AquaNES

Demonstrating Synergies in Combined Natural and Engineered Processes for Water Treatment Systems

Towards indirect potable reuse: the role of enhanced oxidation before soil aquifer treatment

1. Current challenges in conventional Soil Aquifer Treatment (cSAT) operation

- Current capacity of cSAT fields: 130 Mm^3/y
- Solution fir 2040 development goals for infiltration of 160 Mm^3/y
- Average residence is long, typically between 6-12 months.
- Carbamazepine (CBZ) levels in most cases >300 ng/L (MCL set by the German Federal Environmental Agency)
- Ozonation combined with a short SAT (sSAT – 22 days) can be used for lowering TrOCs level and potentially allowing more water to infiltrate

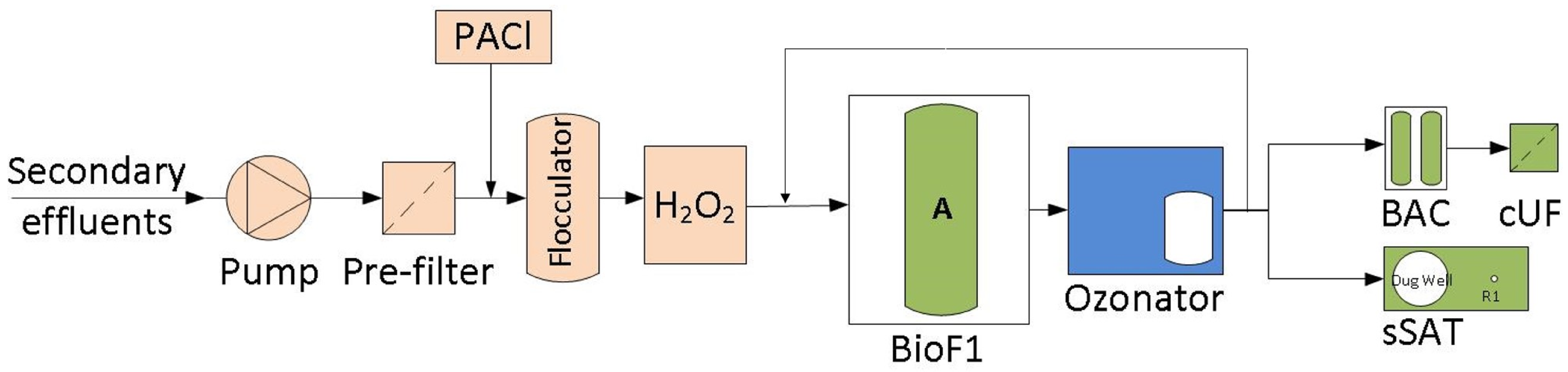

Figure 1. Scheme of the ozonation treatment trains in the pilot plant

2. Demonstrated solutions and aim of the study

Two treatment trains were compared (Figure 1):

- Fully engineered: O_3 – BAC - ceramic UF
- Combined natural and engineered: O_3 - sSAT

The main goals:

- Compare the effect of sSAT residence time with that of the cSAT (typically 6-12 months) with respect reclaimed water quality
- Compare the effect of the engineered (BAC-cUF) and natural (sSAT) polishing treatments
- Reduce operational costs by:
  1. lowering the amount of chemicals used in the process (H_2O_2)
  2. attempting to recirculate ozonated water back through the BioF for further treatment.

Table 1. operating conditions and water quality of cSAT and sSAT

Parameter	Units	cSAT	sSAT	MCL (raw)	MCL (supply)
Res. time*		6-12 mo	22 d		
DOC	mg/L	0.4-0.9	1.0-1.1		
UVA	1/m	0.8-3.2	1.6-3.0		
CBZ	ng/L	121-1650	99-400		
Total bact.	cfu/1ml	0-220	360-750	1000**	--------
Tot. Coli	MPN/100ml	ND	ND	50***	0
Fecal coli.	MPN/100ml	ND	ND	10***	0
Fecal strep.	MPN/100ml	ND	ND	10***	0

**Typical residence time; **Israeli regulations for drinking water wells(1995); ***Israeli regulations for drinking water quality (2013)

