Ammonia Removal from Water by Liquid-Liquid Membrane Contactor under Closed Loop Regime. [1]

Edxon. E. Licon*[1], Aurora Alcaraz[1], Sandra Casas[1], Jose L. Cortina[1], Cesar A.Valderrama[1]
[1]Universitat Politècnica de Catalunya, Chemical Engineering Department, Av. Diagonal 647, Barcelona, Spain 08028.

Introduction: This work study how to remove ammonium by a liquid-liquid membrane contactor from water of a waste water treatment plant, This technology will be applied in the Hydrogen and Oxygen production by electrolysis via renewable energies (Figure 1).

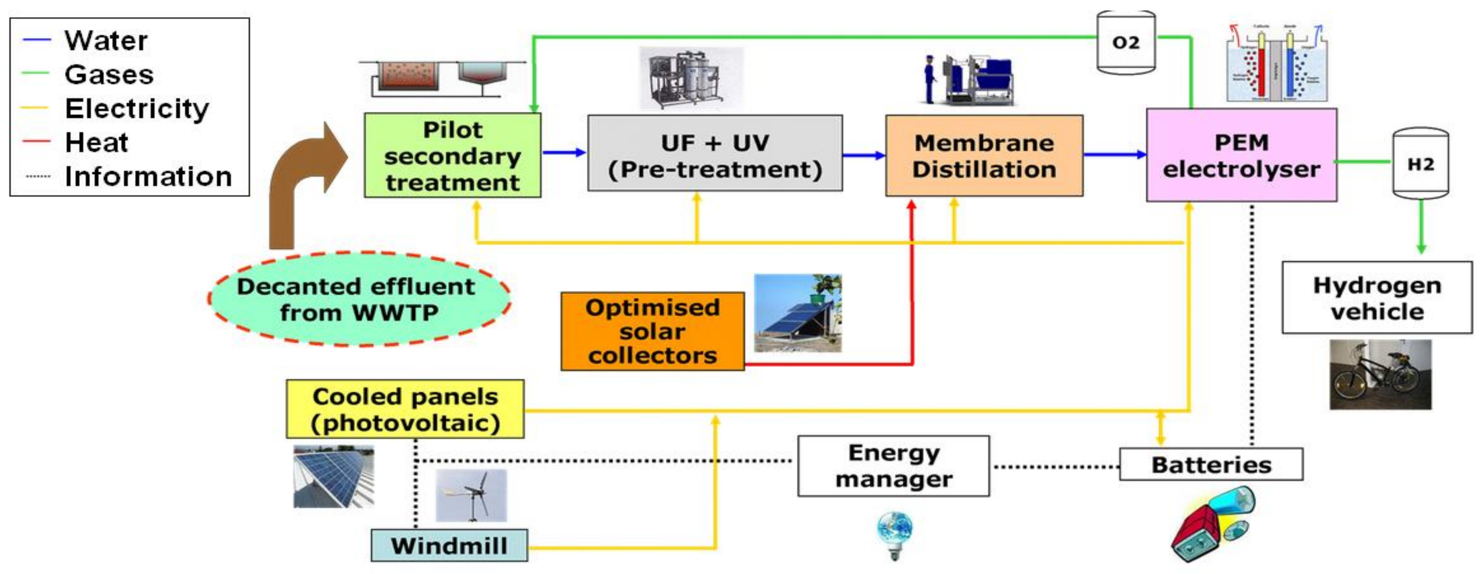

Figure 1. Outline of the Greenlysis project.

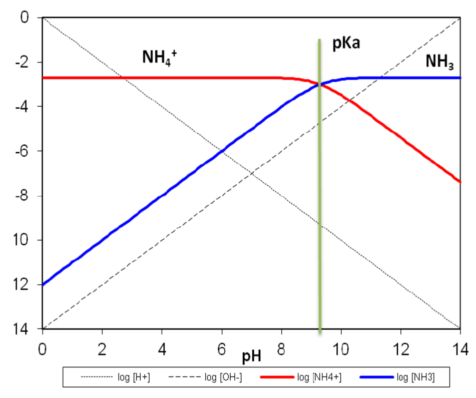

Figure 2. Ammonia equilibrium in water at different values of pH. Ammonia in water exists in free and ionic forms under equilibrium .

$$NH_{3(aq)} + H_2O \Leftrightarrow NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \qquad k_b = \frac{[NH_4^+][OH^-]}{[NH_3]}$$

Experimental: The feed was delivered inside the hollow fiber (lumen) with different flow rates from a 10L tank containing aqueous NH4+ solution and was continuously recycled. In the other hand, the acid solution contained in a 5 L tank was delivered in the outside of the fibers inside the HFMC (shell) at constant flow rate in a countercurrent mode and was continuously recycled (Figure 3 and 4).

