TEHNOLOGIA DE TRATARE A APEI UZATE SONOELCHEMCELL - UN PROCES ELECTROCHIMIC DE OXIDARE AVANSATĂ INOVATIV

SONOELCHEMCELL WASTEWATER TREATMENT TECHNOLOGY - AN INNOVATIVE ELECTROCHEMICAL ADVANCED OXIDATION PROCESS

Constantin DAMIAN*
Ioana BERCU*

ABSTRACT. This Paper presents a new innovative wastewater treatment technology - Sonoelchemcell – that can potentially replace the biological step of a WWTP. This project combines 4 intelligent technologies in one SONOELCHEMCELL small-scale prototype; the hypothesis at this point is that this combined module will have dramatic effects on wastewater treatment/activated sludge treatment to break down the organic load (COD) and persistent micro-pollutants in wastewater with lower capital and OPEX costs, no sludge production and less environmental impact than conventional technologies.

KEYWORDS: Wastewater treatment, disintegration, AOP.

1. INTRODUCTION

This paper presents a new innovative wastewater treatment technology - Sonoelchemcell – that can potentially replace the biological step of a WWTP. The study of this innovative technology has been approved to be studied within NEPTUNE Blue Growth Accelerator - financed by the EU's Horizon 2020 Programme.

SONOELCHEMCELL idea came from the surprising results found at Targu Secuiesc municipal wastewater treatment plant, plant designed by S.C. Kematronic S.R.L.

Targu Secuiesc WWTP includes sonication and electrokinetical disintegration for sludge treatment and has been in operation for 1 year and 6 months with outstanding unexpected results on treated wastewater. The actual raw wastewater has very different characteristics from the design raw wastewater, with a large fraction of hard BOD *(recalcitrant)* in COD in raw wastewater; however this hard BOD was decomposed *(the COD values in the treated wastewater are less than 30 mg/l; also, an internal source of BOD_5 required for denitrification was claerly provided, given the unexpected N removal efficiency)*.

The possible explanation is that transforming COD into readily biodegradable BOD at Targu Secuiesc wwtp was due the latest technology employed for a different purpose at Targu Secuiesc WWTP *(ultrasonic and electrokinetic disintegration)*.

Therefore, based on this experience, a small-scale prototype comprising several types of disintegration is proposed.

The hypothesis at this point is that this combined module will have dramatic effects on wastewater treatment, due to their synergic action, resulting in an advanced oxidation technology, without biological treatment, to break down the organic load *(COD)* and persistent micro-pollutants in wastewater *(low and trace levels of synthetic organic substances released in water through human activity, such as organic pollutants, herbicides and pesticides, personal care products, toxic chemicals, carcinogenic and endocrine disruptive compounds, and emerging contaminants)*, with lower capital and OPEX costs, no sludge production, less environmental impact than conventional te-

* S.C. KEMATRONIC S.R.L., Republicii 3/3, Baia Mare, Romania; e -mail: kematronic@yahoo.com, mobile phone: +40 744636793
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chnologies.

A comprehensive prototype research process is planned, using this small-scale prototype to study the effects of several disintegration technologies on COD degradation in wastewater, individually and together, in different and variable operation regimes. A large-scale environment demonstration will follow.

The results shall be the basis of design of innovative wastewater treatment plants, without biological treatment, with lower capital and OPEX costs, no sludge production, less environmental impact than conventional WWTPs.

2. DISINTEGRATION TECHNOLOGIES

This project intends to combine the following intelligent technologies in one SONOELCHEMCELL small-scale prototype:

A. The sonication disintegration technology;

B. The electrokinetic disintegration technology;

C. The advanced oxidation technology, based on production of free radicals (OH, atomic oxygen);

D. Production of compressed air micro-bubbles.

The first 2 types of disintegration to be included in the innovative module have proven their efficacy in practice *(several references and literature examples are available)* for sludge disintegration, but not for wastewater.

