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Fate of Engineered Nanomaterials in Constructed Wetlands

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The Big Picture

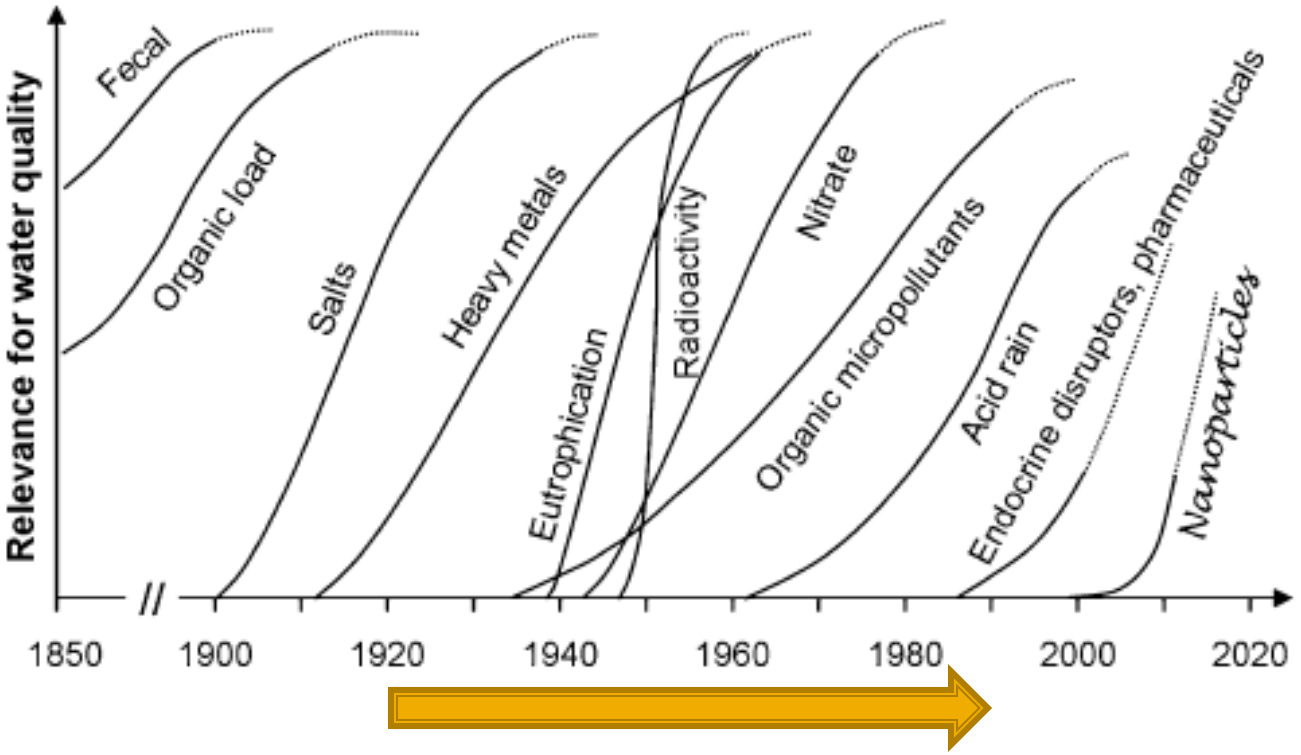
Technological revolutions

Pollution from residuals of products & tools
(Contaminants of Emerging Concerns)

Advanced Treatment
(Energy intensive)

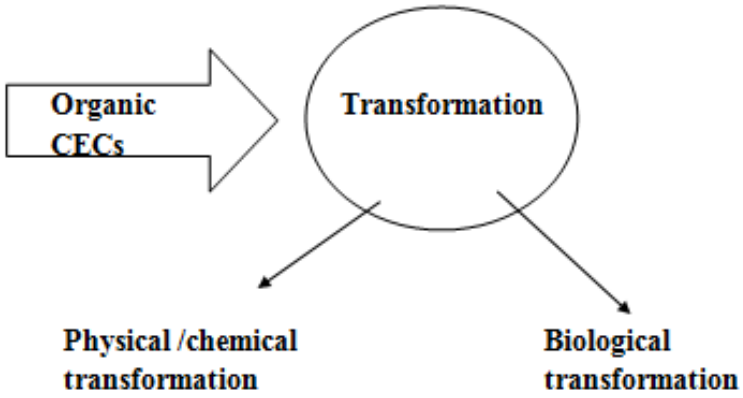
Natural attenuation
(Environmentally benign)