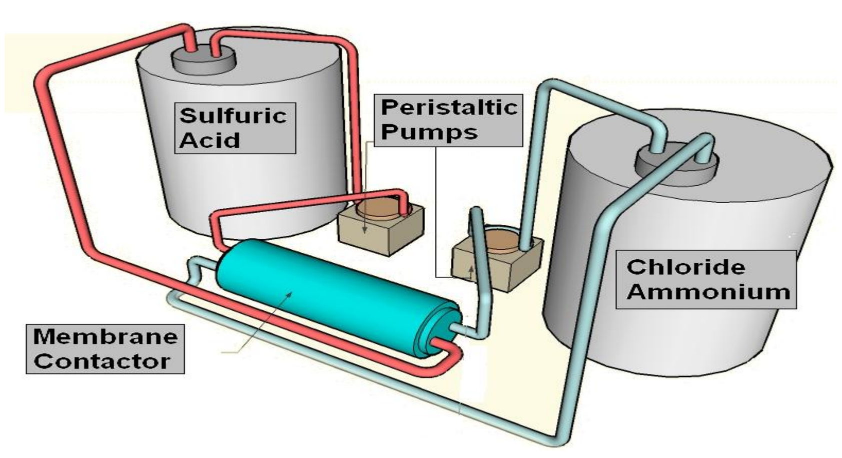

Figure 3. Experimental Setup.

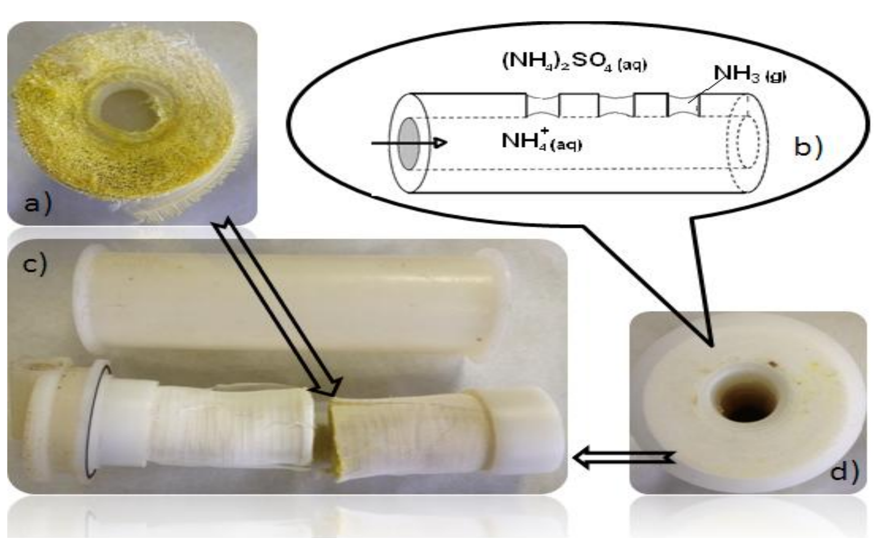

Figure 4. Schematic representation of the transport phenomena occurring inside the hollow fiber.

