Methodical recommendation to use Anolyte produced in a Eurostel[1)] disinfecting Unit supplied by the Aquastel Group to disinfect (municipal) drinking water accordingly to the German Drinking Water Standards (TVO).

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UNIT SPECIFICATION

EUROSTEL®, INDUSTEL® , REDUSTEL® , AQUASTEL® units and *all* other units produced by the Aquastel Group incorporating the following patented diaphragmatic Electrolysers and Methods.

DISINFECTANT TESTED

Superoxidised water (Anolyte) produced in hereafter mentioned diaphragmatic electrolysers and accordingly following methods

Electrolysers:

- Electrochemical Plant
  (Patent *Western Pacific Company Inc*., Tallinn; No. 2100285; RU96122382; WO98/23793; EP0882815A1)
- Electrochemical Installation
  (Patent *Harrisson Investments Ltd.*, Tallinn; No. 2104961; RU97103204; WO98/40536; EP0922788A1)

Methods:

- A Method for Sterilising water and device for realising the same
  (Patent *Western Pacific Company Inc*., Tallinn; No. 2100286; RU96123069; WO98/25855, EP0885849A1)
- A Method for electrochemical treatment of aqueous solutions and device for realising the same
  (*Patent Western Pacific Company Inc*., Tallinn; No. 2100287; RU96123170; WO98/27012; EP0885848A1)

1. Introduction

The bactericidal properties of Anolyte, produced by means of diaphragmatic cells within Eurostel units, was accordingly the German Drinkwater regulations tested.

Several samples with different concentrations of the following bacteria were prepared:

- Escheria Coli and
- Pseudomonas aeruginosa

Anolyte was added to the samples. The bacterei were cultivated in our own laboratoria and the water used for the samples was tapwater of the city of Lollar, Germany.

Apart from the bactericidal properties we investigated the formation of toxic by-product such as THM's.

All tests and measurements were executed in accordance with the DIN-norms.

2. Operating principle of the Eurostel unit.

The unit uses the electrolyses of a solution of common salt in water to produce Activated water (Anolyte). The electrolyser contain two electrodes, one positively charged and another negatively charged. An diaphragm (membrane) separates both chambers. In Anode-chamber so called Anolyte is being produced, that is used as disinfectant. In the Cathode-chamber Catholyte is being produced, that can be used for other purposes e.g. cleansing, but not for disinfecting.

When electricity flows through a molten (fused) salt or through a solution called an electrolyte, the salt or electrolyte is split up in a chemical process called electrolysis. In solid conductors electricity flows by the movement of electrons while in solutions electricity flows by the movement of ions. In a solid, electrons flow from positive to negative. In a solution, positive ions are attracted to the negative charged electrode or cathode and negative ions are attracted to the positive electrode or anode. Positive charged ions are called cations because they are attracted to the cathode, negative charged ions are known as anions because they are attracted to the anode.

Oxidation involves the loss of electrons, while reduction the gain of electrons. Therefore a cation is a reduced ion, that means that electrons are added to them and anions are oxidised ions because electrons are removed from them. For the electrolysis of sodium chloride the sodium ion becomes the cation and the chlorine ion becomes the anion, as a result the chlorine is attracted to the anode and the sodium is attracted to the cathode.

The cell in the Eurostel core is made up of an anode and a cathode, separated by a membrane. A solution of sodium chloride in water passes through the cell, an electric current flows between the electrodes, therefore the solution undergoes electrolysis. The cations are attracted to the cathode and the anions are attracted to the anode. The oxygen ions and the chlorine ions are attracted to the anode, they oxidised i.e. electrons are removed from them. The sodium ions and hydrogen ions are attracted to the cathode electrons are added to them i.e. they are reduced. Thus, the process of electrolyses splits sodiumchloride (NaCl) in e.g. Sodium ions (Na^+) and Chloride ions (Cl^-).