A short description of these technologies is given below:

A. The sonication disintegration technology

Ultrasound technology has been so far used in the field of wastewater treatment plants for sludge treament.

It is defined as a sound wave with a frequency beyond 20 kHz. Depending on the frequency range *(generally between 20 and 40 kHz)* as well as the intensity *(25 to 50 W/cm²)* it is possible to apply ultrasound for environmental protection. There is a special interest in water engineering application because ultrasound wave propagation over these frequencies and intensities produce physical and chemical changes in the liquid system.

These changes result from the effects of the formation and collapse of cavitation bubbles induced by

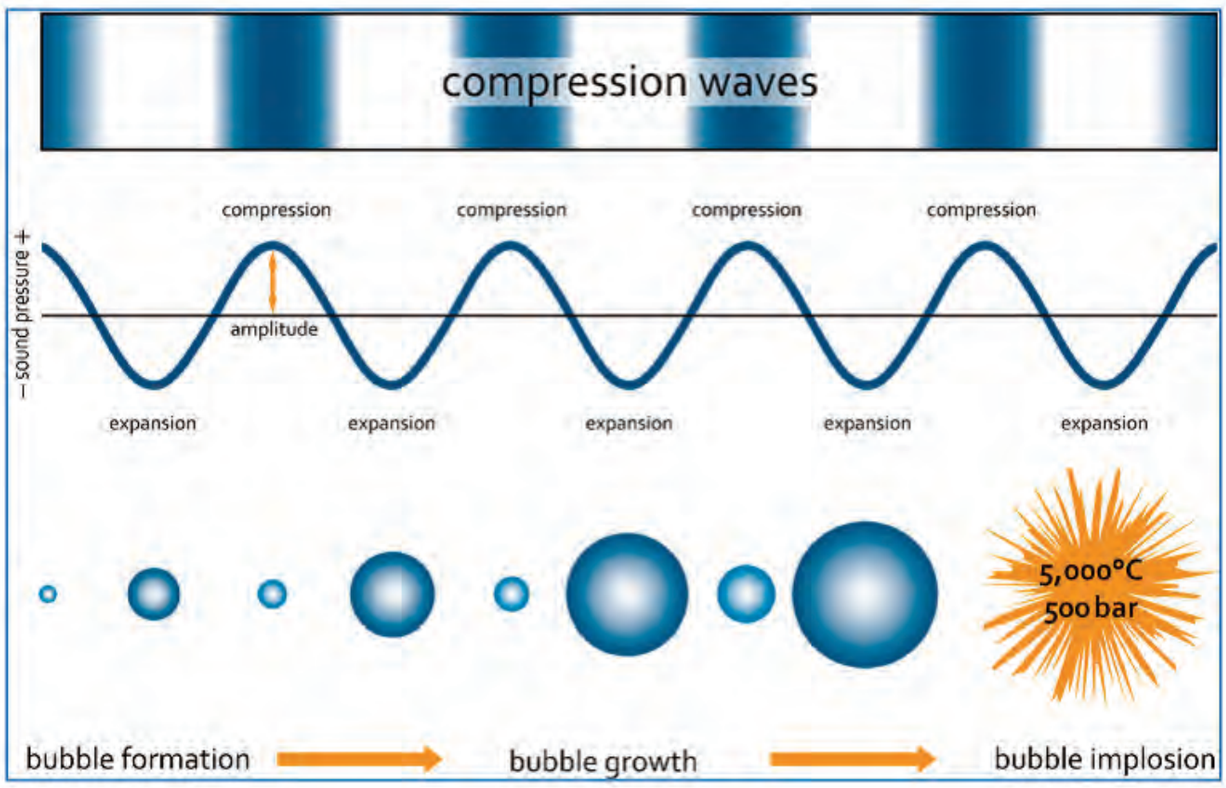

Fig. 1. Ultrasonic cavitation phenomenon

acoustic waves propagation under adequate frequencies and intensities. When sonicating liquids at low frequencies and high intensities, the sound waves that propagate into the liquid media result in alternating high-pressure *(compression)* and low-pressure *(rarefaction)* cycles, with rates depending on the frequency. During the low-pressure cycle, high-intensity ultrasonic waves create small vacuum bubbles in the liquid. When the bubbles attain a volume at which they can no longer absorb energy they collapse violently during a high-pressure cycle. This phenomenon is known as ultrasonic cavitation. At implosion of the bubbles, dramatic conditions in the gaseous phase exist as shown in Figure 1. Extreme temperatures *(≈ 5,000 K)* and high pressures *(≈ 500 bar)* lead to pronounced sonochemical reactions which are due to the creation of highly reactive radicals *(H+ and OH-)* and thermal breakdown of substances *(pyrolysis)*. The cavitation of bubbles are vapour filled and surrounded by a liquid hydrophobic boundary layer and therefore preferably volatile and hydrophobic substances are accumulated in the bubbles where they are subject to pyrolytic or radical reactions.