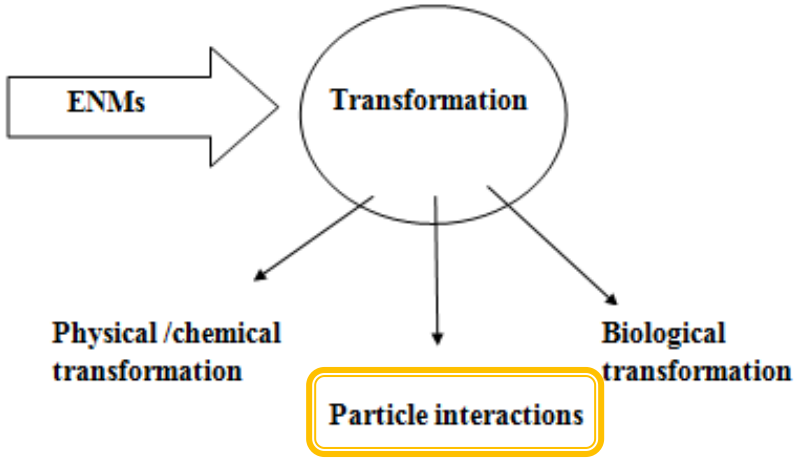
Significance on Water Quality

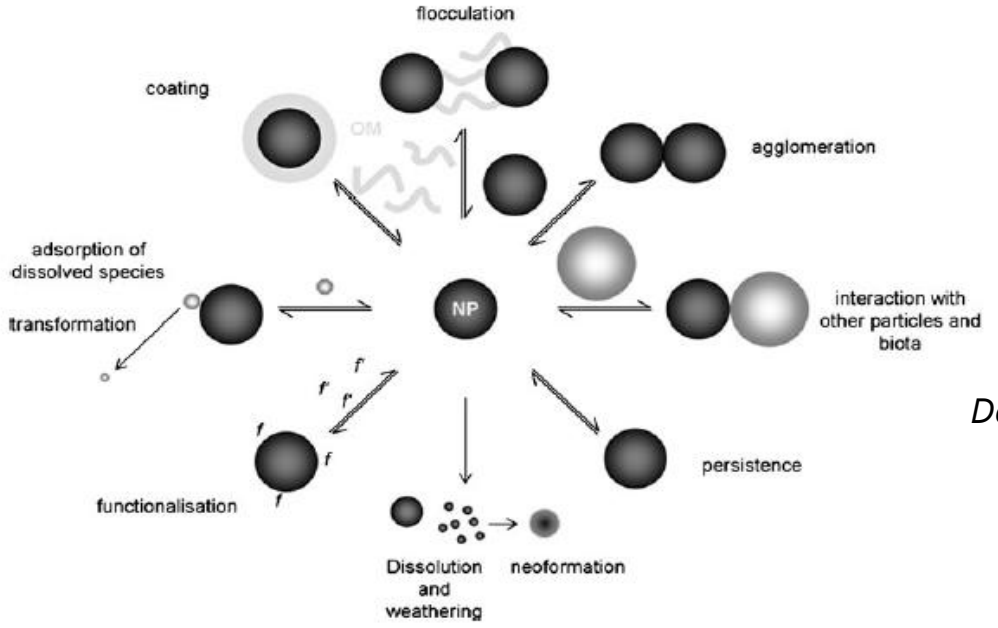


Meybeck & Helmer, 1989

Transformation in Aquatic Environment

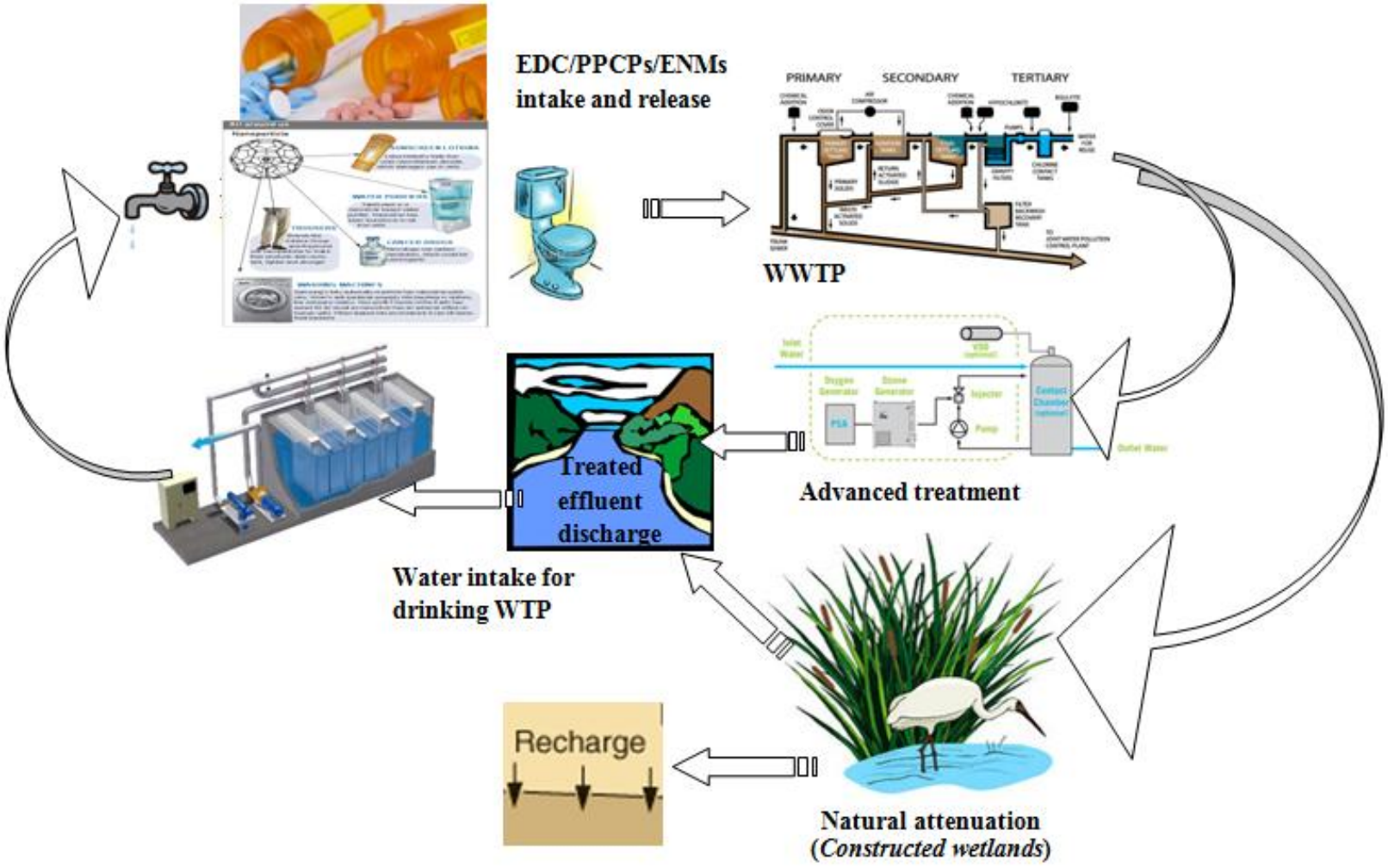






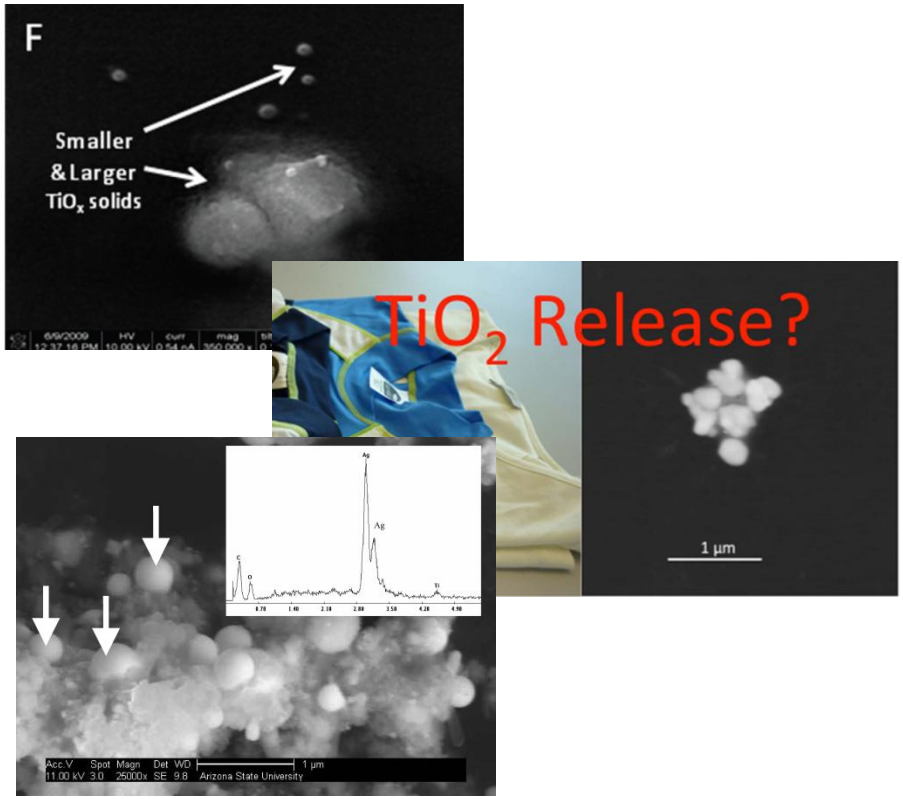
Delay & Frimmel, 2012

Contaminant Flow in the Environment



Current Knowledge on Fate of ENMs

Detection in Environmental matrices/samples (Including consumer products)



Fate and transformation (Simulated treatment processes)