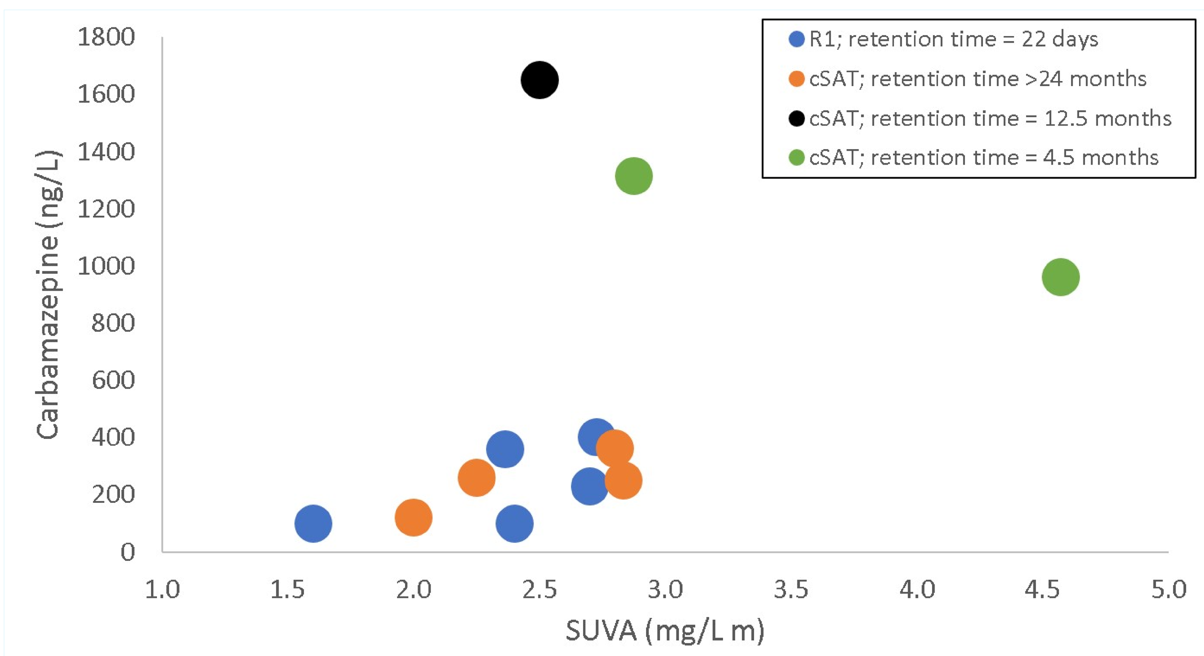

Figure 2. CBZ vs SUVA in R1 and in wells producing water from the Shafdan cSAT. cSAT samples were collected during 2017-2018

3. Performance of the treatment train

cSAT *vs* sSAT

- CBZ at the sSAT were similar to cSAT samples with residence time >24 mo. and significantly lower than cSAT samples with shorter residence times (Figure 2).
- DOC and pathogen indicator bacteria had similar values (Table 1).
- TOTB was lower than allowed by regulations for both cSAT and sSAT (Table 1).
- TrOCs were very low after the sSAT (Table 1); CBZ was below 300 ng/L when continuously infiltrating ozonated water.

O_3 – sSAT *vs* O_3 – BAC - cUF

- DOC, TrOCs and bacterial counts were higher after the fully engineered O_3-BAC-cUF treatment train.

