AIMES

analytical innovation measurement of environment samples

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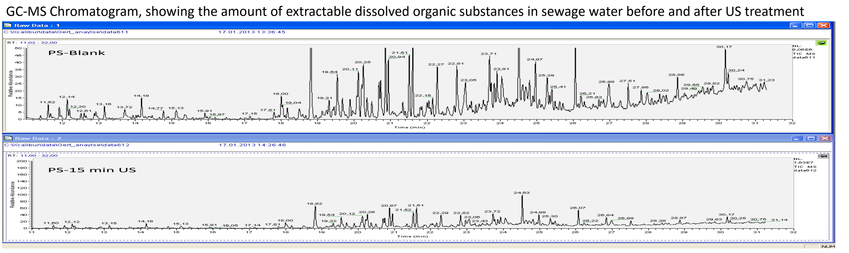
Treatment of waste water with high frequency ultrasonic (US) for sterilisation and reduction of dissolved organic substances

DOC reduction

After US treatment samples were extracted with pentane, dried, concentrated and finally analysed with the GC-MC-technique.

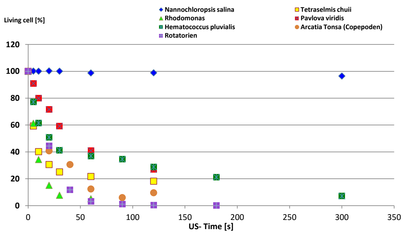
US Lab- Version

GC-MS Chromatogram, showing the amount of extractable dissolved organic substances in sewage water before and after US treatment

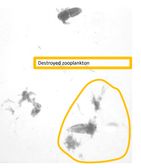


Results on sterilization show that higher US-Frequency (3.000 - 7.000 kHz) will have optimal effect on small species

Sterilisation with 850 kHz



Zooplankton
(Artemia salina)
exposed to ultrasound (850kHz)



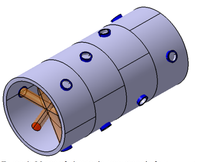
Ratio: size of organism (Ø) and wavelength (λ),
Definition of ratio: $R=\lambda/\varnothing$
Survivable rate of organism: US duration (s) versus % of cells alive

f (kHZ)	λ (wave-Length mm)	Rhodomonas (Ø=0,2mm)	Tetraselmis (Ø=0,02mm)	Nanochloropsis (Ø=0,003mm)	Haematococcus alive (Ø=1,2mm)
20	77	R= 382 25s, 90%	R= 3827 30s, 70%	R= 25516 300s, 95%	R= 63 70 s, 80%
850	1,8	R= 9 25s, 10%	R= 90 30s, 30%	R= 600 400s, 95%	R= 1,5 70s, 40%
1.500	1	R= 5	R= 51	R= 340	R= 0,9
7.500	0,2	R= 1	R= 10	R= 68	R= 0,2
f (kHZ)	**λ (wave-Length mm)**	**Copepods (Ø=2mm)**	**Artmenien (Ø=20mm)**	**Rotatorien (Ø=0,5mm)**	**Haematococcus Cysten (Ø=0,1mm)**
20	77	R= 38 20s, 45%	R= 3,8 5s, 40%	R= 153 60s, 2%	R= 765 20s, 90%
850	1,8	R= 1 20s, 10%	R= 0,1 5s, 10%	R= 4 30s, 2%	R=18 20s, 15%
1.500	1	R= 0,5	R= 0,1	R= 2	R=10
7.500	0,2	R= 0,1	R=0,01	R= 0,4	R= 2

Optimized solution to maximize US effects and water volume. Local German funding has been requested for equipment development and build-up. Founding is granted and project has started August 2017

Detailed rationale:
In order to obtain the most important effect (thermolysis), a maximum of gas bubbles, which passes of into the cavitation, must be produced. This can be achieved by two simple steps.
1. The water should contain as much as possible particles (inorganically/ organic). Because all particles are potential germs for developing gas bubbles. 2. Air should be specially injected. US will divide it into finest blisters, which maximize the cavitation effect.
To create the largest mechanical effect a higher frequency than 850 kHz has to be used. Out of the table above it can be seen that a frequency within the range of 3500-7500 kHz must be optimal to destroy organisms such as bacteria to almost 100%.
Further the system design shall give the possibility to extend it modular in any order.

Four modules has been combined
They are twisted by 30° to each other



To reach 30 sec of ultrasonic treatment in four modules the max volume can be calculated as follows:
$R^2*0,3*4*0,25*120= 34qm/h$

View to the sum of ultrasonic waves.
Four modules are combined and they are twisted by 30° to each other

The technical solution by USAW is more efficient and less expensive than other state of the art techniques. Aim of the proposal is to construct and test a plant of Ultrasonic device which can treat up to 60m³ water per hour. This device will be usable in waste water and aqua culture facilities and other industrial fields (e.g. BWT).

Detailed summary

From the comparison of technologies (ozone, UV-C radiation and US) for the treatment of waste water the ultrasonic follows as optimum solution:
The mechanism of the Thermolyse (5000°) enables the destruction of all solved organic substances (independent of their structure) in each type of process water.
This universal effect enables it to clean waste water (of e.g. hospitals) of antibiotics, medicines and their reduction products before the introduction into the local systems.
The sterilisation achieved parallel thereby (by cavitation: Shearing stresses, released from pressure surges to 1000 bar) reduces the entry of the possible multi-resistant germs.
This is valid just as for anthropogenic materials in RAS (Recycling aquaculture system) e.g. for softener, pesticides, insecticides. The reduction takes place universally up to the CO_2.

Properties of different methods for the sterilisation of waste water

1. Ozon

Benefit	Disadvantage	Energy consumption
Dozens of m³ per hour	**A) Strong Absorption at the DOC → 0,6 g O_3 /g DOC**	0.04 kWh/m³
Less energy consumption	For comparison: 4,5mg DOC/L are the limit for rainbow trout	less than 0,6g DOC/l
DOC reduction (partly)		
	B) Sterilisation, effect depends on the species:	
	1. 40-90% reduction: alge, yeast, Acetylcholinesterase,	
	2. moderate reduction of: Twitching mosquito, gloss worms, cover snail	
	3. Bioburden (bacteria) by the factor 100 -1000 reduces	
	4. Renewed increasing around factor 10 is observed	
	C) Reduction (oxidation) of solve organic substances:	
	Depended on chemical structure	
	e.g. Ipromide → 100% reduction **or** Dichlofenac → 1 % reduction	
	D) Formation of new substances due to radical chemistry:	* can exceed critical value of California (9ng/l)
	1. Nitrosamine (NDMA)* and 2. Bromat → both are cancer-causing!	

2. UV-C radiation

Benefit	Disadvantage	Energy consumption
Several m3 per hour	**A) 100% Absorption at DOC and any particle**	5-6 kWh/m3
Effects all species	**B) Sterilisation:**	less than 1g DOC/l
	Bacteria inside of particle cannot be treated/ killed	
	C) Reduction of solve organic substances:	
	No reduction observed ever	
	D) Formation of new substances due to radical chemistry:	
	No information available in Literature found	

3. Ultrasound, high- frequency (>1000 kHz)

Benefit	Disadvantage	Energy consumption
Dozens of m³ per hour	High technical effort	Sterilization: 1.5 kWh/m³
Efficiency independent from water quality	More energy consumption than Ozon	DOC reduction:
(sea or fresh water, turbidity, etc.)		3 kWh/m³
Removal of DOC (Thermolyse)		
No formation of new substances		
Radical chemistry cannot take place		