Sorption to WWTP biomass (Restricts the use of wastewater biosolids for land application)

Conversion to sulfide species (sulifidation) e.g. Ag_2S, ZnS

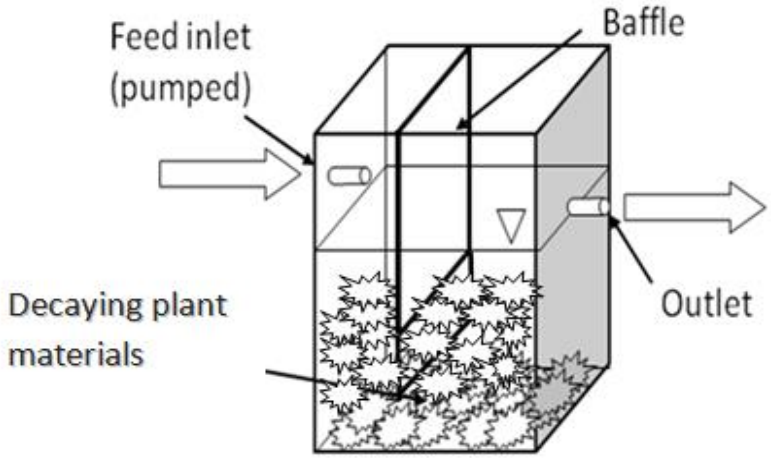
Windler et al., 2012,Lowry et al., 2012
Kaegi et al., 2011, Jarvie et ak., 2009
Kiser et al., 2009, Benn and Westerhoff, 2008

Constructed Wetlands- 'Natural Treatment Systems'

- Currently used to treat bulk and organic pollutants
- Limitations for application as a treatment system
  - Contaminants loading rate affects hydraulic retention time (HRT), wetlands size

