

Phosphorus recovery from wastewater as vivianite using electro-coagulation

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Who Am I?

- Rania Souidi
- Tunisia
- 2 years of preparatory school (Physics and chemistry)
- 3 years of engineering studies: Hydraulics and environment
Waste and water management and treatment
- Intern at Université Laval: Mitacs Program
- MSc studies: Université Laval
 - *modelEAU team, Create-TEDGIEER & CentrEau research cluster QC*
 - *Supervisor: Peter Vanrolleghem*
 - *Co-supervisors: Céline Vaneekhaute (UL), Patrick Drogui (INRS)*
- Hobbies: Reading, swimming

modelEAU team ☀



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Introduction

I - Nitrogen and phosphorus are causing environmental problems leading to environmental stress on aquatic ecosystems such as eutrophication and toxicity.



Strict discharge limits

II - An annual increase in nutrient use by society is observed while global phosphorus (P) and potassium (K) reserves are becoming limited (a few centuries to go).

Phosphorus is essentially used as a **fertilizer**: 80% of all mined phosphorus is used in agriculture



Beneficial for humans, yet it's not used in a sustainable way

Electrochemical processes can be used as **tertiary treatment** for P removal

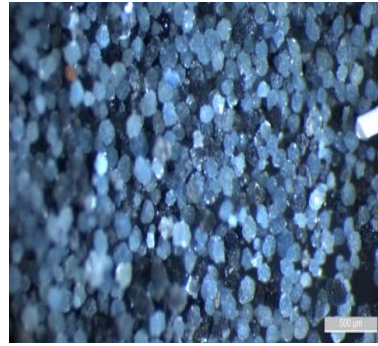
a new tool for nutrient recovery processes
(electrodialysis, electrocoagulation, electrochemical magnesium dosage)



All these processes have currently only been studied at pilot-scale, and full-scale application still needs more investigation and research

Phosphorus recovery as vivianite

What is Vivianite?



Wilfert (2018)

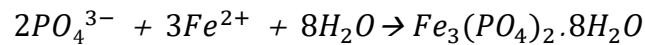
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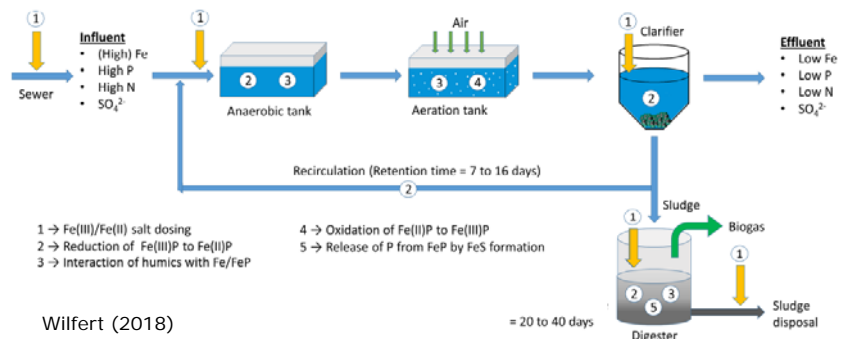
Phosphorus recovery as vivianite

What is Vivianite?

Vivianite is an important iron phosphate compound



Iron dosing appears everywhere in WRRFs

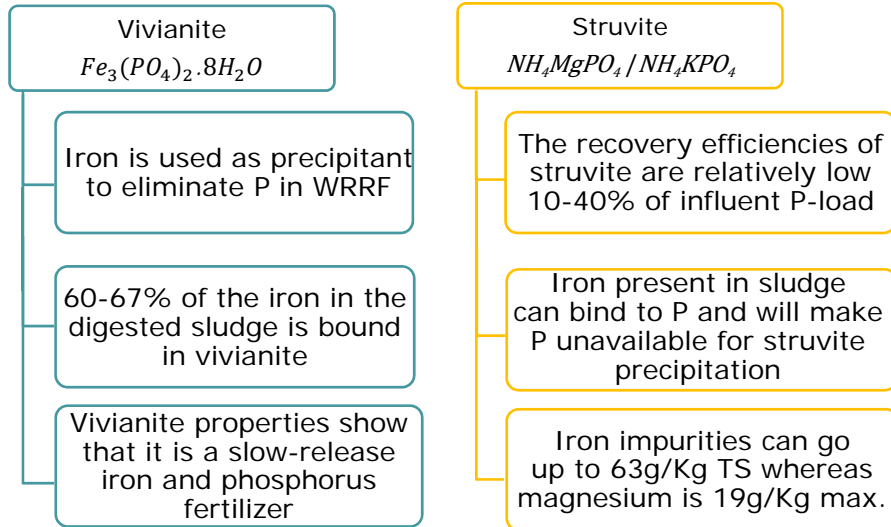


Wilfert (2018)

