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Are biosurfactant and chelating agent mixtures good additives for electro-kinetic remediation of multi-contaminated sediments?

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Why this study ?

Many organic pollutants such as PAHs, PCBs and metal contaminants are cumulated in dredged sediments which are immobilized in deposit areas with no possible valorization. Specially, the sediment of Seine River at Tancarville (Normandy, France) is rich in clay, carbonates and organic matters which make the sediment difficult to be treated for remediation.

Consequences:

- Damage to aquatic ecosystems, possible transfers (groundwater)
- Toxic for living organisms including human-beings

Aims of researches :

- Enhancing electro-kinetic remediation
- Using combinations of biodegradable surfactants and chelating agents

Sediment information

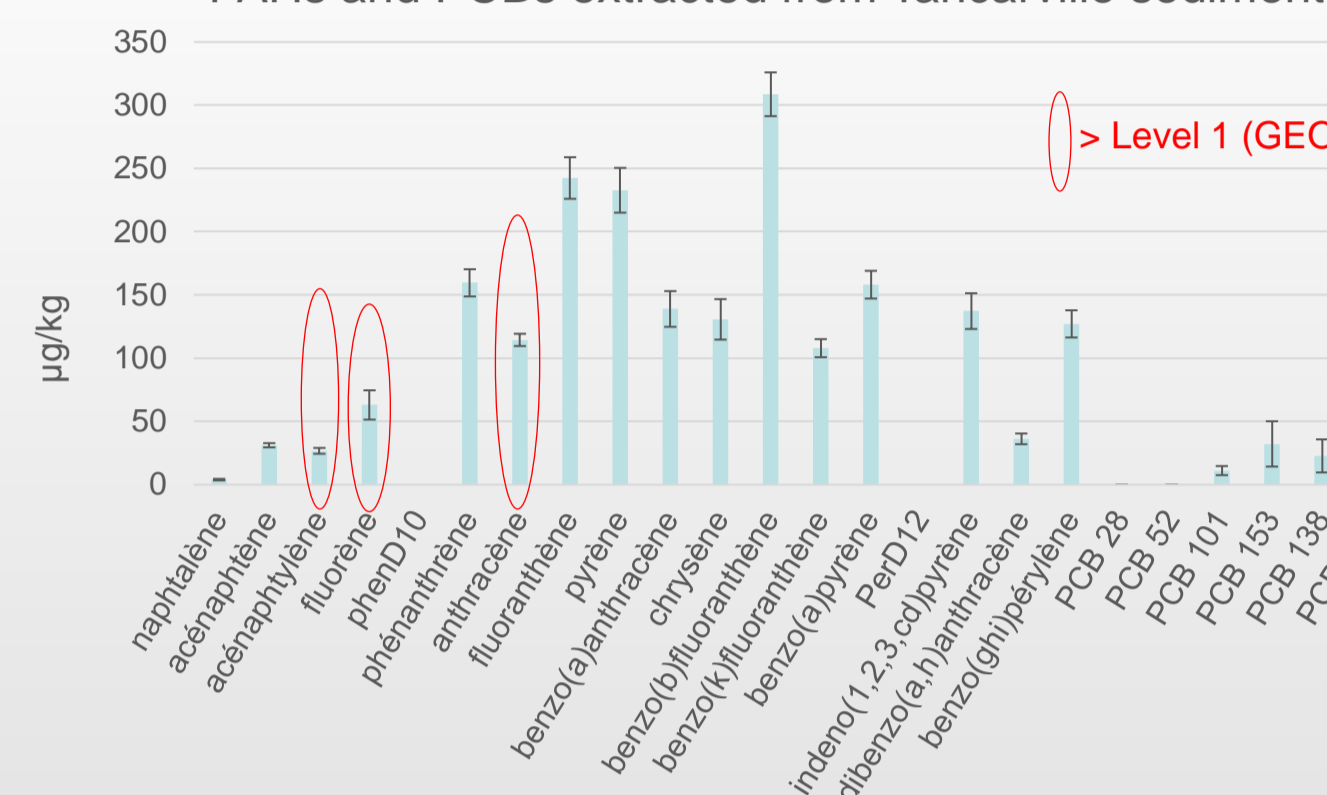
Harbor dredged sediments



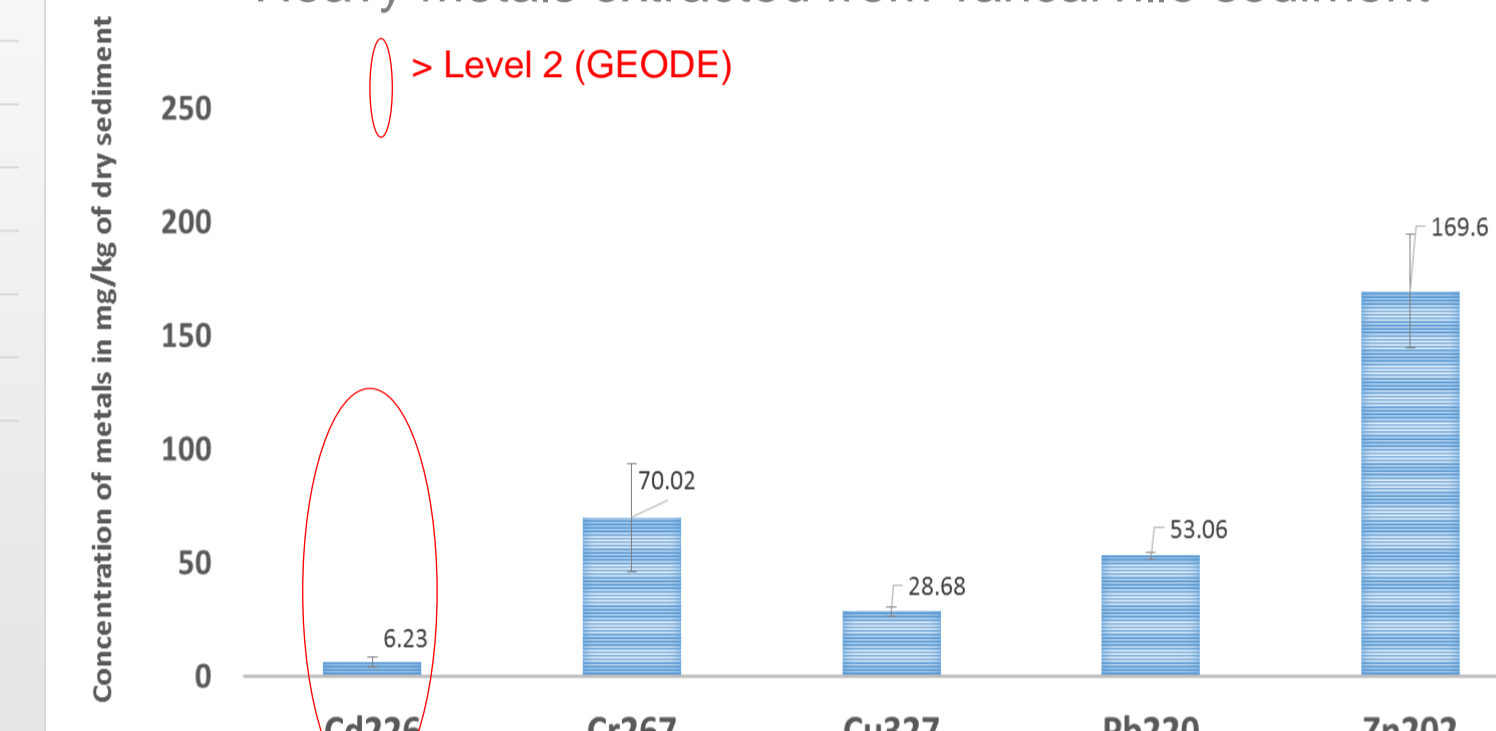
Rich in clay, carbonates ($pH_{\text{sediment}}=8.4$) and organic matter (OM~6%)

- High retentive power for metals (clays) and organic contaminants (OM)
- Buffer effect (carbonates) : Reduce metal mobility

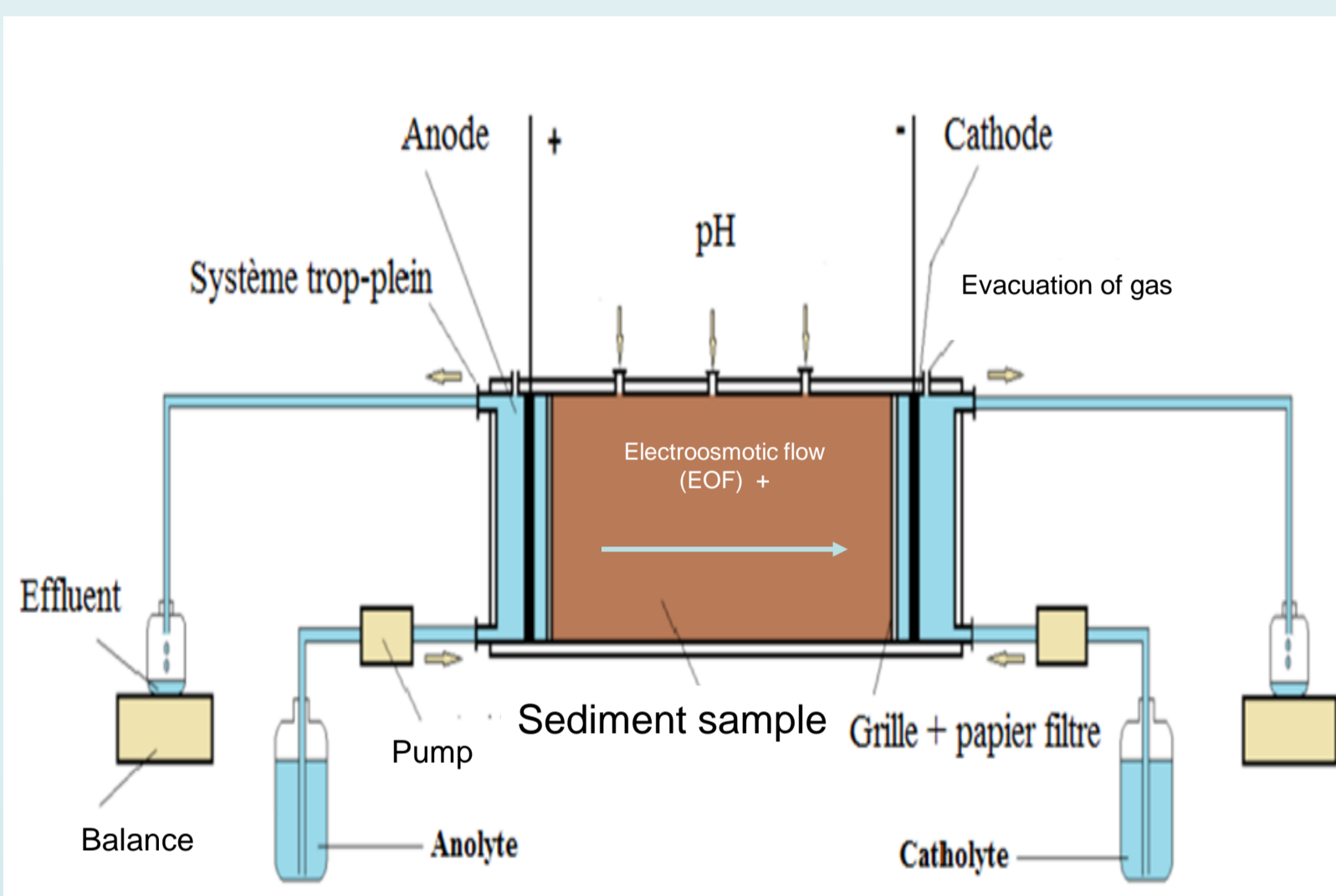
PAHs and PCBs extracted from Tancarville sediment