Loading rate ↓ **HRT** ↑ **Wetland size** ↑

Wetland Microcosm Approach



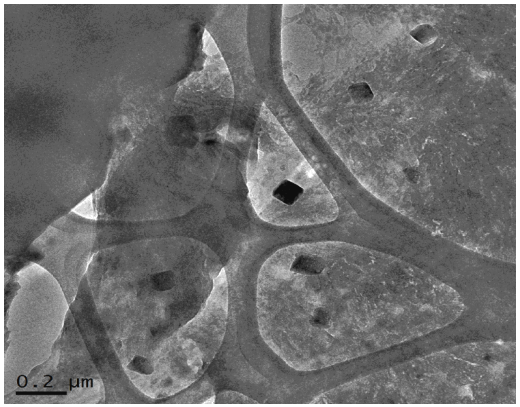
- **Microcosms mimic**
  - Growing plants of wetlands senescing in water
  - Leaching of DOC during plant decomposition

- **Significance on Fate of ENMs**
  - Organics can stabilize ENMs
  - ENMs can sorb onto organic rich plant biomass

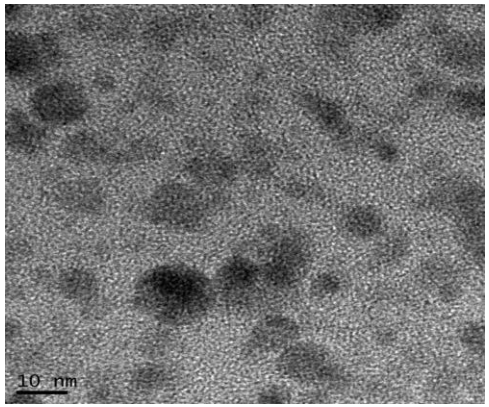
Investigation Using Microcosm Studies

- Effect of HRT on ENM removal
- Possible Removal mechanisms
  - Approach- 'Pulse input of ENMs'

Aqueous fullerene (aq-*n*C_{60})



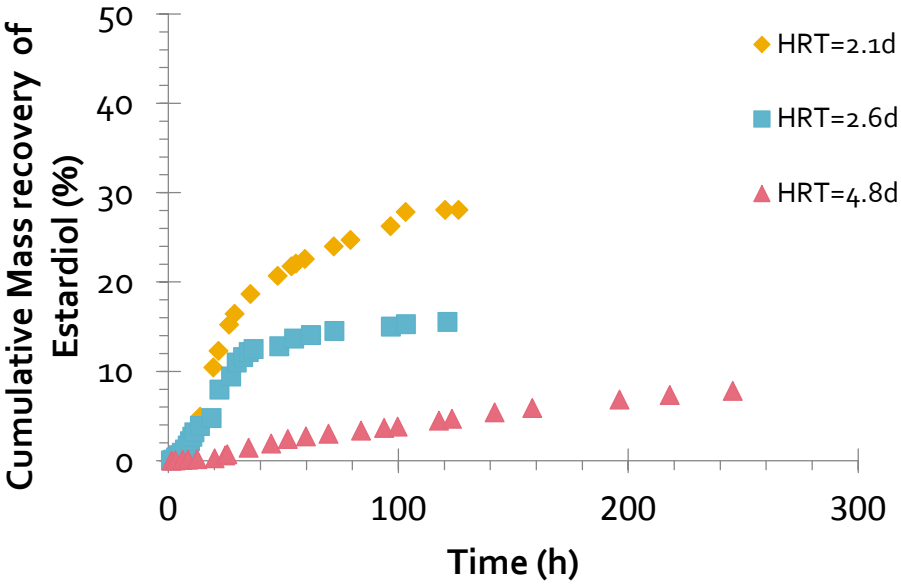
Functionalized Nano silver (*fn*-Ag)