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Vivianite Vs Struvite (Wilfert, 2018)



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Is Fe bad for P-recovery? 🤔

Iron plays a crucial role in sewage treatment

P removal As a coagulant Preventing H₂S emission

The presence of Iron in a WRRF has often been considered a disadvantage for P recovery: "In soils FeP is not bioavailable"

Efforts to immobilize phosphate in like sediments by using iron often ends in vain



Fe and P interactions are so complex

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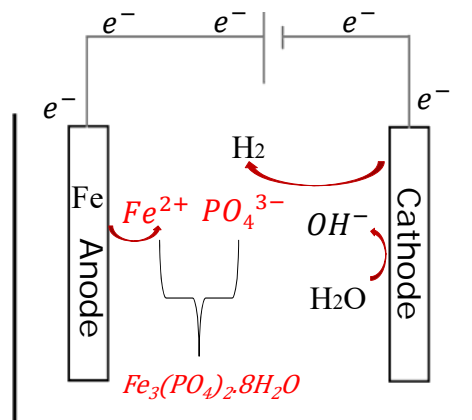
What is electro-coagulation?



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What is electro-coagulation?



At the anode: Oxidation
 $Fe \rightarrow Fe^{2+} + 2e^-$

At the cathode: Reduction
 $2H_2O + 2e^- \rightarrow 2OH^- + H_2$

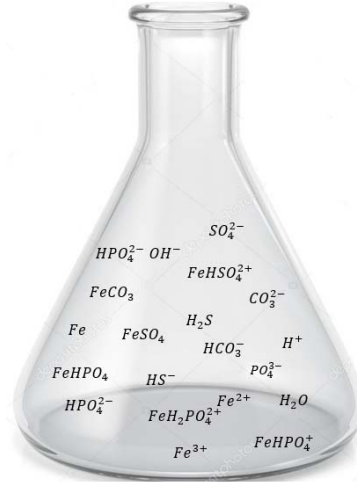
In the bulk solution: Vivianite Precipitation
 $2PO_4^{3-} + 3Fe^{2+} + 8H_2O \rightarrow Fe_3(PO_4)_2 \cdot 8H_2O$

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Results

PHREEQC simulations

| Parameter | Value |
|------------|-----------|
| pH | 7 |
| Fe (mole) | 0.0044 |
| Phosphorus | 2 mmole |
| Carbonate | 30 mmole |
| Sulfide | 0.1 mmole |



Complicated!

Results

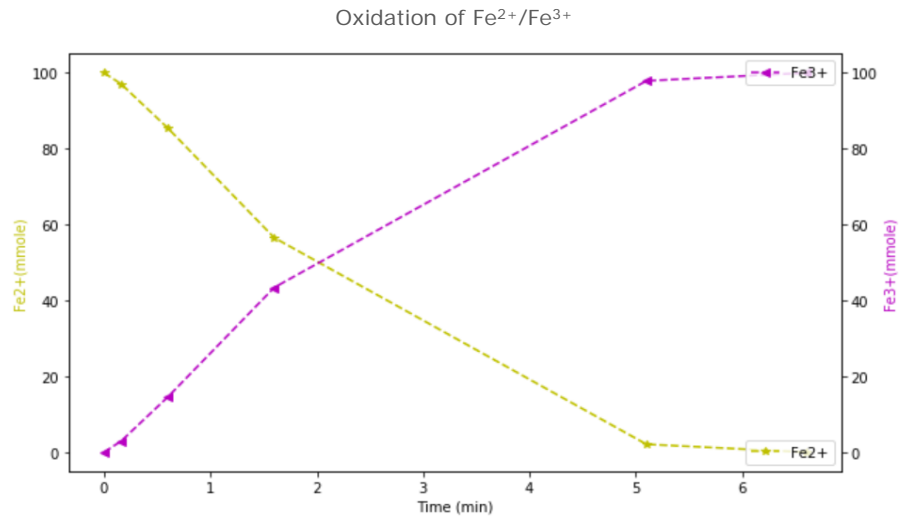
PHREEQC (pH REdox Equilibrium) simulations

Phreeqc capabilities: Geochemical calculations
Speciation Calculation
Batch reactions
Saturation index
Kinetically controlled reactions...