3. Goal of the Approval

The goal of these tests and analyses is to confirm the bactericidal activity of Anolyte produced in patented diaphragmatic electrolysers used into Eurostel units accordingly the German Drinking Water Standards.

For the tests and analyses all criteria of the German Drinking Water Standards will be consulted. This means that the micro-biological (biocidal) effect of Anolyte at different levels of contamination with different pathogens is tested. The following pathogens must be tested to obtain approval accordingly the Drinking Water Standard.

- Escherichia coli und
- Pseudomonas aeruginosa

To meet obligations of the Drinking water Standard all by-products such as Trihalogenmethanes must be tested and analysed.

3. Results of the micro-biological (bactericidal) tests

The results with *Escherichia coli* proved that Anolyte with a concentration of free chlorine (dosage rate in water) between 1,2 mg/l and 0,3 mg/l destroys concentrations of 140.000 cfu/100 ml within 1 Minute. At a free-chlorine concentration less than 0,3 mg/l Anolyte destroys a high *Escherichia coli*-concentration within 5 Minutes.

At *Escherichia coli*-concentrations up to 7.500 cfu/100 ml, Anolyte with a free-chlorine concentration of 0,15 mg/l proved to be effective and destroys all bacteria within 1 Minute.

Table 1: Destruction of *Escherichia coli* at different concentration of free chlorine in relation of time

Concentration of Escherichia Coli [cfu/100mL]	Concentration of free chlorine [mg/L]			
	0,15	0,3	0,5	1,2
78.000 - 140.000	After 5 Minutes	After 1 Minute	After 1 Minute	After 1 Minute
< 7.500	After 1 Minute	After 1 Minute	After 1 Minute	After 1 Minute

Time of disinfection: no spores in 100 mL

The tests with *Pseudomonas aeruginosa* showed that this bacterium is more resistant against Anolyte. Anolyte with a concentration of free chlorine (dosage rate in water) between 1,2 mg/l and 0,15 mg/l destroys a high *Pseudomonas aeruginosa*-concentration in the range of 120.000 and 150.000 CFU/100 ml within 5 Minutes. This is in contrary with *Escherichia coli* where bacteria are destroyed within 1 Minute. At medium concentrations of *Pseudomonas aeruginosa* of 4.100 up to 5.600 CFU/100ml, Anolyte with a concentration of free chlorine (dosage rate in water) between 1,2 mg/l and 0,3 mg/l destroys all bacteria within 1 Minute.

However, the following tests proved that Anolyte with a concentration of free chlorine (dosage rate in water) does not destroy *Pseudomonas aeruginosa* within 1 Minute, even at a low concentration *Pseudomonas aeruginosa* of 300 CFU/100. Complete disinfecting of a low concentration *Pseudomonas aeruginosa* with a concentration of 300 CFU/100 was achieved with Anolyte with a free-chlorine concentration of 0,15mg/l within 5 Minutes.

Table 2: Destruction of *Pseudomonas aeruginosa* at different concentration of free chlorine in relation of time

Concentration of Pseudomonas aeruginosa Coli [CFU/100mL]	Concentration of free chlorine [mg/L]			
	0,15	0,3	0,5	1,2
120.000 - 150.000	After 5 Minutes	After 5 Minutes	After 5 Minutes	After 5 Minutes
4.100 – 5.600	After 5 Minutes	After 1 Minute	After 1 Minute	After 1 Minute
< 300	After 5 Minutes			

Time of disinfection: no spores in 100 mL.

4. Results of chemical-physical tests

The determination of organic chlorine compounds and trihalogenmethanes proved that the disinfecting of tap water with Anolyte result in a formation of mentioned by-products that is significant less than according the limits defined in the German Drinking Water Standards (TVO) regardless the concentration of free chlorine (0,15 mg/l up to 1,2 mg/l) in Anolyte. Besides, the bounded chlorine proved even after 1 hour reaction time at high initial concentration of free chlorine (0,5 - 1,2 mg/l) in the testsamples with a high concentration of bacteria a Maximum value of only 0,05 mg/l.