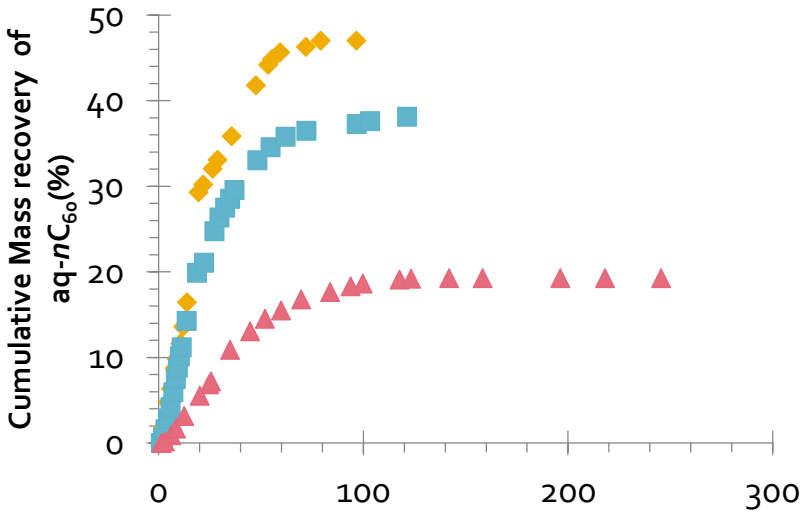
ENMs in WWTP biomass

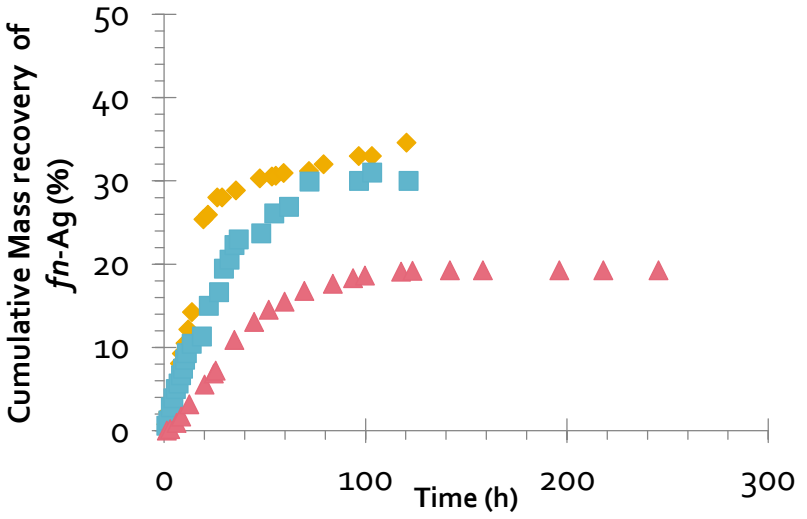
Comparable Removal of aq-nC_{60} and *fn*-Ag with Organic CECs in Microcosms

Example CEC: Estradiol



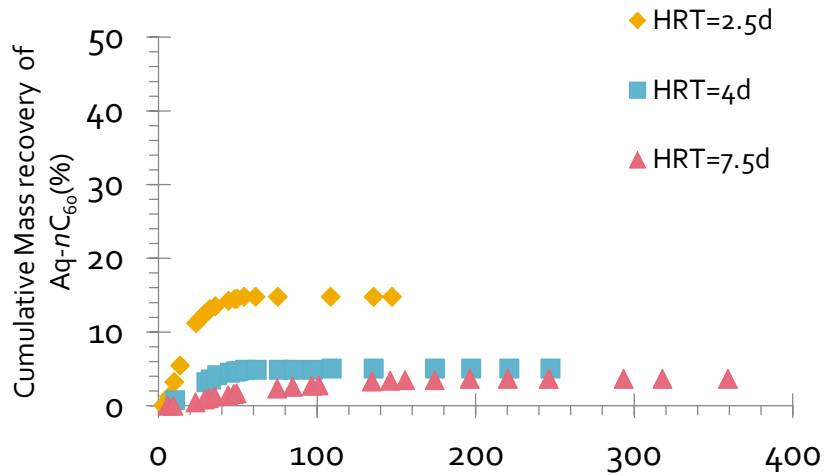
Mass recovery decreases with increasing HRT
'Better removal at longer HRT'

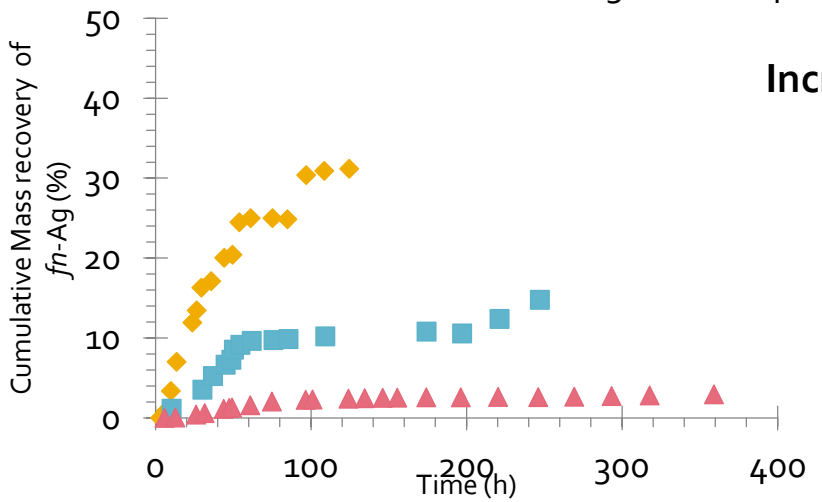




aq-nC_{60} and *fn*-Ag removal in Microcosms

Higher Plant biomass (accumulation with time)