Follow: Vivianite $Fe_3(PO_4)_2 \cdot 8H_2O$
Pyrite FeS_2
Mackinawite $FeSm$
Hematite Fe_2O_3
Iron Hydroxyde $Fe(OH)_2$
Siderite $FeCO_3$

Simulation 1 - Fe²⁺ / Fe³⁺ oxidation

Aerobic conditions

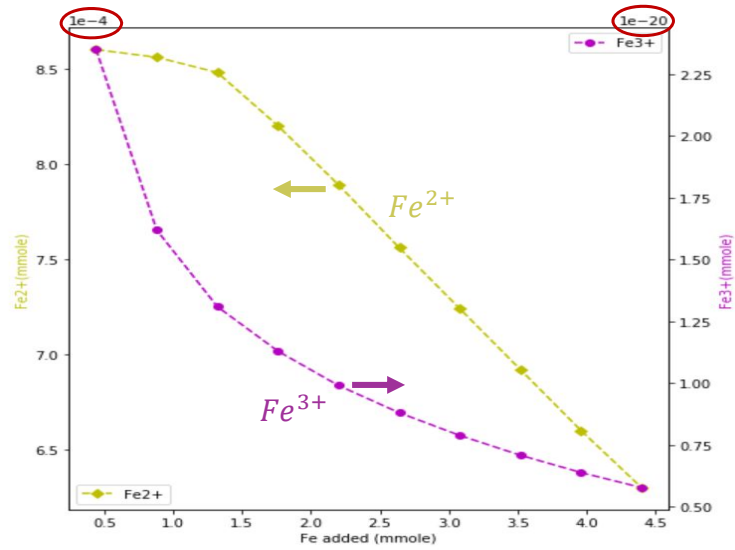


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Simulation 1 - Iron oxidation

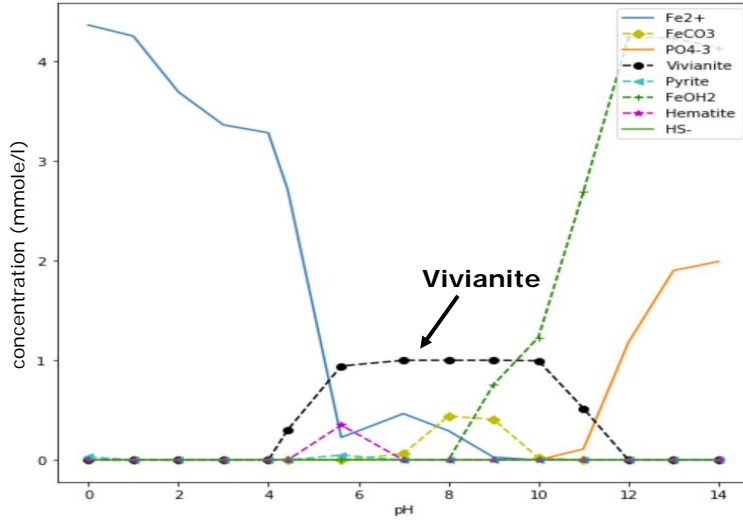
Anaerobic conditions



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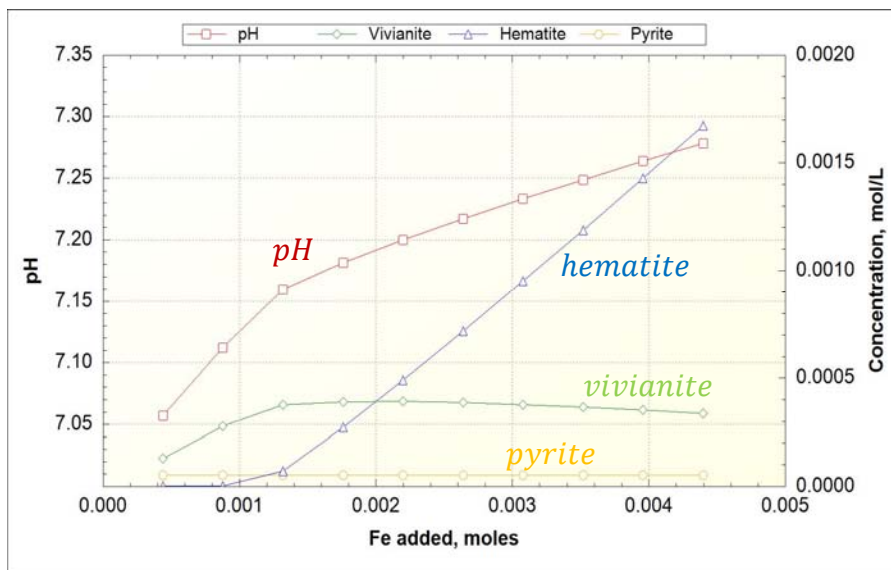
Simulation 2 - All possible mineral precipitations as f(pH)



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Simulation 3 - With Fe dosage



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Conclusions

- 1- Kinetics of Iron oxidation in aerobic / anaerobic conditions ✓
Ferrous Iron oxidation is fast in aerobic conditions
In anaerobic conditions, Iron is mostly oxidized to Fe^{2+}
- 2- Vivianite precipitation is highly influenced by pH, ✓
and carbonate and sulfide presence
Ideal pH for precipitation: neutral
- 3- The bioavailability of P in iron phosphate fertilizer ✓
needs more research
The interactions in soils are complex and the availability
depend on the conditions of vivianite formation (crystal
structure)

Thank you for your attention!



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