Workshop

Drug lifecycle control in Subsaharan Africa

From production to responsible safe disposal and elimination in wastewater treatment plants

(Med4Africa)

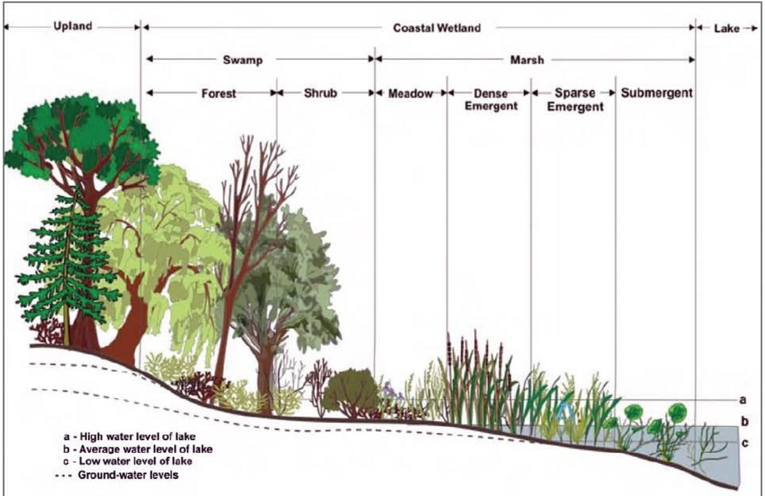
The potential of constructed wetlands to treat different waste water including emerging components.

Uwe Kappelmeyer

September 1. 2022

Introduction - Constructed Wetland (CW)

Artificial wetland



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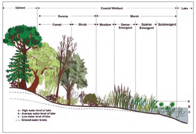


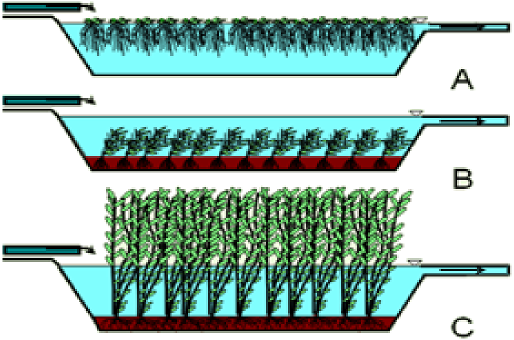
Engineered systems use natural functions of vegetation, soil, and organisms to treat different water streams

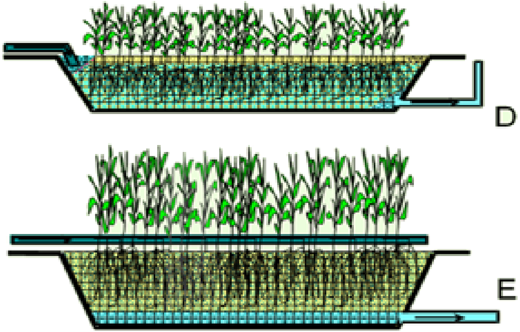
Classification based on filter matrix and flow behavior

Treating anthropogenic discharge

Introduction - Types of ponds / CWs

- **A** Pond with free floating plants
- **B** Pond with submersed water plants
- **C** Pond with emersed water plants
- **D** CW, horizontal subsurface-flow
- **E** CW, vertical flow





Construction phases of the first module Teneria Europea – Leon, Mexico

Pros and Cons for Constructed Wetlands in Waste-water Treatment

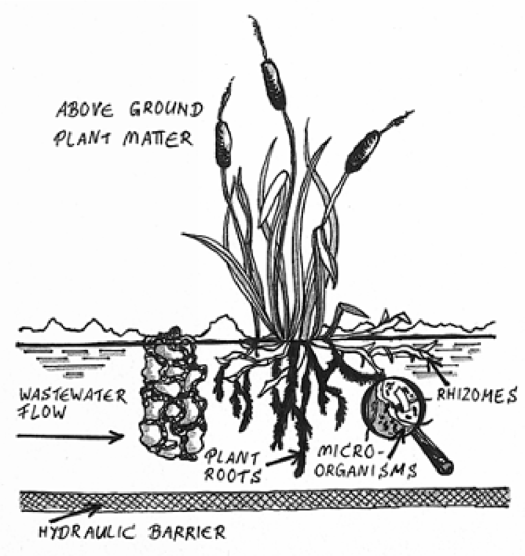
pros

1. Low investment technique
2. Low power requirement
3. Low costs of maintenance
4. Close to nature plant
5. One's own contribution