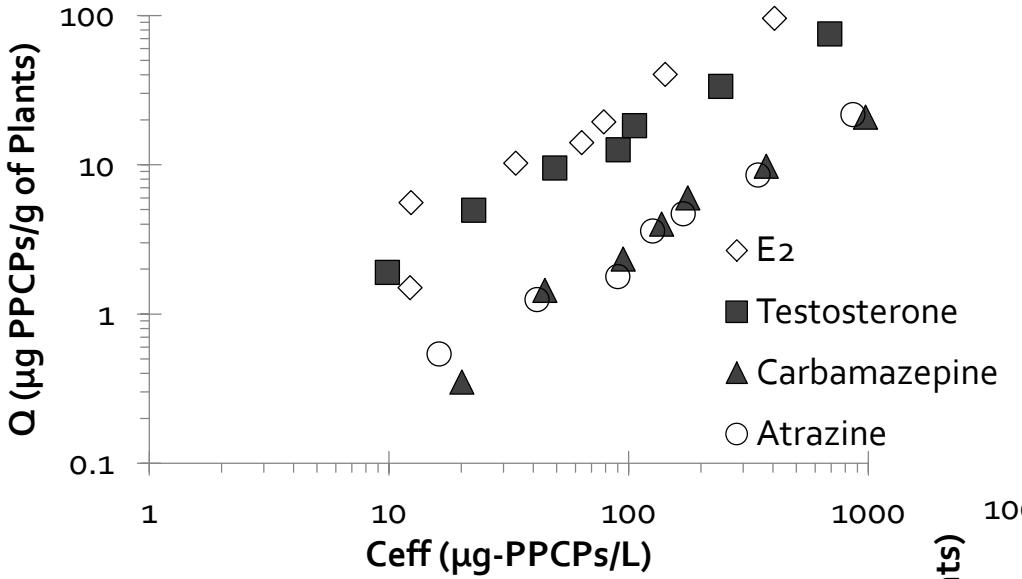


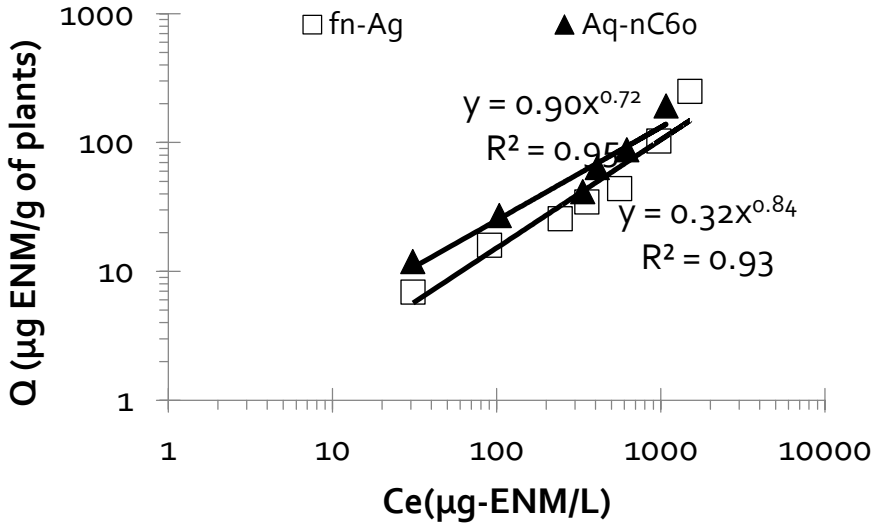


Increasing plant biomass causes better removal of ENMs

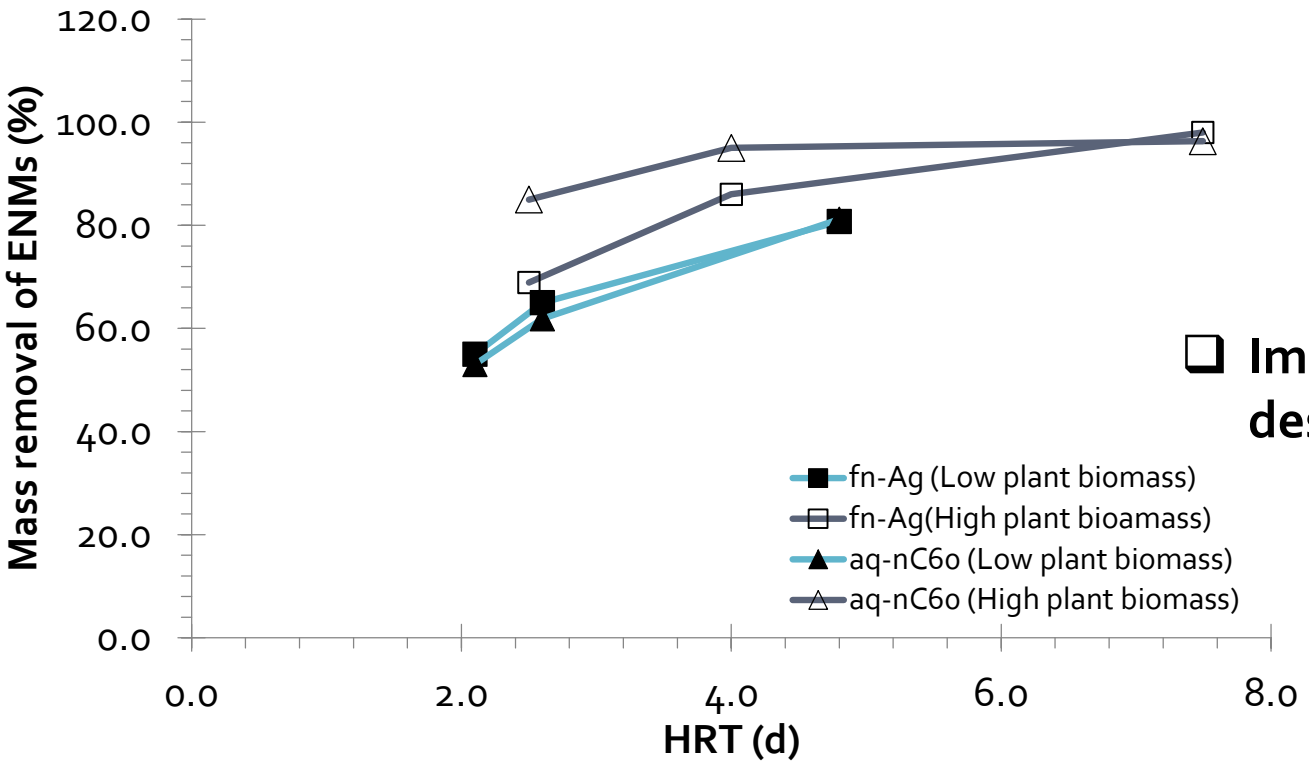
Sorption could be the major removal process