Heavy metals extracted from Tancarville sediment



Electro-kinetic remediation



Advantages:

- For low permeability sediment
- Multi-decontamination
- Fast
- Site implementation

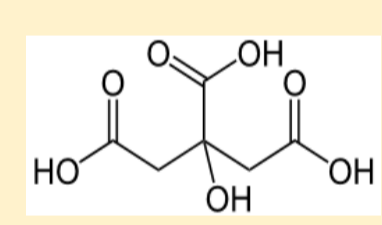
Difficulties: suitable efficient additives

- Maintain pH: acid
- Solubilize lipophilic compounds
- Transport heavy metals
- Environmentally friendly treatment



Enhancing Additives

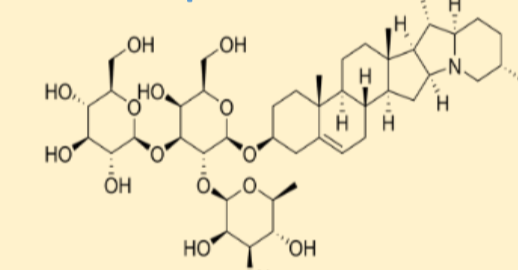
Citric acid



- Good chelating agent
- Maintain pH ≈ 4
- Natural molecule

- Biosurfactants: Non toxic, Biodegradable
- Solubilize PAHs, PCBs, etc.

Saponin



anionic

Rhamnolipid

nonionic

2 dominant processes :

- Electro migration
- Electro osmose

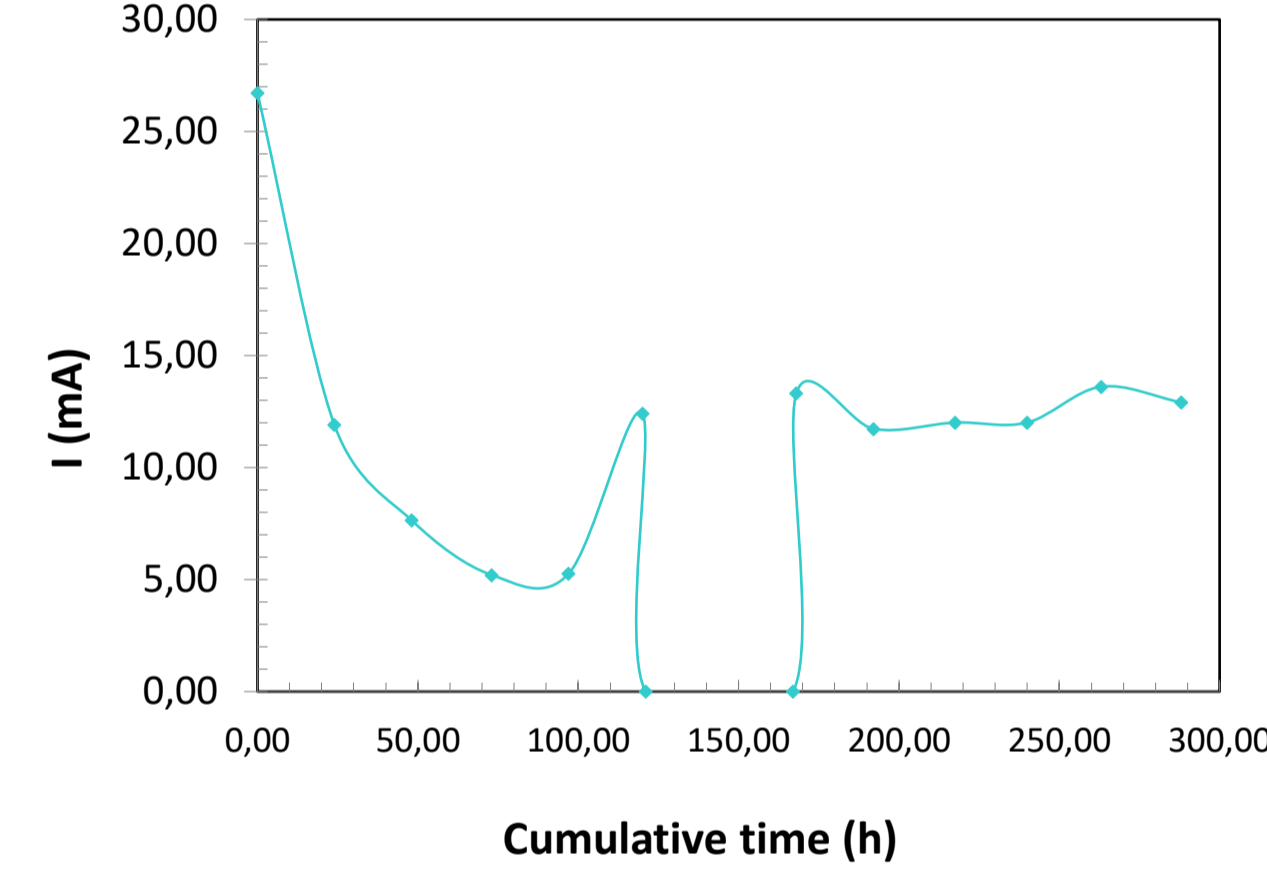
Objective:

Desorb, solubilize the pollutants in sediment pores and transport them toward the electrodes by applying an electric field (1 V/cm)

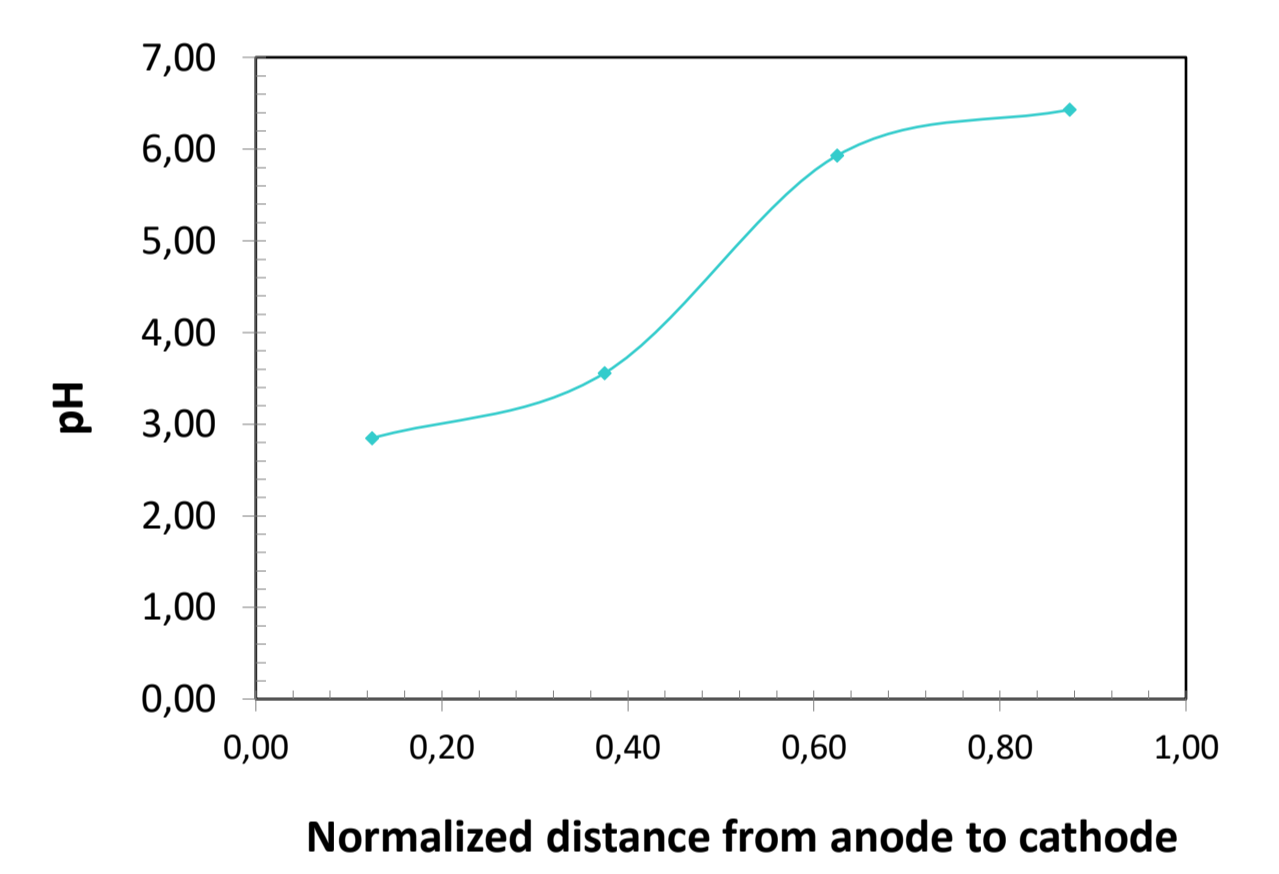
Tests with a chelating agent and a surfactant

12-days treatment : Mixing citric acid + Rhamnolipid (biosurfactant) (periodic voltage: 5 days on/2 days off, energy savings)

