UNIVERSITY OF HOHENHEIM
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Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute) (490)

Ozonation to enhance plant based mining of metals from polluted water

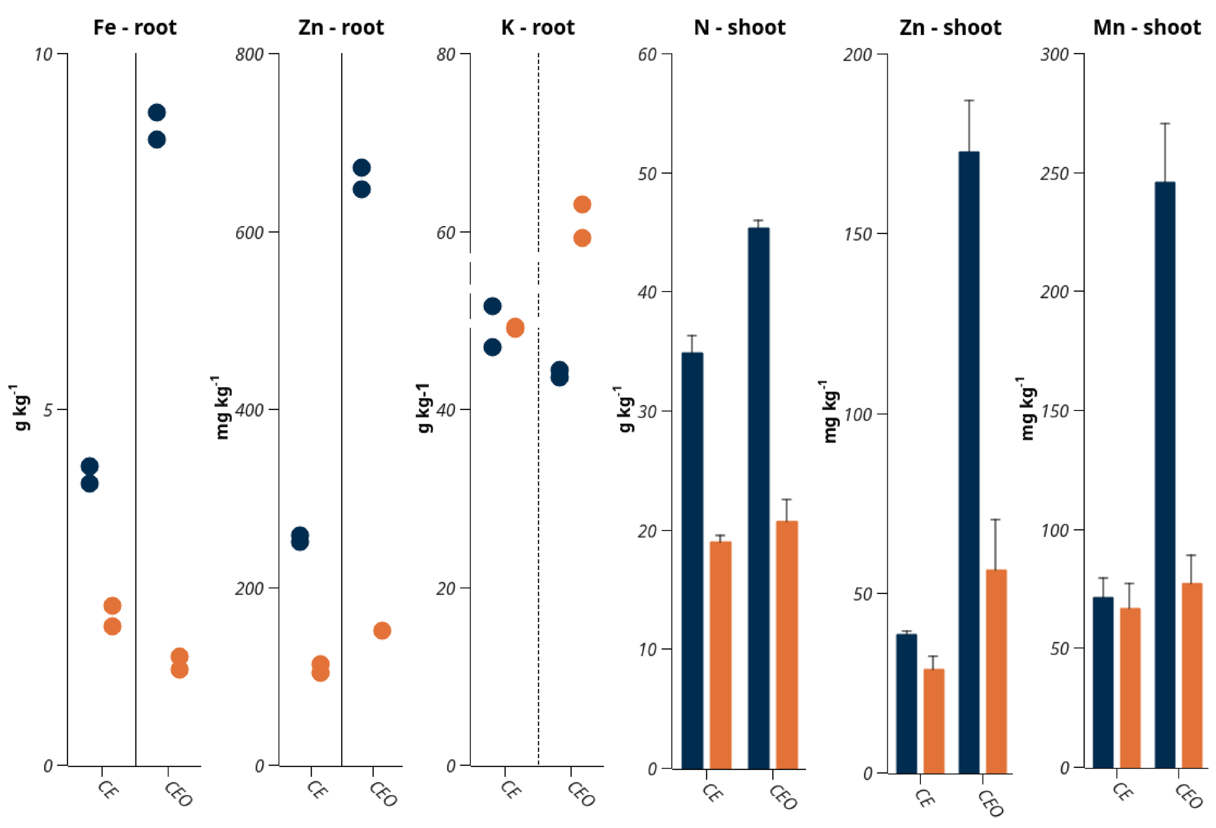
Potential use of a coincidental observation – Jörn Germer & Folkard Asch

Experimental ozonation unit & lettuce grown with treated wastewater

Water treatment by ozonation

The effect of ozon treatment on the biological and chemical pollution of hydroponically lettuce grown in treated municipal waste water was validated[1]. Following additional observations were made:

- Lettuce depleted N from 1.25 to 0.25mg/l between in- & outflow.
- Ozonation increased the N content in the roots and shoots as well as the fresh biomass.
- The root Fe and Zn contents and shoot Ca, Mg, Mn, Zn and Cu contents were increased by 100 to 200% by ozonation.
- The contents of the heavy metals As, Cd, Co, Cr and Pb increased also. Heavy metals contents in the shoot remained, however, always below current threshold values.