Further, the analyses prove that the Redoxpotential, that is at a level of 245 mV when using tap water form the city of Lollar, increases as result of addition of Anolyte. Redoxpotential is at approx. 666 mV having a concentration of free chlorine of 0,15 mg/l and Redoxpotential is at approx. 770 mV having a concentration of free chlorine of 1,2 mg/l. These values are for disinfecting within the optimum range.

The pH-Value of the tap water is only slightly by Anolyte effected. As Anolyte is an acidic solution, it decreases the pH-Value of tap water. However the decrease in pH-value is even at a high addition of Anolyte, reflecting a dosage of 1,2 mg/l of free chlorine less than 0,2 pH-units.

All testsamples and the for dilution used water were measured on halogenated and hydrocarbon as well as on Trihalogenmethanes accordingly Enclosure 2 and 3 of the Drinking water Standard. All testsamples were measured on organic chlorine compounds (CKW)

- Dichlormethane,
- 1,1,1-Trichlorethane,
- Tetrachlormethane,
- Trichlorethene and
- Tetrachlorethene,

as well on Trihalogenmethanes (THM)

- Chloroform,
- Dichlorbrommethane,
- Dibromchlormethan and
- Bromoform

For the analyses separated samples of 10ml were prepared. The determination was executed with help of capillar-gaschromatography and for detection an ECD-Detector was used. The following pictures show:

- The testsample with organic chlorine compounds (CKW) and trihalomethanes (THM'S)
- The testsample with a high concentration of escheria Coli and with Anolyte diluted to 1.2mg/L free chlorine at the start of a 60 minute testperiod.

The gaschromatographs show clearly that at the maximal dosing of 1.2mg/l of free chlorine result in only very minor amounts of chlorinated hydrocarbon and trihalomethanes. The amount is very low and clearly below the limits as stated in paragraph 3 of the German Drinkingwater regulations. The limits are:

- A total of 0,010mg/L of all following organic chlorine compounds (CKW)
    - 1,1,1-Trichlorethane
    - Thrichlorethene
    - Tetrachlorethene
    - Dichlormethane
- Organic chlorine compound tetrachlormethane 0,003 mg/L
- A total 0,010 mg/L of all following trihalomethanes (THM'S)
    - Chloroform
    - Dichlorbrommethane
    - Dibromchlormethane
    - Bromoform

Also the bounded chlorine showed even after one hour reaction time in samples with a high of free chlorine concentration of 0,5-1,2mg/L and high concentrations of spores, a maximum value of only 0,05mg/L.

Pic. 1 Gaschromatogramme of a testsample of chlorinated hydrocarbon and trihalomethanes .

(a) 1,1,1-Trichlormethan e	0,00107 mg/L
(b) Trichlorethene	0,00107 mg/L
(c) Tetrachlorethene	0,00130 mg/L
(d) Dichlormethane	0,01264 mg/L
(e) Tetrachlormethane	0,00127 mg/L
(f) Chloroform	0,00119 mg/L
(g) Dichlorbrommethan	0,00160 mg/L
(h) Dibrommethan	0,00196 mg/L
(i) Bromoform	0,00231 mg/L

Pic. 2 Gaschromatogramme of a testsample with a concentration of *Escherichia coli* and with Anolyte with an initial concentration of 1,2mg/L free chlorine after 60 minutes.

5. Conclusion

As a result of all the tests and analyses executed, it can be concluded that Anolyte produced in diaphragmatic electrolysers as installed in Eurostel units, is an effective disinfectant.

Moreover, as the formation of halogens at all analysed dosage rates of Anolyte proved to be significant less than the limits defined in the German Drinking Water Standard (TVO) and the pH-Value only slightly decreases as result of Anolyte dosage, can Anolyte produced in diaphragmatic electrolysers patented by the Aquastel Group be recommended as safe effective disinfectant suitable for disinfecting drinking water.

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