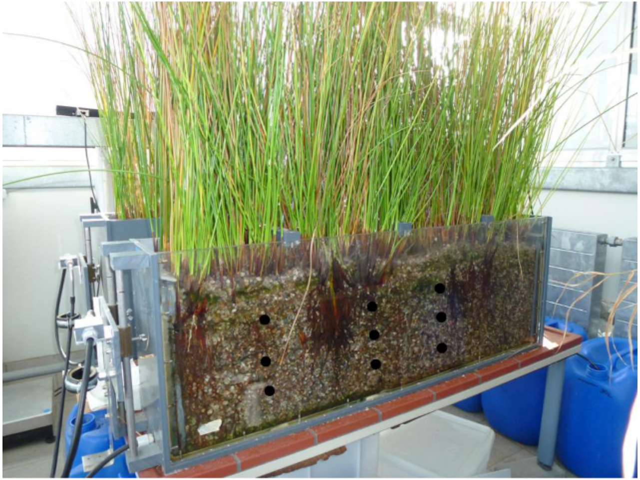
cons

1. High area requirement
2. Control cleaning efficiency
3. Effects of seasonal influence

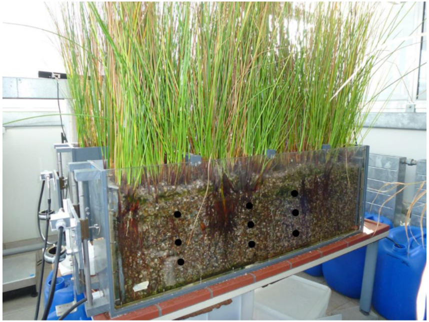
Elements of a CW



Elements of a CW



Elements of a CW



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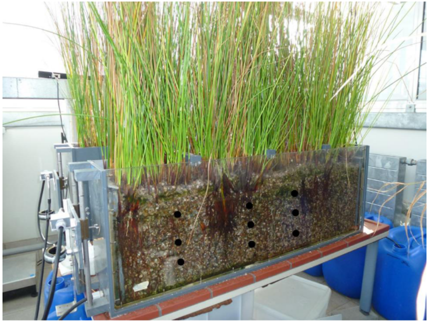
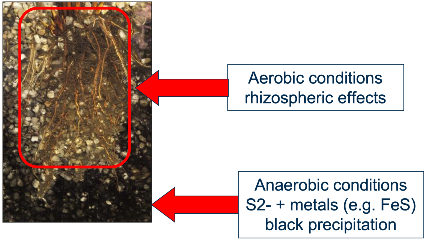
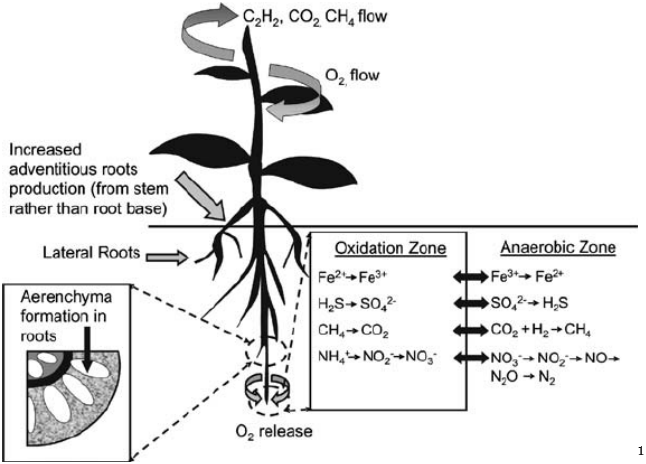




Elements of a CW



[1]

