Bioelectrochemical peroxide production for water disinfection

Case study for regenerative water services

MSc. Suanny Mosquera Romero

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1. Introduction

- Water is an essential necessity.
- SDG 6: Clean water and sanitation, influence other areas of development (ONU, 2017).
- Substantial inequalities for provision of sanitary services between urban (reaching full coverage) and rural areas (~25% coverage) in Latin America (WHO, 2017).

Guayaquil-Ecuador, 2017

Babahoyo-Ecuador, 2017

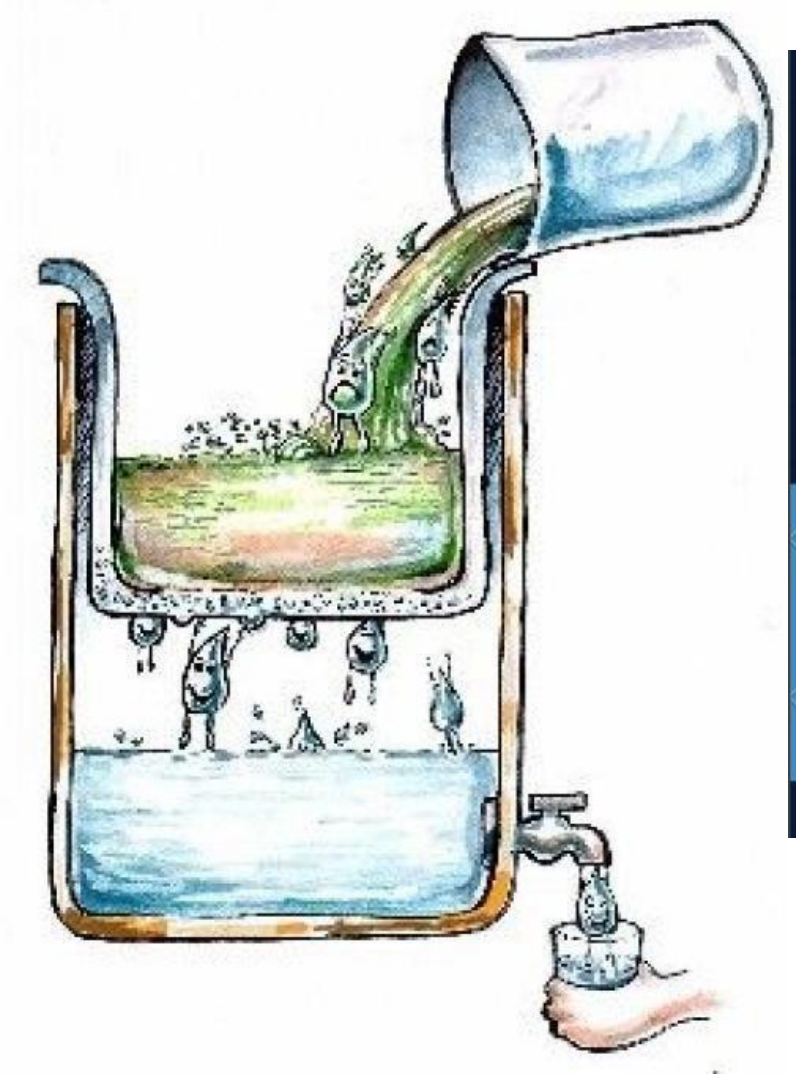
Areas with water stress: supply shortage and poor waste treatment on areas of dispersed population

- 33% of households have access to water through a network.
- 10% counts with sewage system (Cuesta, *et al* 2017).
- Larger distances hinder the coverage of water services.
- Waterborne diseases by water supplied from polluted water bodies (MSP, 2014).

Tsáchilas-Ecuador, 2017

Capital: Quito
Language: Spanish
Total Surface: 283561 km^2
Population: 16 628 217
Dispersed population: 3 715 343
Density: 15 hab/km2

Solution for waste water treatment and water supply: **Water reuse**



2. Definition of the project

Decentralized waste water treatment systems: **Constructed wetlands**

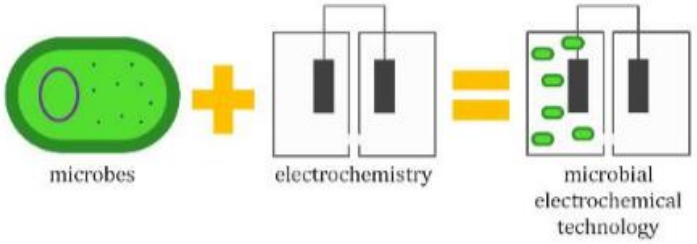
- ✓ Filtration, degradation, and stabilization.
- ✓ Optimal for (sub)tropical countries.
- ✓ Capital and maintenance cost are reduced.
- ✓ Long-term solution/health protection/ Promote job opportunities and local services.