Variation of electric current



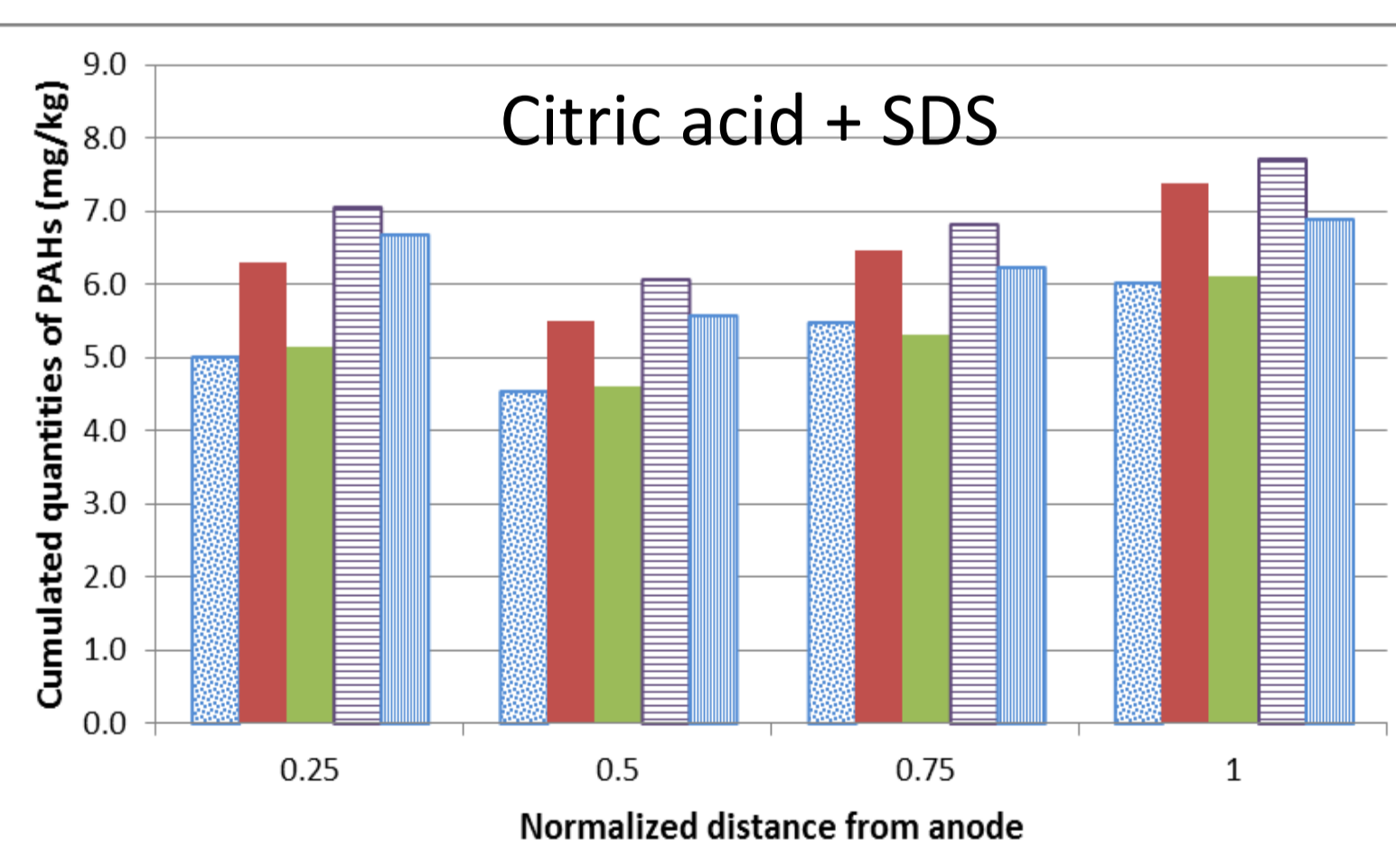
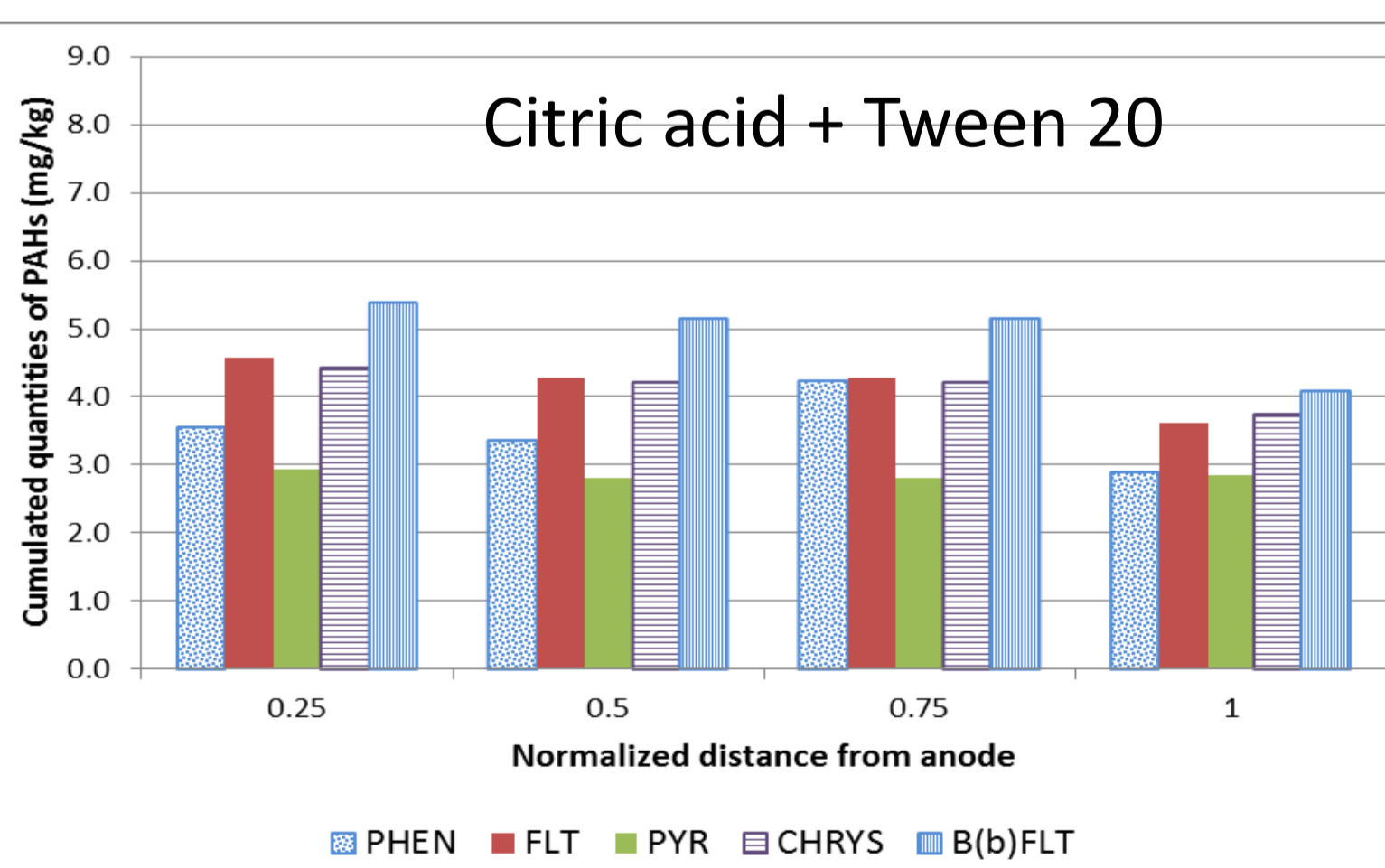
Variation of pH of treated sediment



- “Flush” effect of periodic voltage on I : not very pronounced
- Acid maintenance successful
- But $pH > pK_{a,Rhamnolipid} \sim 4.8$, Rhamnolipid: anionic → migrate s to anode (opposed to EOF) → detrimental for removing organics?