The shear force breaks down bacterial cell wall and releases the intracellular substances into aqueous phase. This changes the physical, chemical and biological properties of sludge during the pre-treatment by ultrasonication.

Therefore, the effects that can be observed when cavitation is generated in an aqueous phase could be summarised in high mechanical shear stress, but also radical reactions *(creation of H+ and OH- radicals and chemical transformation of organic substances)* and thermal breakdown of volatile hydrophobic substances.

Ultrasound can also be used for the disinfection of turbid and highly concentrated media, e.g. process water and wastewater, where the standard chlorine and UV methods fail. Germs attach to suspended particles or flocs and therefore easily escape disinfection by UV. Ultrasound can be used to break down these agglomerations, so that the germs exist in isolation and re-suspended. This makes them accessible to the classic methods once again and they can be successfully attacked. Whether ultrasound is used alone or in combination with conventional variants – effective disinfection is ensured.

B. The electrokinetic disintegration technology

Electrokinetic technology provided by Vogelsang GmbH has been so far used for sludge treament in the field of wastewater treatment plants.

BioCrack is an innovative electrokinetic sludge disintegration technology, which streamlines the digestion process to lower costs while increasing biogas yields. During the disintegration process, a high-voltage field is generated within the BioCrack module *(Figure 2)*, which breaks up agglomerations of dead organic matter and bacteria. This enhances the exposure of nutrients in bio-suspensions to the fermenting bacteria, resulting in higher gas yield and more efficient use of the substrates.

A BioCrack-system consists of several BioCrack modules. Each module is made up of three major components. The electrode head is where the voltage is converted. The internal electrode disperses the electric field within the housing. The housing contains the electric field.

The number of modules is determined by the characteristics of the sludge and digestion process.