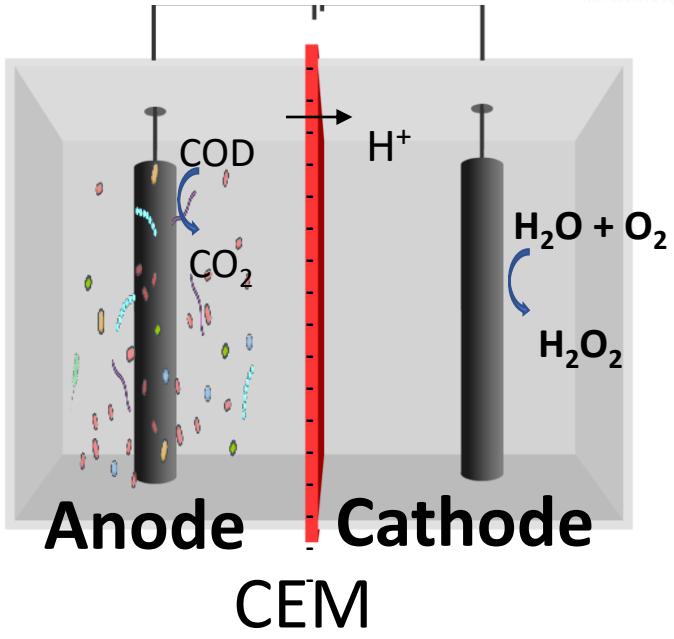
- **Removal of pathogens is not guaranteed.**

Household level

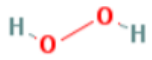
Community level

Enhanced disinfection by (bio)electrochemical systems





$$O_2 + 2\bar{e} + 2\,H^+ \rightarrow\ H_2O_2$$



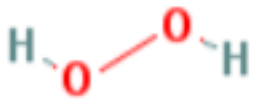
Pros:

- Organic degradation + clean energy input.
- *In-situ* production of disinfectants without external reagents.
- Avoid transportation and storage.

Why disinfection with peroxide?

- Degrades to non harmful products.
- Production of strong oxidant reagents (OH°, HO_2^-) at alkaline pH, Uv-light, and/or Fenton reactions.
- Cheap carbon electrodes.

Peroxide disinfection towards water reuse



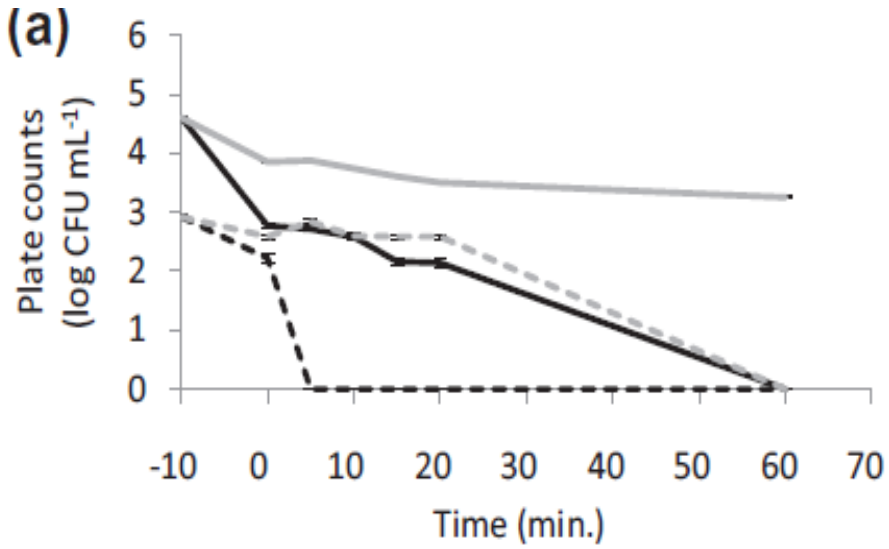


Plate counts 0.1% total bacteria: ——, 0.1% coliforms: – –, 0.01% total bacteri
——, 0.01% coliforms: – –. Error bars indicate 95% confidence interval

(Arends et al, 2014)

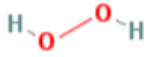
Compliance:

- 3 log removal for discharge to water bodies.
- < 1 log CFU mL^{-1} for agricultural use.
- Reuse?