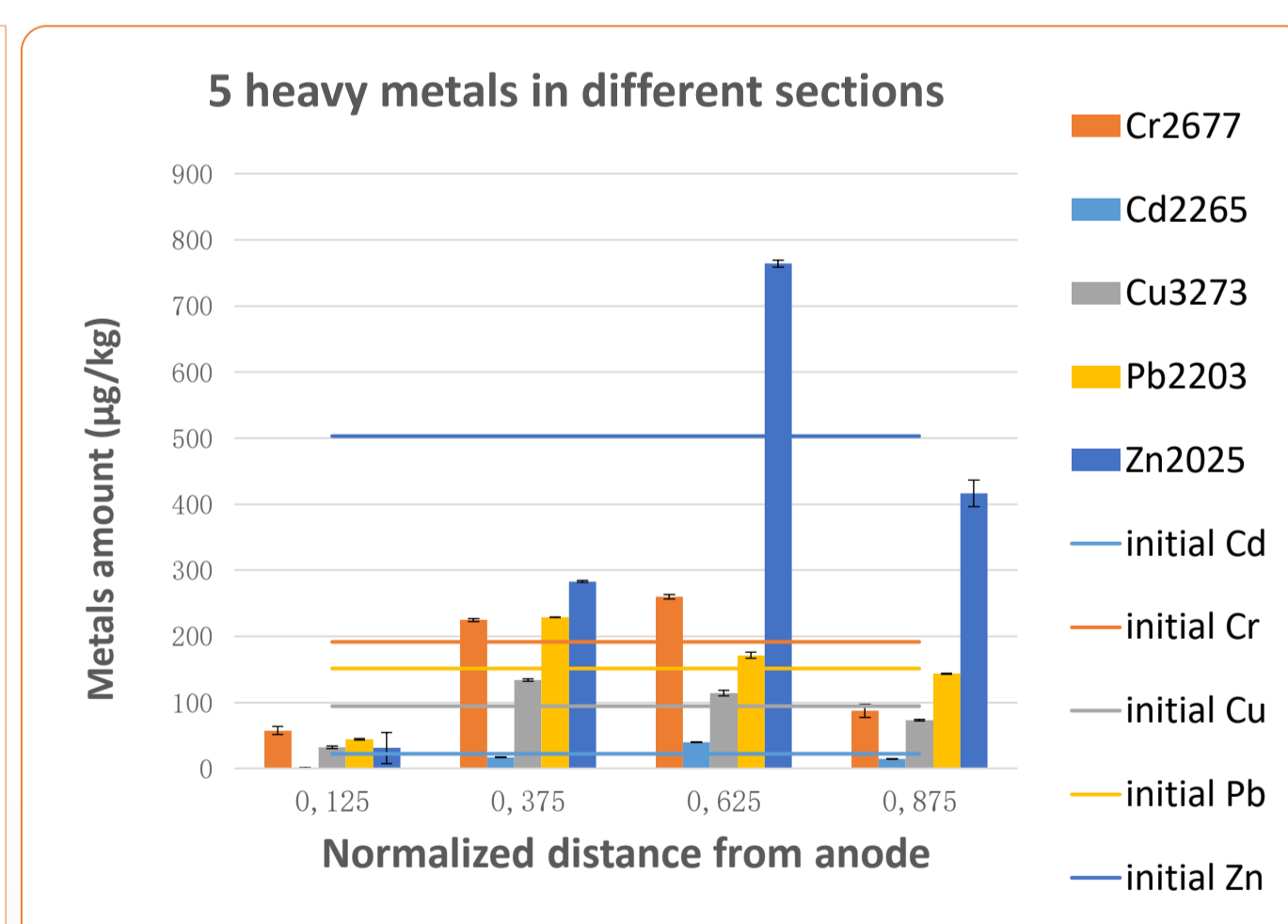
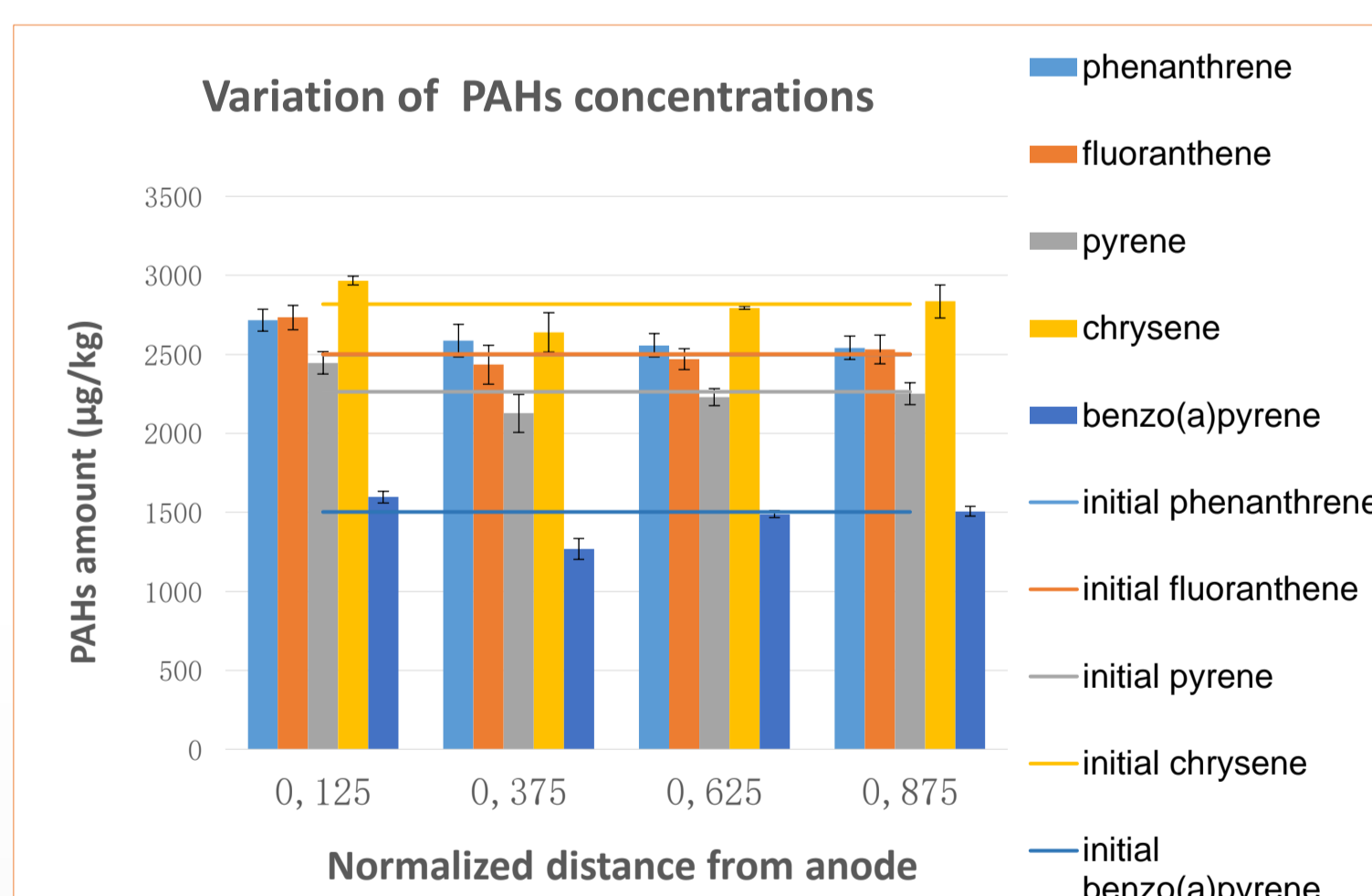
Anionic or nonionic surfactants ?