Sorption to Wetland Plant Materials



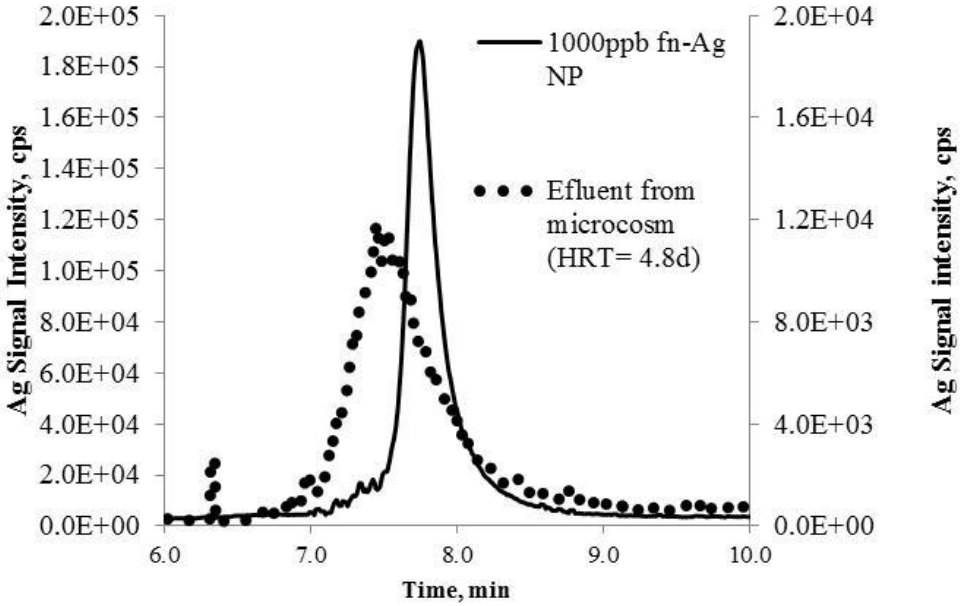


Effect of HRT on ENM Removal

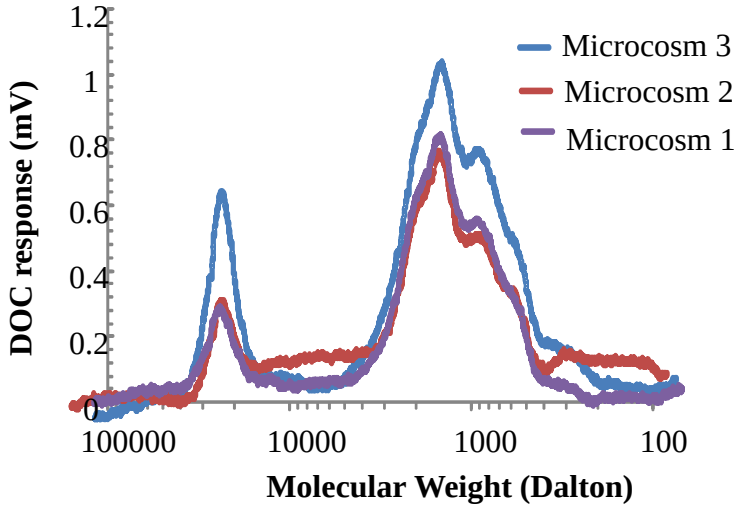


- Implication on wetland design and operation

Size Distribution of Ag NMs in Microcosm Effluent



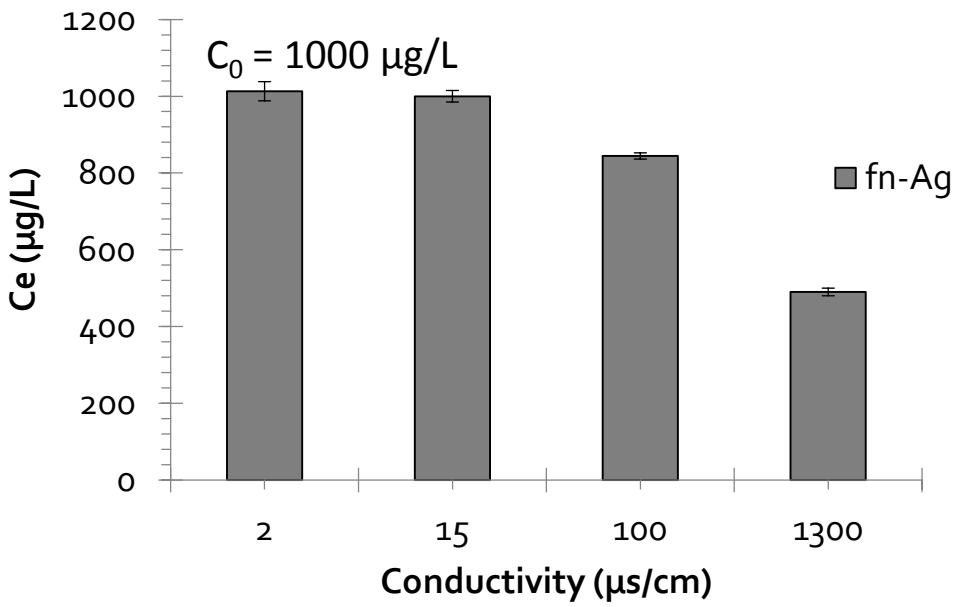
Silver is "larger" coming out than going in