(Tulsma, Ecuador 2003)

Peroxide production in (bio)electrochemical cells

$$O_2 + 2\bar{e} + 2\,H^+ \rightarrow\ H_2O_2$$

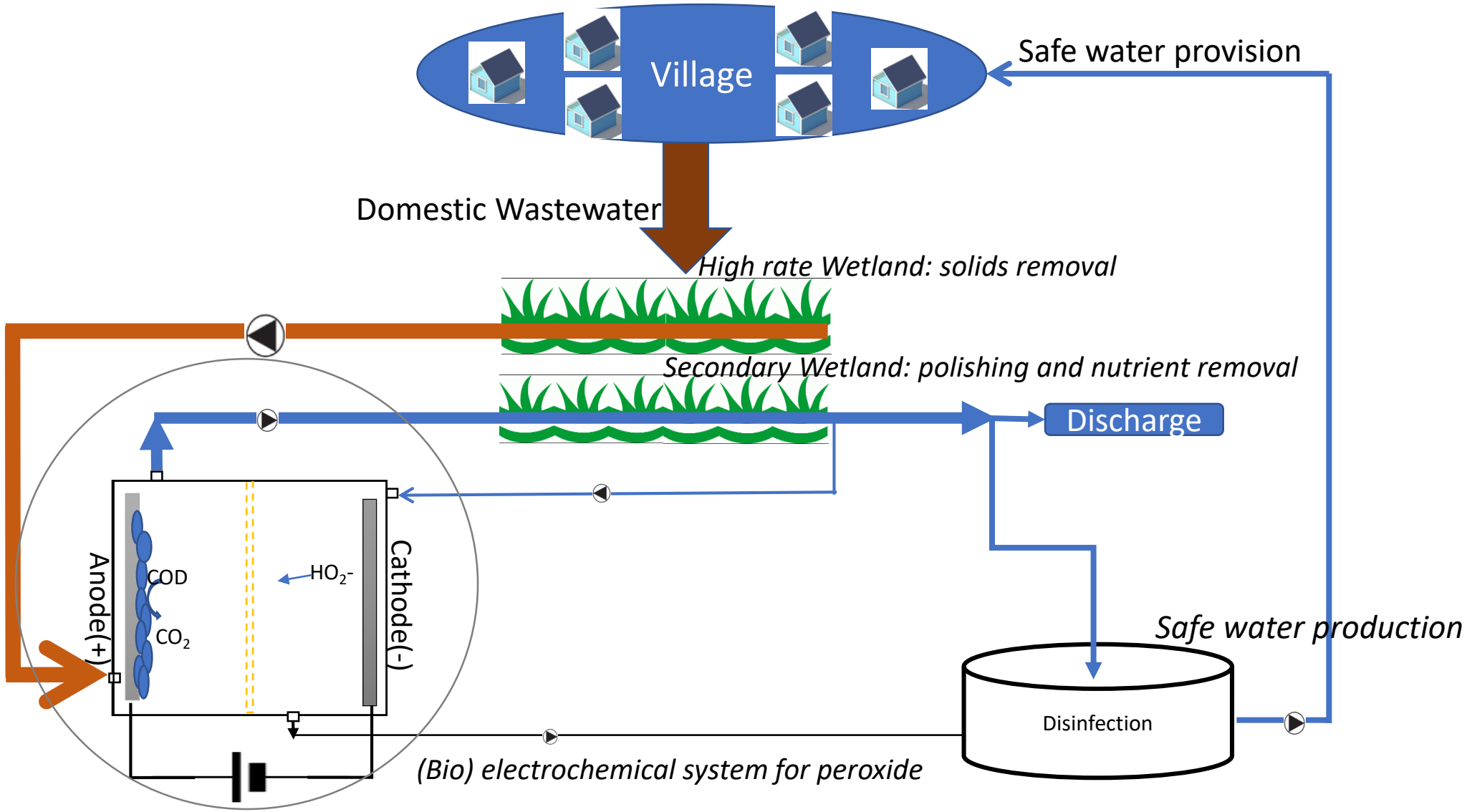


Peroxide production	Current densities/ Potential or Voltage applied	Power input	
1.3 g H_2O_2 L^{-1}	5.3 A m^{-2} at 0.5V	0.93 Wh g^{-1} H_2O_2	Rozendal, *et al.,* 2009
1.4 g H_2O_2 L^{-1}	7.7 A m^{-2} at 1 V	2.6 Wh g^{-1} H_2O_2	Simm *et al.,* 2015
9.7 g H_2O_2 L^{-1}	1.7 A m^{-2} at 11.8V	2.9 Wh g^{-1} H_2O_2	Modin and Fukushi 2013
3.1 g H_2O_2 L^{-1}	10.1 A m^{-2} at 0.31V	<0.4 Wh g^{-1} H_2O_2	Torres, *et al.,* 2018

- Appropriate for disinfection and micro pollutant removal (5-20 mg H_2O_2 L^{-1}) when coupled with UV and Fenton processes.

- Energy input for H_2O_2 significant less than the 10 Wh g^{-1} H_2O_2 by anthraquinone oxidation and 4−5 Wh g^{-1} H_2O_2 by electrochemical technologies.