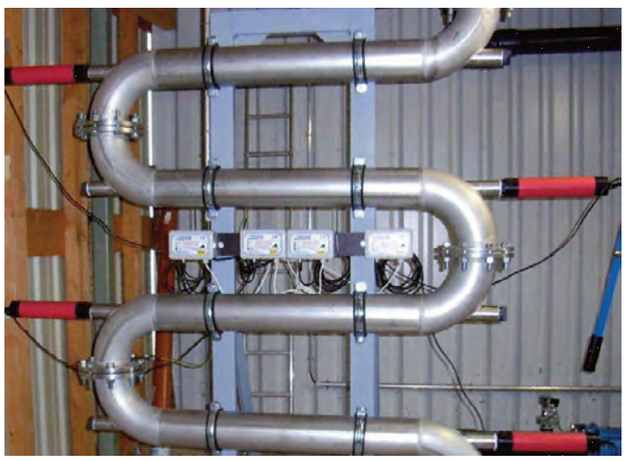

Fig. 2. Biocrack electrokinetical disintegration tube

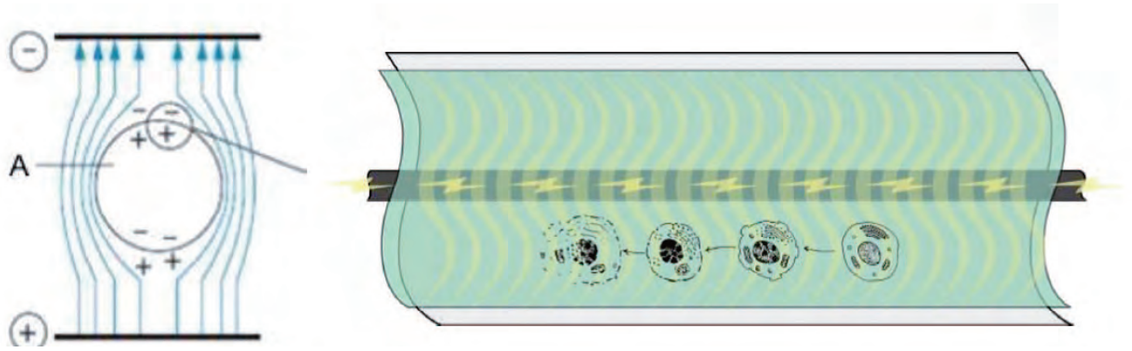

Fig. 3. Biocrack electrokinetical disintegration process

Key Product Benefits when using Biocrack prior anaerobic sludge treatment include:

- *Increases biogas yields by up to 20%;*
- *Offers up to 30% downstream energy savings from reduced pumping and mixing power requirements;*
- *Small footprint take-up and flexible layout and orientation;*
- *Stabilised biology increases reliability/consistency of operation and improves de-watering performance;*
- *Faster biomass decomposition reduces residence time and increases digester throughput;*
- *No moving parts and no routine maintenance requirements.*

C. The advanced oxidation technology

The Electrochemical Advanced Oxidation Processes *(EAOP)* are a very new class of oxidation processes that have been under research. The hydroxyl radical *(•OH)* is a highly reactive radical which can rapidly degrade recalcitrant organics such as aromatic, chlorinated and phenolic compounds. This radical readily reacts with pollutants in wastewater.

The proposed combined technology is a type of EAOP, obtained by the synergic effects of electrokinetical and ultrasonic treatments in the presence of generated nano- and micro- air bubbles:

- *the ultrasonic disintegration produces via cavitation radicals that oxidize organic substances, therefore electro-oxidation of COD (hard BOD) occurs;*
- *the electrokinetic disintegration tube is basically a high voltage electrochemical cell, thus facilitating again the electrochemical oxidation of COD. Also, the electrokinetic disintegration tube produces non-thermal plasma. Non-thermal plasma is an emerging technique in environmental pollution control technology, produced by the high-voltage discharge processes, where a large amount of high energy electrons and active species are generated;*
- *the production of free radicals is boosted by the presence of the air micro-bubbles; the flux of electrons, shock waves, etc., molecular oxygen decomposes into atomic oxygen (superoxide radical anion O2−), with high reactivity.*

D. Production of compressed air micro-bubbles

This technology is similar to the technology used to produce the fine bubbles for activated sludge aeration in biological wastewater treatment plants.

The micro-bubbles introduced in the liquid are transformed from molecular Oxygen to atomic Oxygen *(superoxide radical anion O_2^-, an important radical formed in oxygen-containing plasmas, formed from the reaction of molecular oxygen with electrons or by the deprotonation of the hydroperoxyl radical •OOH, which can be produced, for example, by the reaction of ozone with the hydroxyl radical).*

3. DESIGN OF SMALL-SCALE PROTOTYPE TECHNOLOGY

The proposed technology mission would be to deliver an economically viable and efficient treatment

technology to make treated wastewater ready to discharge or reuse, by advanced electrochemical oxidation induced by sonication and electrokinetical disintegration in the presence of nano- and micro- air bubbles.

The small-scale prototype shall include the following components:

1) The sonication module for ultrasonic disintegration (Ultrawaves GmbH)

The ultrasonic system consists of the following components: Ultrasonic system body, 19“ generator case with 1 KS1000/2000 ultrasonic generator, electrical connecting cables between the generators and the ultrasonic system body.