[1] Hodge et al. (2009) "Plant root growth, architecture and function", Plant and Soil 321(1):153-187 - DOI:10.1007/s11104-009-9929-9

Alexandra Township - URBWAT Project

Accessible GreyWATer Solutions for URBan Informal Townships in South Africa

EU WaterJPI Project: 3 Partners (Craig Sheridan - University of the Witwatersrand, Johannesburg, Uwe Kappelmeyer - UFZ, Genevieve Metson, Karin Tonderski - Linköping University)

Problem:

- 54% of world population lives in cities (in 2014) [2]
- 62% of Africa urban population live in informal settlements

Aim: Wastewater treatment studies and technology development are combined in multidisciplinary interaction with the local community. For this purpose, individual small-scale sewage treatment plants are built in a slum and operated by the local community and scientifically accompanied by the URBWAT consortium.

[2] UN-HABITAT 2015

Alexandra Township - URBWAT Project

Accessible GreyWATer Solutions for URBan Informal Townships in South Africa

UFZ Project topics:

- Lab based assessment of treatment efficiency for different loads
- Monitoring of CW in Alexanda (SA)
- Describing and modeling treatment and flow behavior during pulse loading

Producct: Guidlines for tailor-made wetlands for greywater treatment in urban slums

Geywater Overview - URBWAT Project

Grap sample collection during the first field trip

analyzed for COD ($610 \pm 500\,\mathrm{mg\,L^{-1}}$), PO_4^{3-} ($0.67 \pm 1\,\mathrm{mg\,L^{-1}}$), NH_4^+ ($21.78 \pm 6.3\,\mathrm{mg\,L^{-1}}$), NO_3^- ($1.5 \pm 0.75\,\mathrm{mg\,L^{-1}}$) and emerging components

42 components analysed on a LC-MS (Sciex)

Table: LC-MS results of selected emerging components. Values in $\mathrm{ng\,mL^{-1}}$

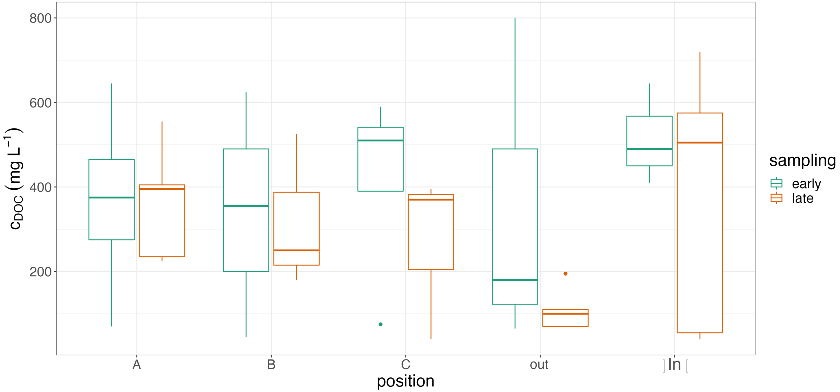
	Ibuprofen	Diclofenac	Acesulfam	Sucralose	Nicotine
grap sample (bucket)	0.31±0.2	0.1±0.09	85.1±115.2	3.29±4.14	5.7±1.9
Juksey River	0.67±0.6	0.35±0.05	15.8±8.8	3.5±0.2	0.2±0.02
min. $c_{min,cal}$	0.1	0.01	0.01	0.1	0.1