Citric acid + nonionic Tween 20 OR Citric acid + anionic SDS, 12 days treatment



Citric acid + Tween 20: better removals for PAHs

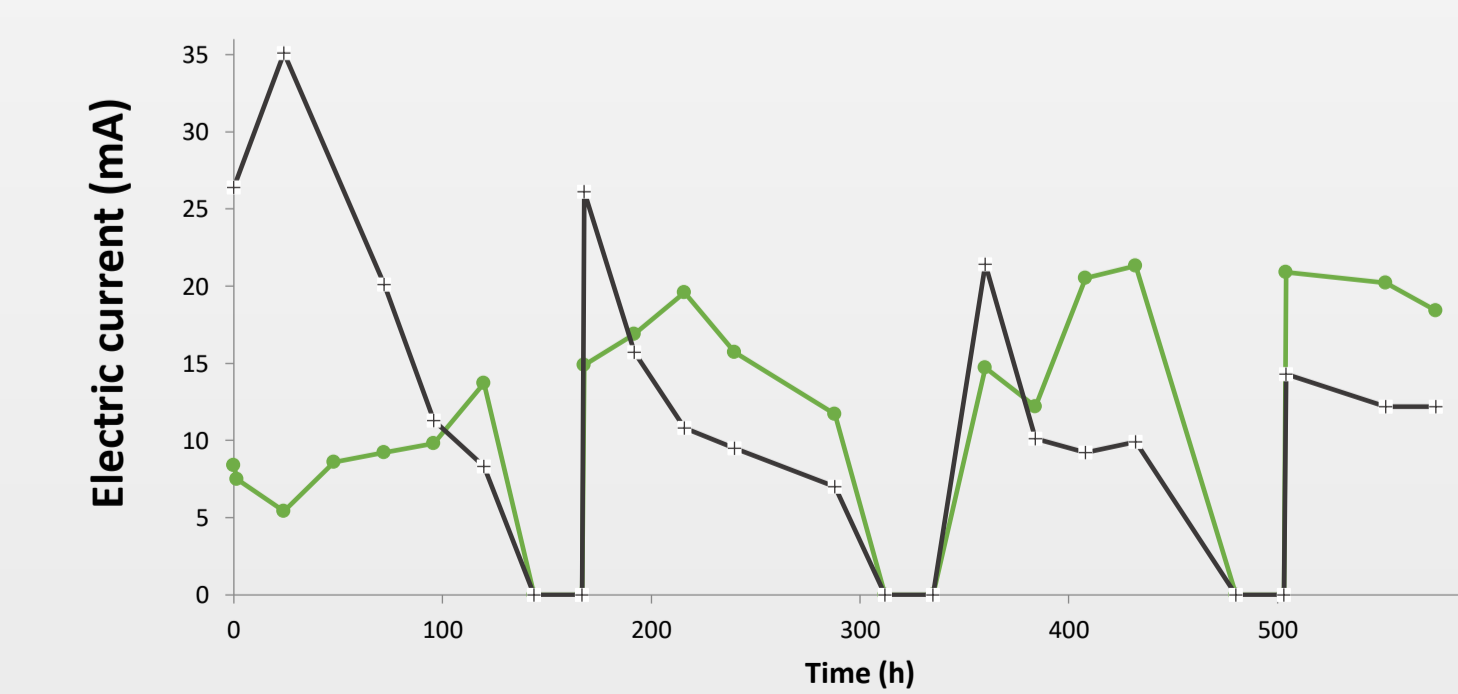
Anionic surfactant SDS moves against EOF → detrimental for removing organics



