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Procedia Engineering 44 (2012) 1835 – 1836

Procedia Engineering

www.elsevier.com/locate/procedia

Euromembrane Conference 2012

[P3.071]

Biofilm evolution in pre-treatment line to reverse osmosis

E. Dionisio[1], J. Pérez[1], F. Plaza[2], G. Garralón[2], A. Garralón[3], M.A. Gómez*[1]

[1]University of Granada, Spain, [2]CADAGUA S.A., Spain, [3]CIEMAT, Spain

Bacterial biofilm development is a serious problem in many fields of water treatment, included seawater desalination by reverse osmosis (RO). Biofouling on RO membranes is one of the problems caused by this phenomenon, whose main source is the presence of bacteria in the water to be treated. Like of membrane, all surfaces in contact with water are susceptible of being colonised by bacteria which can reduce the efficiency of the pre-treatment and the quality of the water to be afterwards desalted.

To avoid biofouling, chlorine is commonly added as a disinfectant during pre-treatment phase. Continuous chlorination has been the industrial standard for years, but biofilm formation downstream of the dechlorination point is common. On the other hand, chlorine is believed to cut down small fragments of deposits from pipes or water tanks which serve as nutrients for enhanced biological growth at the RO membrane surface where chlorine is not present. To overcome this problem, periodical shock injection of chlorine with off-line RO stage is conducted.

In view of this, the microbiological quality of pre-treated seawater and the evolution of biofilm in the walls of the different water tanks which compose the treatment line of two advanced pre-treatment to RO were analysed. One of the pre-treatment consisted on aerated spiral wound ultra filtration (ASWUF) membranes of polysulfone (20 KDa of molecular weight cut-off (MWCO), flux 45 l/m^2 h). The other one consisted on a physic-chemical (PC) pre-treatment based on Cl_3Fe coagulation, hydraulic flocculation, sedimentation and two-stage filtration by dual media (anthracite and silica sand) pressure filters. To control the evolution of bacteria in the installation and avoid biofilm formation, the seawater was chlorinated at the head of the intake pipe using sodium hypochlorite solution, so as to obtain 1 mg/l of free residual chlorine at the outlet of the cartridge filters. These operations were carried out constantly or weekly (shock) and affected both PC and UF treatments. Direct intense chlorination (100 mg Cl_2/L) in water tanks of installation was applied occasionally to avoid massive growth of bacteria.

The effectiveness of chlorination has been evaluated by total aerobic bacteria (22ºC) count, with a culture taken daily from different parts of the experimental installation. Residual free chlorine (RFC) was quantified by means of the volumetric evaluation method using *N*, *N*-diethyl-1, and 4-phenylenediamine.

The development of biofilm was controlled by analysing the presence of bacteria in the wall of all water tanks of both pre-treatment (influent, UF effluent, sedimentation effluent and filtration effluent tanks). For this, an immersed PVC fragment was sampled monthly from each water tanks which were preserved with glutaraldehyde (3 %) in phosphate-buffered saline solution (PBS) (130 mM NaCl and 10 mM Na_2HPO_4/NaH_2PO_4 pH 7) in order to be able to fix the possible biofilm on the PVC fragment. The fragments were analysed by scanning electron microscopy (SEM) using a Zeiss DSM 950 SEM operating at 5–30 kV, equipped with an Energy Dispersive Spectrometer (EDS Link Analytical Pentafet Si(Li)). The observed areas of obtained

doi:10.1016/j.proeng.2012.08.967

micrographs were calculated and singles bacteria in this area were counted. The medium value was extrapolated to singles bacteria units per m^2.

All influent samples analysed for total aerobic bacteria showed a positive count, ranging from 10 to 200 cfu/ml whereas ASWUF and PC effluent samples were positive in 56.3% and 46.3%, respectively when chlorination was achieved continuously in function of residual free chlorine (RFC) concentration. During the period working with chlorination shocks all effluent contain aerobic bacteria which were more significant for effluent from ASWUF. Aerobic bacteria are frequent after membrane or sand filter treated water tanks due to biofilm generation, which was not controlled sufficiently by RFC. As the installations do not operate in sterile conditions, external conditions could lead to the development of biofilms, resulting in a loss of water quality.

Highest capacity for colonisation and biofilm formation were observed in the walls of influent tank with 100 % of SEM monographs showing an important development of biofilm with medium values of 1.5 $x10^{10}$ units/ m^2. The bacterial density increases with time independently of chlorination methods. Only when intense chlorination was applied directly to the tanks the presence of bacteria decrease up to 1.0 $x10^{10}$ units/ m^2. SEM revealed the presence of fimbri and pili, expolysaccharide material and cells in process of division, etc. All of these are structural elements of a biofilm in the irreversible formation phase.

The presence of bacteria on the walls of the others tanks were lower intense than the observed on the influent tanks mainly for ultra filtered water tank with no significant biofilm structures. The different development of biofilm on the walls of treated water tanks revealed the effectiveness of the studied systems at removing bacteria which was more significant when chlorination was applied continuously. However, only the intense chlorination on the tanks turned out to be effective in the reduction of the density of bacteria which affect to the evolution of biofilm too.

Direct intense chlorination gave high inhibition of biofilm development to tank surfaces. However, the resistance of bacteria to chlorination was significant since after application biofilms were observed on the surfaces of tanks mainly in those that receive lower quality water.

Keywords: RO pre-treatment, Biofilm development, SEM, Aerobic bacteria