System performance

- Pre-treatment and ozonation were operated using 25% less H_2O_2 and 27% less O_3 (based on the ratio of O_3/DOC) as compared to a similar system used before (Figure 3; Demoware, FP7, Lakretz et al., 2017)

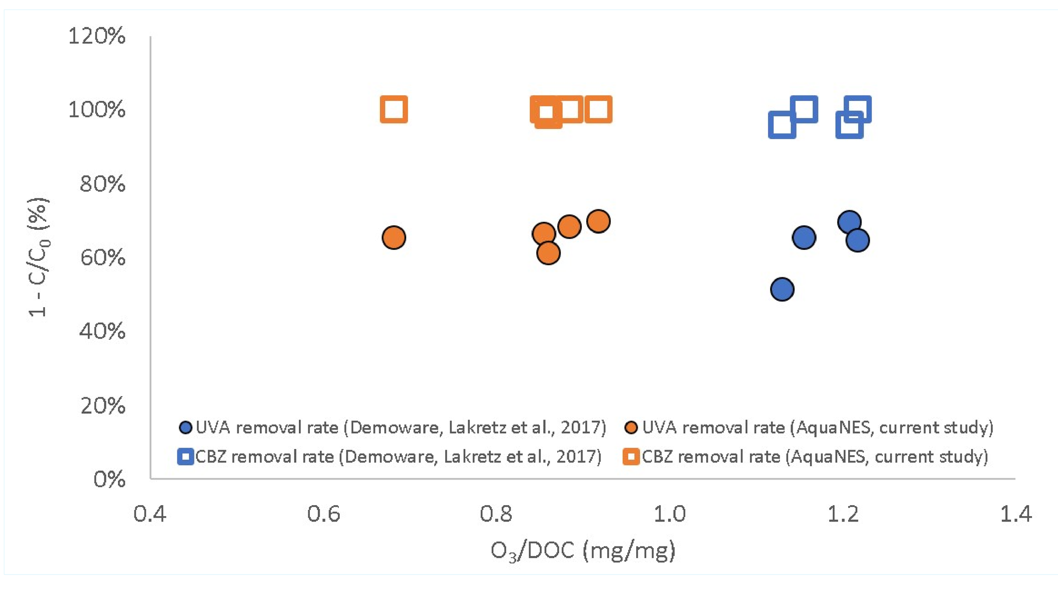

Figure 3. CBZ and UVA removal rates after ozonation vs the ratio of ozone to DOC, which represents the energy consumption of the ozonation step. Blue data points represent previous research which used 28 mg H_2O_2/L, HRT of 4.5 min, and a BioF flow velocity of 5.8 m/hr. Red data points represent the current study, using 21 mg H_2O_2/L, HRT of 9 min, and a BioF flow velocity of 6.2 m/hr.

Table 2. Average TrOCs and ozonation by products along the ozonation treatment trains and related target maximum concentrations based on available IPR regulations

Water type	n	TrOCs									Ozonation by-products	
		IPDL ng/L	IHX ng/L	IPRM ng/L	Ibuprofen ng/L	Naproxen ng/L	BZF ng/L	CBZ ng/L	DCF ng/L	SMX ng/L	NDMA ng/L	BrO_3^- mg/L
Secondary effluents*	5	59	32,600	9,900	176	568	223	698	1,180	202	5	<DL
After ozonation*	5	31	13,920	5,120	66	<DL	26	<11	<23	<DL	56	11
After BAC**	3	30	12,000	2,433	<DL	<DL	23	26	<12	20	20	11
After sSAT	**5**	**<14**	**<DL**	**<11**	**<DL**	**<DL**	**<DL**	**238**	**<DL**	**80**	**<2**	**7**
Target max. concentration* **		1000			1000			300	300		10	10****

* For NDMA n=3; **BrO_3^- measured after BAC; ***List of substances assessed according to GOW 2276-90-6 - German Federal Environmental Agency; ****Israeli Regulations for Drinking Water Quality (2013)

4. Conclusions

- sSAT water quality after only 22 days is similar to cSAT after typically 6-12 months, and has lower CBZ concentrations compared to cSAT.
- The O_3-sSAT system complies with existing IPR criteria with respect to bacterial, TrOCs, ozonation by products, and DOC requirements (assuming the fraction of recycled water in the reclaimed water is ≤50%).
- The engineered O_3 – BAC - cUF solution requires optimization before it can reach water quality comparable with that of the O_3-sSAT system.
- A new aquifer management scheme with significantly shorter residence times will allow to increase effluent reuse using a smaller footprint and without having a negative effect on the quality of the reclaimed water. Due to high CAPEX, this approach might only be applicable to new SAT basins.

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