- PAHs, PCBs: migrate from middle to anode
- poor removals for PAHs
- no removals for PCBs
- Problem with the anionic biosurfactant?

- Heavy metals: migration only begins
- poor removals (1-18%)
- Not enough time to migrate more to the electrodes?

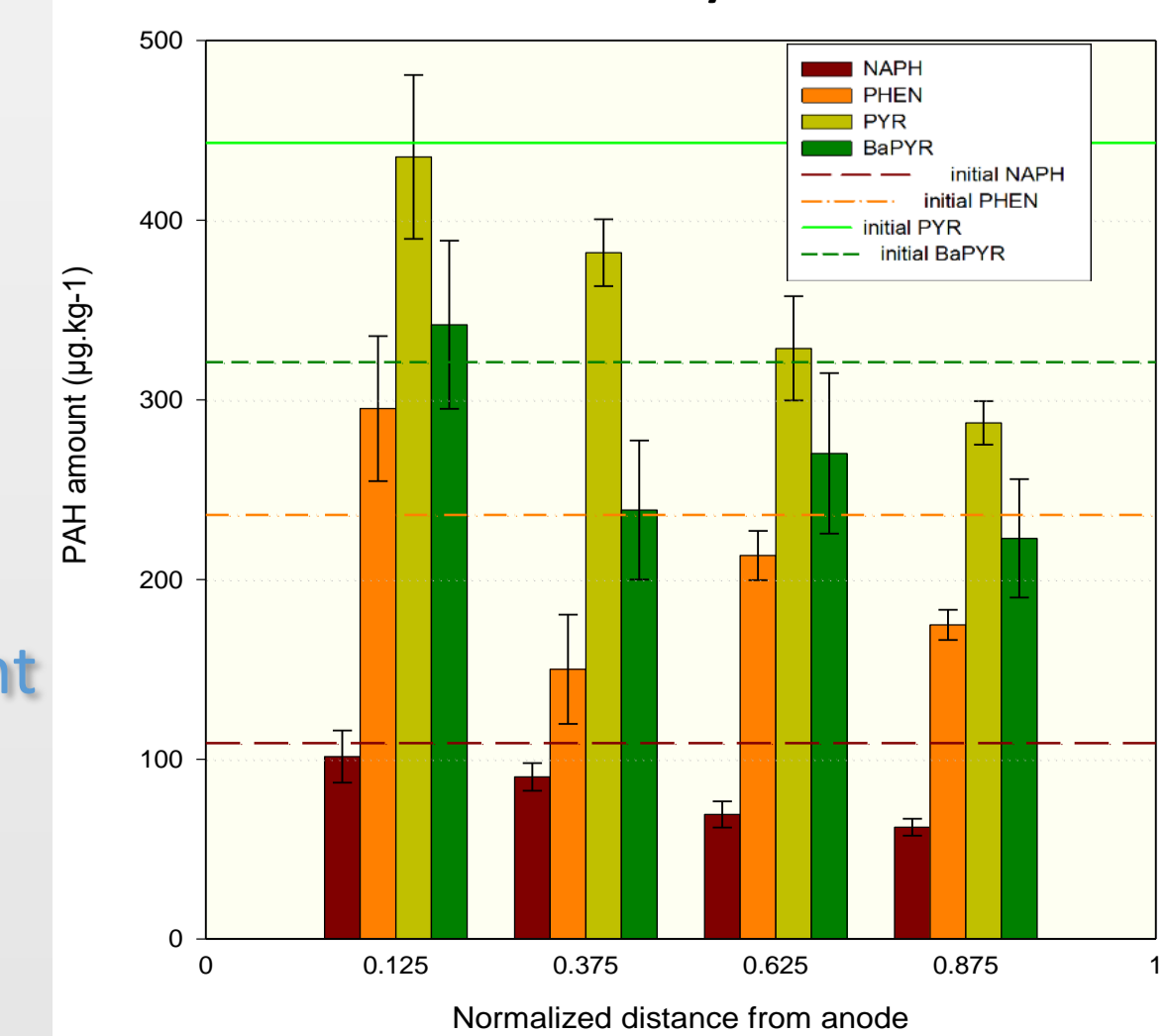
24-days treatment : Citric acid + Rhamnolipid or viscosin-like biosurfactants (periodic voltage: 5 days on/2 days off, energy savings)



- “Flush” effect of periodic voltage on I : more important
- PAHs depletion at cathode side
- Better removals (~25%)
- Heavy metals: Cd, Pb, Zn: better removals than 1st test (11-34%)

Need longer-time treatment

PAHs remediation by 2nd treatment



Possible improvements

- Testing saponin (nonionic biosurfactant) instead of rhamnolipid
- Higher saponin concentration (biodegradability: regular renewal)
- Longer treatment time for clay and carbonate rich sediments

Conclusion

- Mixtures of biodegradable chelating agents + biosurfactants
- Promising candidates for EK multi-decontamination