Ballast water treatment by membrane processes

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Introduction: Non-native aquatic species can be introduced in new areas through emptying of the ballast tanks. These introductions induce a high impact on health, economy and environment. This is considered by the International Maritime Organization (IMO): the Ballast Water and Sediments (BMW Convention) entered into force on 8 September 2017 and opens the market for ballast water treatment. The major contribution and novelty of this study is to show successful ballast water treatment using an ultrafiltration process at industrial scale with a high technological readiness level, in order to show the applicability of the ultrafiltration processes for ballast water treatment. Another aim is to compare UV and ultrafiltration treatments applied to fresh water and seawater, from an economic perspective. This comparison accounts for the positioning of the treatment and the specific constraints associated to this positioning. The best membrane processes and the operating conditions were determined for fresh and seawater.

Material and Methods: The study was conducted during 18 months. The first part, using seawater, was conducted at the Marine Station of Sète (Thau Lagoon, Experimental Marine Ecology Center MEDIMEER UMS 3301, University of Montpellier-2, France) and the second part, using fresh water, was conducted at the Wageningen Marine Research Ballast Water Test Facility, Den Helder (the Netherlands). Constant flux in dead-end ultrafiltration experiments were performed in a mobile unit containing an automatic pilot plant at semi-industrial scale (Figure 1).

Figure 1. UF pilot plant [2 industrial modules 84m2, MWCO = 100kDa]

Results and Discussion: This paper emphasizes the challenges of the application: ballast water treatment has to retain all microorganisms whatever water quality while being compact and cheap. This first study highlights the high potential of ultrafiltration, compared to microfiltration, for microorganisms retentions compared to UV treatment. A correlation between sequence duration, fouling rates, CEB efficiency and the variation of concentrations of microorganisms smaller than 1 µm

(picoplankton and bacteria) is observed. Microorganism (<1 µm) concentration increases induce a decrease of sequence duration and irreversible fouling rate and an increase of irreversible fouling rate which seems to be more or less temporary impacted. Indeed, fouling rates decrease with microorganisms concentrations. With seawater runs, the conditions did not reach threshold conditions in the first sequences of filtration at 5 $m^3.h^{-1}$; 30 min despite seawater quality variation. Contrary to seawater runs, critical conditions of filtration seem to appear with fresh water for 3 $m^3.h^{-1}$. The ultrafiltration process was assessed using 2 different types of water of different quality, and over a long time-scale, as required by the IMO for approval of ballast water treatment processes onboard ships. It should be noted that, during those studies in real waters, planktonic blooms and large variations of turbidity were met. Concerning seawater, with investment costs from 2.3 to 6.5 times higher for ultrafiltration than for UV, CAPEX for the membrane process is far too high to equip a ship. On-board ultrafiltration (Onb) for the treatment of ballast water is not competitive enough compared to the UV system. However, as the production cost of barge-based ultrafiltration during ballast loading is from 5 to 5.4 times lower than the cost of on-board UV treatment for seawater. It could be the subject of an in-depth study which would show the economic interest of the process. With a production cost (Figure 2) from 2.5 to 2.7 times lower for treatment of ballast water with barge-based (B) semi-continuous or continuous ultrafiltration than for UV treatment, ultrafiltration treatment during ballast discharge seems to be the more economically viable and the most efficient solution. Trials in fresh water were carried out with raw water with no pre-treatment as in the case of treatment during ballast loading. If the same experimental conditions as for ultrafiltration had been applied to the UV system, i.e. treating raw water without settling, treatment would have been more difficult or even impossible because of the very low transmittance. Barge-based membrane treatment during ballast loading and ballast discharge seems to be a viable solution, both economically and in terms of retention.

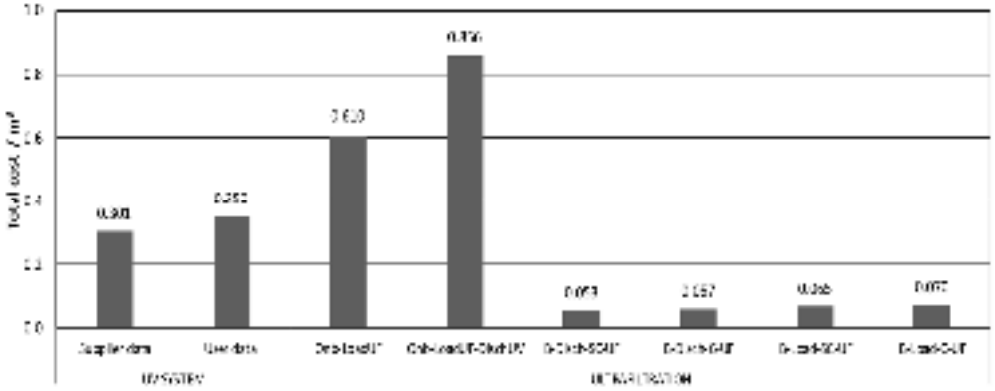

Figure 2: Cost productions per cubic meter treated volume for each case [Seawater]

Conclusion: To conclude on the trials on seawater and fresh water, the quality of the water produced by ultrafiltration is, as expected, of excellent quality, which will remove without a doubt the problem of ballast cleaning-out when the membrane treatment is carried out during ballast loading. However, the on-board ultrafiltration installation is not economically viable, whereas the barge-based installation is very competitive and could considered as new services proposed by ports to meet the international an/or national standards.