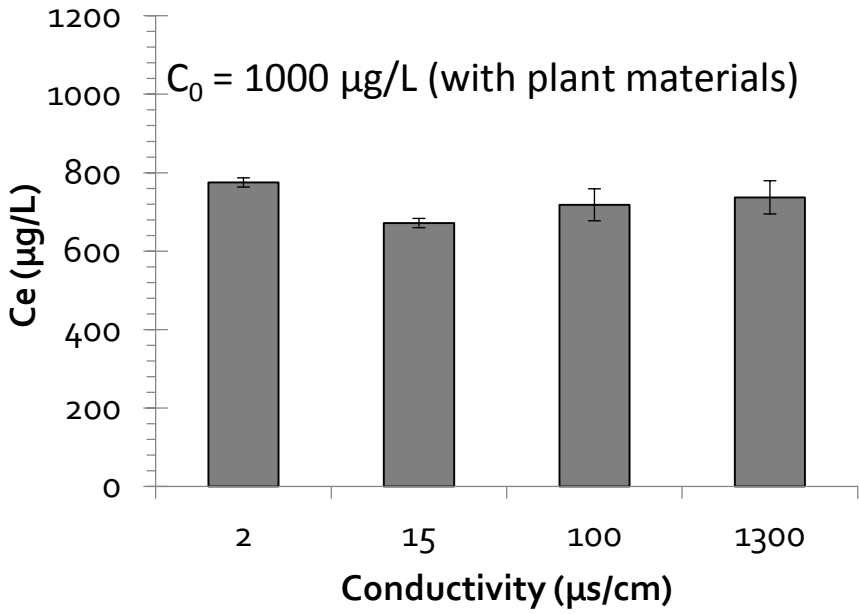
- ❑ Colloidal organics and humics exit wetlands
- ❑ Facilitated transport of *fn*-Ag (and potentially other CECs) on wetland colloids

Influence of Wetland Water Matrix

- Microcosm influent water
  - **Filtered tap water with nutrients (1300 µs/cm)**



- **When wetland plants are present**

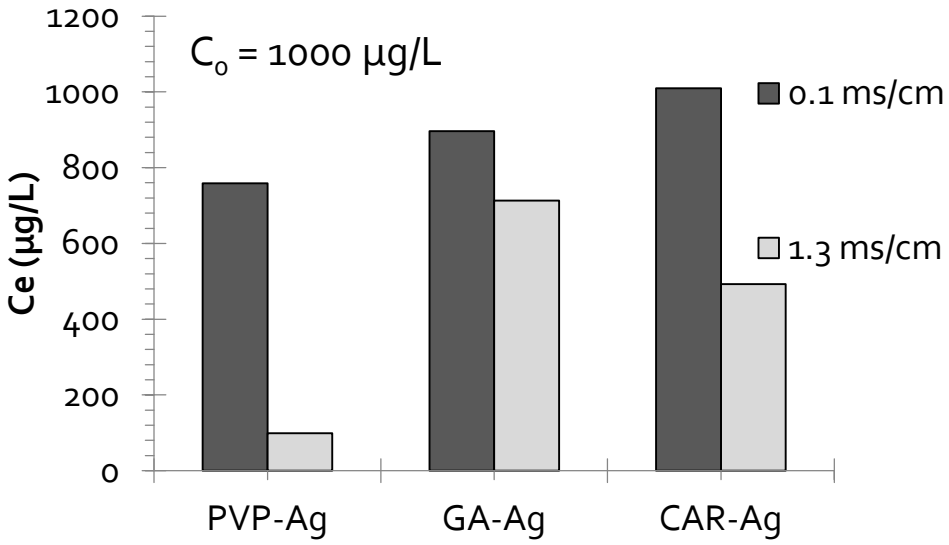


DOC leached from hydrated wetland plants stabilize ENMs

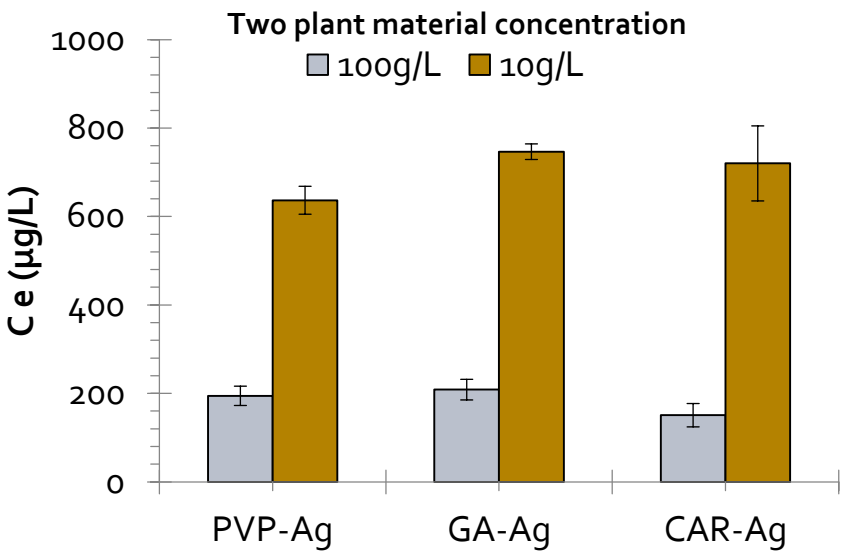
Effect of Surface Coating on Ag NM Stability and Sorption

- **Stability of different types of surface coated Ag NMs**

PVP-coated, Gum Arabic (GA) and Carboxylated



- **Effect of surface coating on sorption**



Conclusions

- ***Design and operating criteria (HRT, plant growth)*** influences ENM removal in constructed wetlands.
- ***Sorption onto the wetland plant materials*** can be considered a major removal mechanism for ENMs in wetlands.
- ***Wetland water matrix (ionic strength, DOC leached by plants)*** significantly affects fate of ENM in the aquatic environment.

Acknowledgements

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Thank you.