Closed-loop decentralized systems

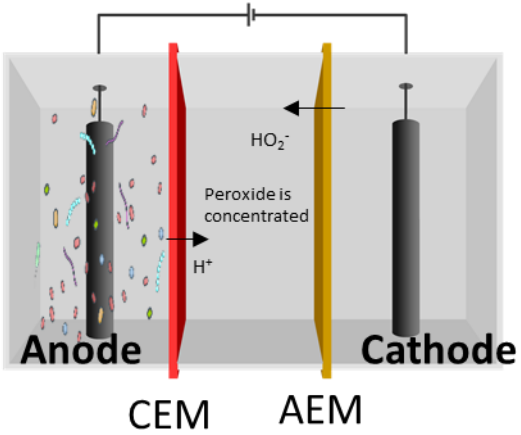


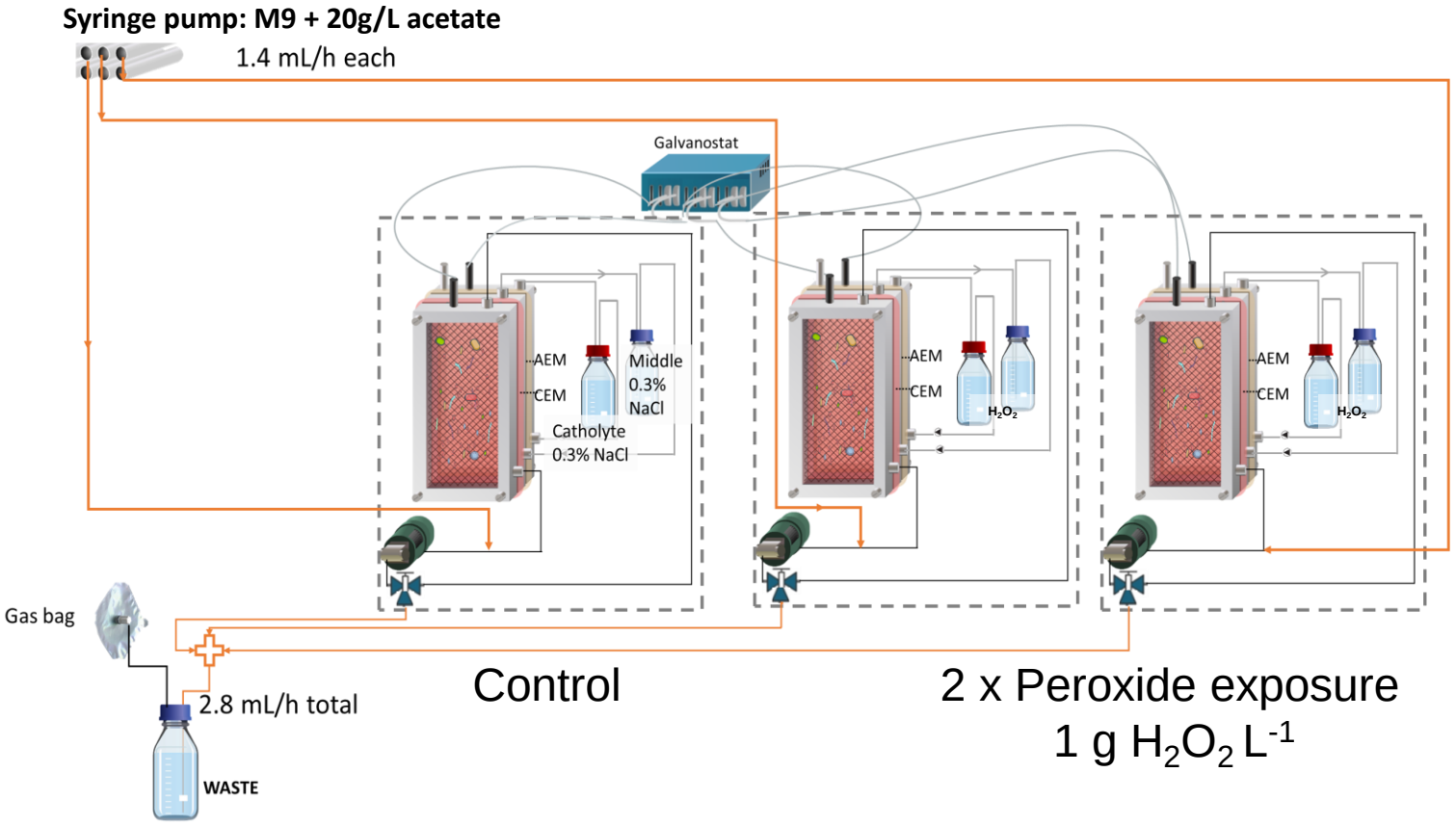
3. Research outcomes

Bioelectrochemical system performance exposed to > 1 g H_2O_2 L^{-1} during long-term

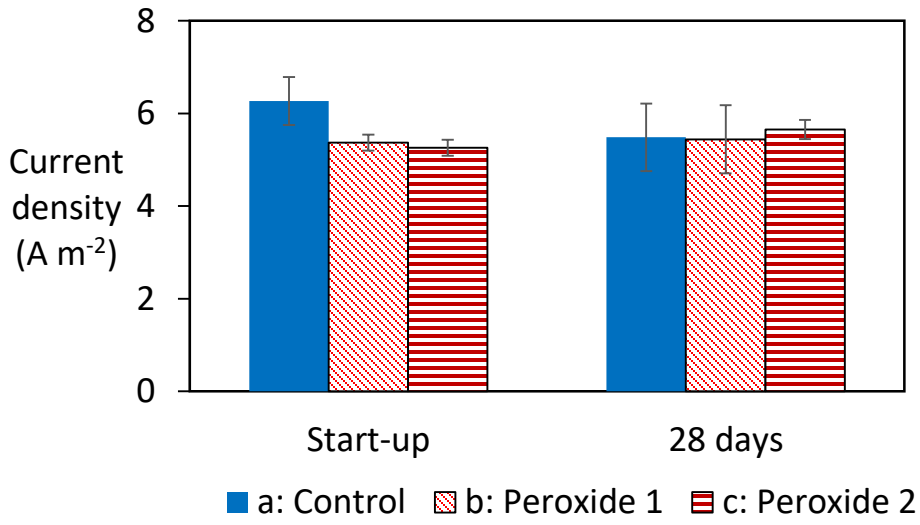
H_2O_2 can be <u>concentrated in a middle compartment</u> for post-disinfection purposes.

<u>Challenge: could interfere with the desirable microbial community in the bioanode</u>, affecting the performance during long-term.





✓ Current densities of duplicates <u>exposed to 1 g H_2O_2 L^{-1}</u> (load 0.5 g/day, 6day of HRT) in the middle compartment <u>were not affected during 28 days.</u>



Conclusions and insights

- 1 g H_2O_2 L^{-1} concentrated in a middle compartment do not alter bioanodes performance during a 28 days test.
- Higher concentrations of 5 g H_2O_2 L^{-1} showed a decrease in current densities after 15 days, and 30 g H_2O_2 L^{-1} provoke a drop in current production to zero within hours.
- A trade-off: organic load/ peroxide production/ up-concentration in a middle compartment should be analysed in more realistic scenarios for water disinfection.
- Preliminary results demonstrate the limits and feasibility for applying this idea in decentralized systems in areas of water stress.

MSc. Suanny Mosquera Romero
Suannysophia.mosqueraromero@UGent.be, suasomos@espol.edu.ec

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Questions?