Geywater CW Alex - URBWAT Project

CW $18.5\,m^2$

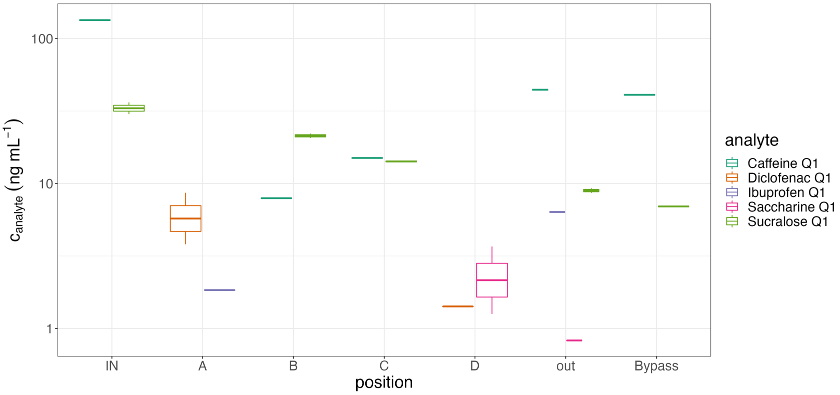
monitored over longer period

DOC in CW Alex

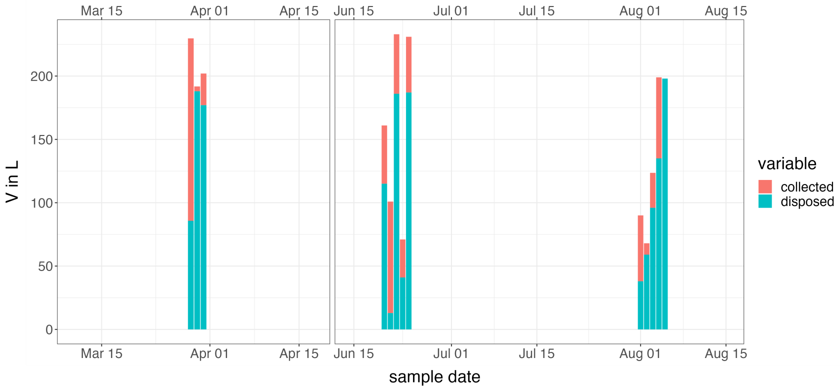


COD concentration in the demonstration CW from inflow to outflow including internal samples shows high variability and no significant trend in removal

Emerging components in CW Alex



Concentration of selected emerging components samples at the demonstration CW in Alex.



Water disposal at the demonstration CW during sample phase shows high variability

Joburg Samples

- in-situ: pH, redox, T
- analyzed on site at WITS (COD; PO_4^{3-}, SO_4^{3-}, S^{2-}, NH_4^+, NO_3^-)

    cold and dark transport
- transported to Germany and analyzed at UFZ

    cold and dark transport

    frozen and on dry-ice DHL

    filtered and acidified

    ...

Lab Systems

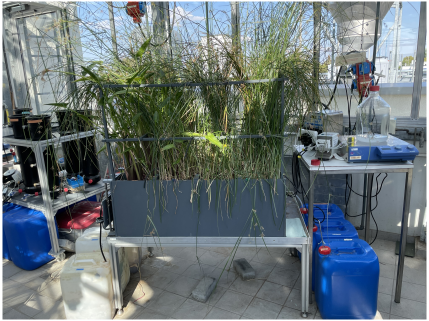


Figure: 1 m subsurface horizontal flow CW

Figure: **P**lanted **F**ixed Bed **R**eactor

PFR - Planted Fixed Bed Reactor

- Idealized model reactor for wetlands
- Ideal (mixed) flow condition
- Independence of sample location
- Automated recording of pH, redox, dissolved oxygen and weather condition

PFR - behavior of Selected Emerging Comp.

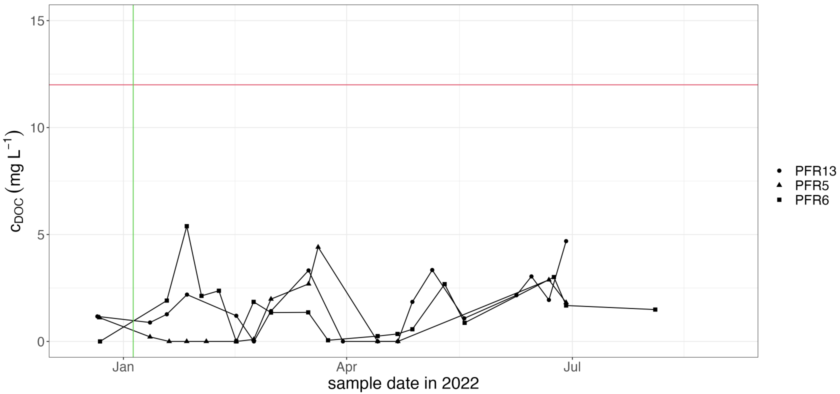


Figure: DOC concentration pattern in PFR

Lab based Experimental Systems

Ibuprofen not detectable (< 0.1 ng/ml) in the PFR; inflow ranged about 100 ng/ml; analytically method: direct injection in HPLC-MS/MS