Table 1. Characteristics: With control panel

Number of oscillating units	1
Converter cooling	air
Amplitude of the sonotrode at 100%	17 - 20 µm
Continuous power output of each oscillating unit	1000 Watt
Continuous power output of the reactor module	1000 Watt
Allowed overpressure	0,5 to max. 1,2 bar, depending on the medium
Recommended flow rate	0,36 m^3/h
Thread of the intake/outlet connectors	2“ Whitworth external thread
Ambient temperature	5°C - 35°C
Air moisture	30% - 90%, non condensing
Protection class	IP20, up to IP44 if equipped with the acoustic protection case
Requirement to the cooling air	Clean, non aggressive air
Generator module KS1000/2000	
Weight	3,5 kg
Service tension	230V / 50-60Hz
Absorbed power at a power output of 1000W	4,8A
Power output	800 to 1000 Watt, depending in the medium
ON period	100% OP
Regulation	30% - 90%, non condensing
Air moisture	5°C - 40°C

2) The Biocrack module for electrokinetic disintegration (Hugo Vogelsang Gmbh)

Table 2. With one tube and control panel

Specifications	XS-100
Housing Ø	DN 100
Housing flange	DN 100
Maximum module length	1940 mm
Electrode length	1500 mm
Pressure	max. 5 bar
Power requirement for each BioCrack module	max. 35
Electrode head (voltage)	High voltage 30 - 100 KV
Electrode (voltage)	24 V
Power supply (electrical supply voltage)	230

3) Raw waste water/ mixed liquor tank, 1000 l

4) Feeding/Recirculation peristaltic pump with frequency converter, Q- 0,35 m³/h

5) Electromagnetic blower

Type: IDK-S-120- SECOM Germany or similar;

Q: 120 l/s

p: 260 mbar

6) Air diffuser disc: Φ250 mm, Bibus or similar

7) Air and hydraulic pipes, supports

8) General control panel

9) Supply cables

4. TESTS

The proposed small-scale Sonoelchem prototype shall be able to achieve the following combinations of effects:

a) Ultrasonic disintegration of the constituents of wastewater or thickened activated sludge in the presence of air micro bubbles (oxygen). Tests shall be conducted with/without air. Therefore the quantity of produced free radicals can be assessed;

b) Electrokinetic disintegration of the constituents of wastewater or thickened activated sludge in the presence of air micro bubbles (oxygen). Tests shall be conducted with / without air. Therefore the quantity of produced free radicals and their effect can be assessed;

c) Ultrasonic disintegration and electrokinetic disintegration of the constituents of wastewater or thickened activated sludge in the presence of air micro bubbles (oxygen). Tests shall be conducted with / without air. Therefore the quantity of produced free radicals and their effect can be assessed.

By measuring the wastewater and activated sludge parameters before and after the treatment cycles, the efficiency of the employed technologies and their synergic effect can be assessed.

Therefore the following can be determined:

- *The parameters to be considered when designing small wastewater treatment plants / upgrading big wastewater treatment plants;*
- *The disinfection degree of the treated wastewater and the pasteurization degree of activated sludge.*

5. CONCLUSION

The new combined technology, presented in this paper, is expected to:

- *Achieve low discharge organic consent, destruct recalcitrant organics, persistent micro-pollutants in wastewater (low and trace levels of synthetic organic substances released in water through human activity, such as organic pollutants, herbicides and pesticides, personal care products, toxic chemicals, carcinogenic and endocrine disruptive compound;*
- *Disrupt microorganisms: achieve disinfection of wastewater / pasteurization of activated sludge to enable its use in agriculture;*
- *Operate without chemicals;*
- *Generate no secondary waste or sludge;*
- *Can be retrofitted into an existing plant/process stream without disruption to current processes;*
- *Have low capital and OPEX costs, low footprint - modular, scalable, mobile, no internal moving parts, low maintenance and low downtime.*

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