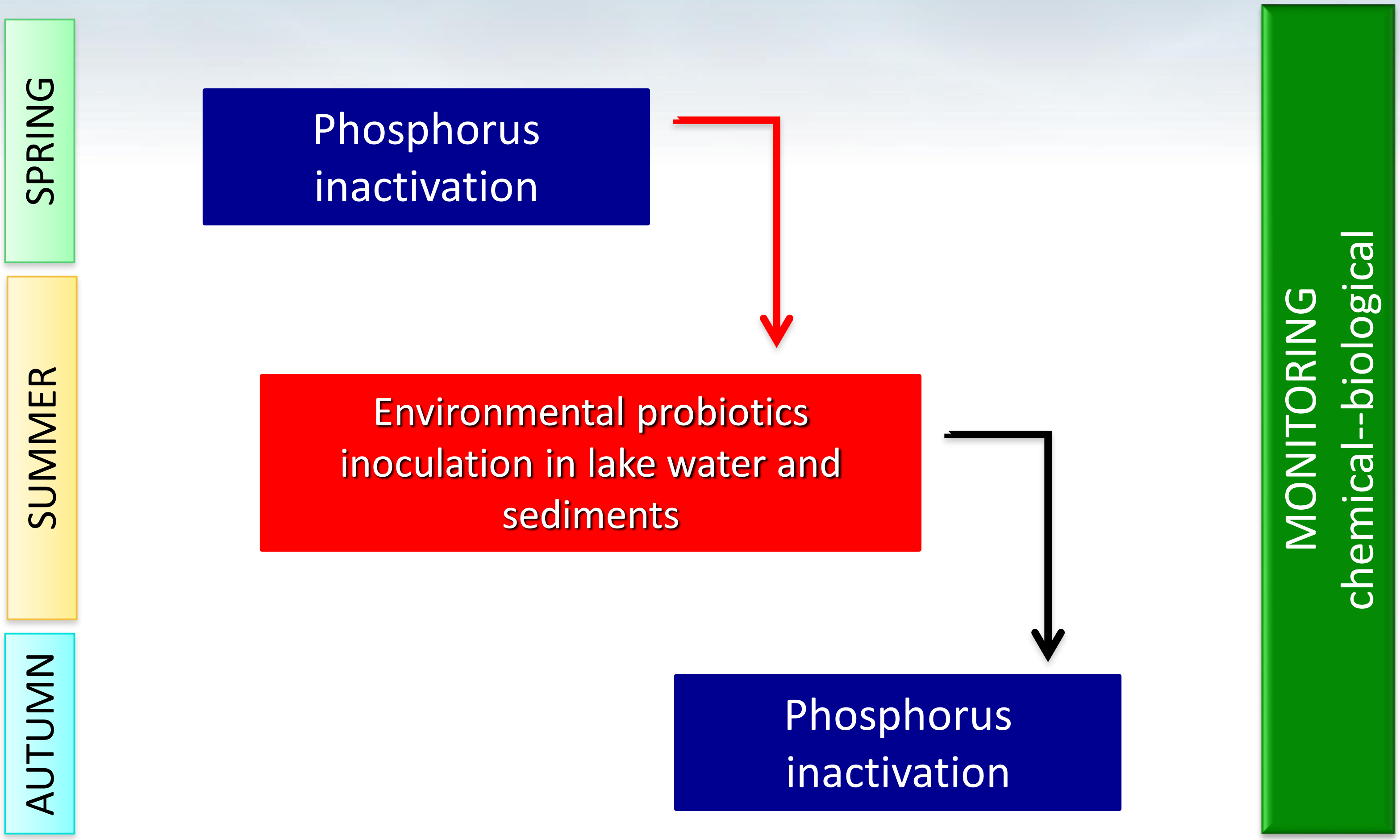
2. **Environmental probiotics inoculated into lake water and sediments stimulate mineralization of organic matter and enzymatically dephosphorylate P-organic compunds thus releasing inorganic orthophosphate**

3. **Released by microbial biochemical activity free, dissolved in water inorganic orthophosphate is fixed and precipitated by Phoslock**

Complex Microbial Bioremediation Technology - COBIOMIC (1st stage)



Complex Microbial Bioremediation Technology - COBIOMIC (2nd stage)



Complex Microbial Bioremediation Technology - COBIOMIC

Final results of COBIOMIC technology in lake ecosystem are:

1. Drastic decrease of phosphorus bioavailability in lake water and sediments. Phosphorus internal loading from sediments to water column is stopped.
2. Increase of water quality parameters:
   - Higher water transparency, lower chlorophyll$_a$ content, better oxygenation, lower phytoplankton biomass
3. Purification of the lake: removal of an excessive amount of accumulated organic and mineral impurities (de-eutrophication of the lake)
4. Growth of natural, recreational and economic values of lakes

COBIOMIC technology is subject to patent claim

Example how does COBIOMIK work?

Example 1. Lake Suskie

Swimming area (5.08.2014 r.)

Swimming area, 18.08.2014 r.

Example how does COBIOMIK work?

Example 2. Pond in Radom

Before COBIOMIC, 02.07.2014 r.

During OBIOMIC, 18.08.2014 r.

Thanks
for your attention