Effect of ozonation on selected nutrient concentrations in lettuce (blue = front and orange = end of pipe)

Improved N availability and induced Fe starvation

We postulate i) that the ozonation led to degradation of organic and inorganic compounds improving the availability of contained N and ii) that ozone enhanced the oxidation of metals contained in the treated waste water and their consequent settlement on the roots. The roots in turn exuded protons into the rhizosphere to reduce Fe^{3+} to facilitate the uptake, but either these protons reacted with remnant ozone or reduced Fe was immediately oxidised again. To counter-balance the constant proton loss roots took up other oxidised divalent metals. To keep the cation-anion balance the uptake of nitrate increased as well.

The same effect led to the accumulation of divalent Cd, Co and Pb in the front, while the trivalent Cr content was higher in end of the pipe. The high heavy metal content of the roots indicates efficient root mat filtration of oxidised metals.

Line˅	Lettuce dry matter heavy metal content in μg kg^{-1}									
	As		Cd		Co		Cr		Pd	
Section˃	front	end	front	end	front	end	front	end	front	end
CE shoot	**34** 53 (1)					**35** 62 (1)	**576** 1258 (6)	**934** 1909 (6)	**93** 122 (6)	**70** 110 (5)
CEO shoot	**34** 52 (1)		**111** 122 (6)	**34** 55 (1)	**72** 114 (5)	**56** 133 (2)	**603** 1234 (6)	**2078** 7423 (6)	**254** 983 (6)	**104** 249 (6)
CE root	**696** 729	**354** 378	**198** 206	**66** 71	**43208** 47416	**19824** 20607	**8120** 8902	**5283** 6378	**3369** 3474	**1018** 1023
CEO root	**1973** 2025	**419** 451	**492** 495	**120** 123	**60968** 66373	**12436** 13952	**14829** 16511	**6153** 7148	**7458** 7542	**1272** 1372

Heavy metal loads in the dry matter of shoots (n=6) and roots (n=2) of lettuce irrigated with CE and CEO. Average (bold), maximum (plain) and frequency of detection (in brackets).

Potential application for combined ozonation and hydroponics

- Coupling tertiary waste water treatment with hydroponics lowers the biological N removal demand, reducing the plants operating costs.
- Hydroponic pre-post ozonation could represent a cost efficient drinking water treatment option where ground or surface water contains high concentrations of nitrate and metals. Facilities using ozone to remove Fe and Mn from drinking water could be easily expanded by hydroponic filtration.
- Mining of specific divalent metals from water for concentration and extraction.

Materials and Methods

- The experiment was part of the BMBF funded HypoWave project (02WAV1402) conducted at the Hattorf municipal waste water treatment plant (www.hypowave.de). Partner: aquadrat, ACS-Umwelttechnik, Abwasserverband Braunschweig, aquatectura, aquatune, BIOTEC, Fraunhofer-Institut für Grenzflächen- und Bioverfahrenstechnik, Institut für sozial-ökologische Forschung, Technische Universität Carolo-Wilhelmina zu Braunschweig, Julius Kühn-Institut, Wolfsburger Entwässerungsbetriebe.
- The hydroponic setup consisted 8 m long pipes with an inner diameter of 100 mm. Each pipe had a capacity of 68 lettuce plants. The total daily through-flow per pipe was 565 l.
- Plant samples were analysed by the Core Facility Hohenheim. Concentrations of Fe, Zn, K and Mn were determined with ICP-OES, N with the combustion method and heavy metals with ICP-MS.

References

[1]doi: 10.1007/s11356-021-14144-6, [2]doi.org/10.2166/wrd.2020.014