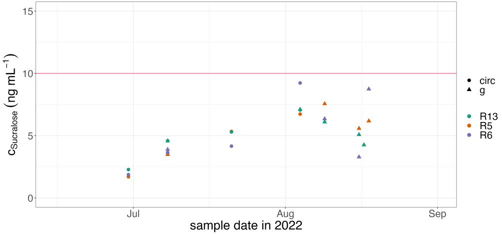


Figure: Sucralose concentration in PFR

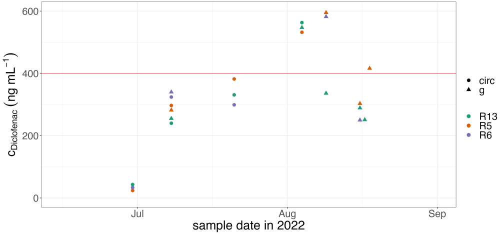


Figure: Diclofenac concentration in PFR reactor

Increasing Ibuprofen Degradation by Bioaugmentation

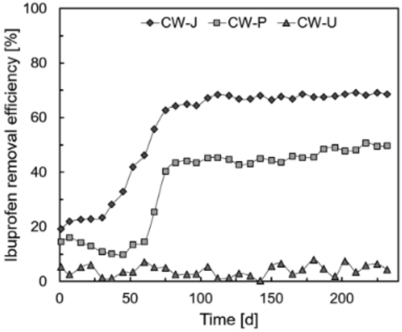


Figure: Ibuprofen removal efficiency of the constructedwetlands planted with *Juncus effusus* (CW-J), *Phalaris arundinacea* (CW-P) and an unplanted system (CW-U)

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[3] E.M.Balciunas, U.Kappelmeyer, H.Harms, H.J.Heipieper (2920) Increasing ibuprofen degradation in constructed wetlands by bioaugmentation with gravel containing biofilms of an ibuprofen-degrading *Sphingobium yanoikuyae*, Eng Life Sci. 2020;20:160–167 - DOI: 10.1002/elsc.201900097

Increasing Ibuprofen Degradation by Bioaugmentation

Bioaugmentation with *Sphingobium yanoikuyae* a ibuprofen-degrading strain isolated from Langenreichenbach CW[4]

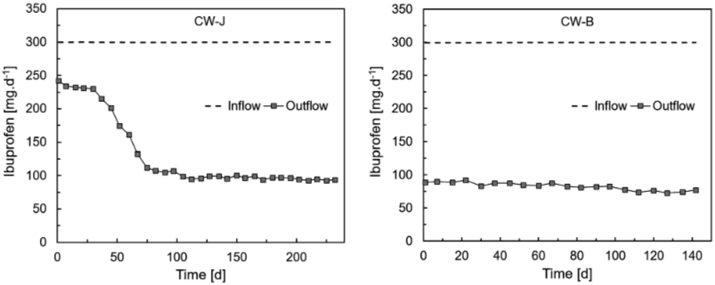

Figure: Ibuprofen load of an untreated constructed wetland planted with *Juncus effusus* (CW-J) and one planted with *Juncus effusus* to which gravel loaded with biofilms of *Sphingobium yanoikuyae* were incorporated (CW-B)

[4] E.M.Balciunas, U.Kappelmeyer, H.Harms, H.J.Heipieper (2920) Increasing ibuprofen degradation in constructed wetlands by bioaugmentation with gravel containing biofilms of an ibuprofen-degrading *Sphingobium yanoikuyae*. Eng Life Sci. 2020;20:160–167 - DOI: 10.1002/elsc.201900097

Thank you

Asante sana kwa kusikiliza. Na sasa nimefurahi kujibu maswali yako.