Computational Methods: One single hollow fiber is simulated using a 2D axisymmetric model (Figure 4). The model equations were developed considering radial and axial diffusion and convection in the lumen with laminar flow conditions (Figure 5-a) and nondimensionalized only in terms of the aspect ratio of the hollow fibbers in order to solve them using the PDE coefficient form (Figure 5-c). The recirculation is taken into account as a boundary condition, where a global equation that describes the concentration in the tank is solved (Figure 5-b).

a)

$$\frac{\partial C_j}{\partial t} + U_z \frac{\partial C_j}{\partial Z} = D_j\left\{\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial C_j}{\partial r}\right)+\frac{\partial^2 C_j}{\partial Z^2}\right\}$$

$$-D_j\left(\frac{\partial C_j}{\partial r}\right)_{r=r_{hf}} = k_{g,pore}\left(\frac{p^g{}_{a,\text{int}}}{R_g T}\right)$$

$$\left(\frac{\partial C_j}{\partial r}\right)_{r=0} = 0 \qquad C_{j,Z=0} = C_{\tan k}$$

b)

$$V\frac{dC_{\tan k}}{dt} = Q\left(C_{j,z=L} - C_{\tan k}\right)$$

$$C_{j,Z=0} = C_{\tan k}(t)$$

c)

$$d_a\frac{\partial C_j}{\partial t} + \beta\cdot\nabla C_j = c\nabla^2 C_j$$

$$-D_j\left(\frac{\partial C_j}{\partial R}\right)_{R=1} = \frac{k_{g,pore}}{r_{hf}}\left(\frac{p^g{}_{a,\text{int}}}{R_g T}\right)$$

$$d_a = 1 \qquad \beta = \begin{bmatrix} -D/r_{hf} \\ 2\bar{U}\left(1-R^2\right)/L \end{bmatrix}$$

$$p^g{}_{a,\text{int}} = \frac{H_a C_{j,R=1}}{1+\frac{K_b}{10^{pH-14}}} \qquad c = \begin{bmatrix} \frac{D}{r_{hf}^2} & 0 \\ 0 & \frac{D}{L^2} \end{bmatrix}$$

Figure 5. Equations

Figure 6 shown the domain and how the concentration is decreasing when the fluid pass trough a fiber. At R=1 the transport of the ammonia trough the membrane to the acid solution is occurring.

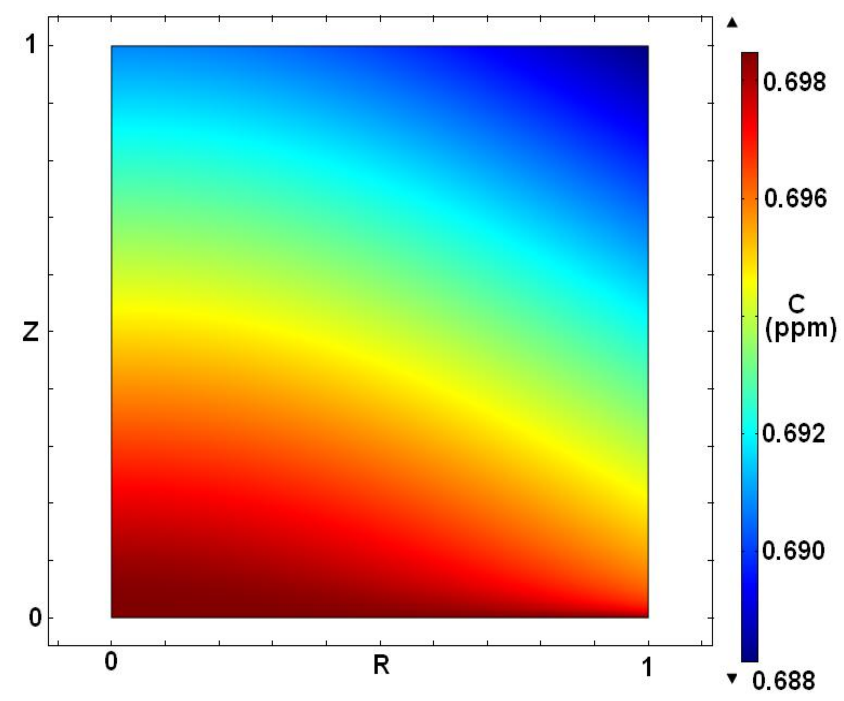

Figure 6. Distribution of Cj over a the domain, inside the fiber at a t=10000s.

Results: From the Figure 7-a is evident that this model is independent of the initial concentration set in the tank. According to 7-b and 7-c, the improvement in the efficiency of this separation process by rising the pH or the flow rate is limited. Similar qualitative behavior is present in previous works[1-4] . Some experiments were done to test the performance of the model. Some deviation were observed figure 7-d experiment, but nevertheless, a good agreement were observed between experimental and simulated values.

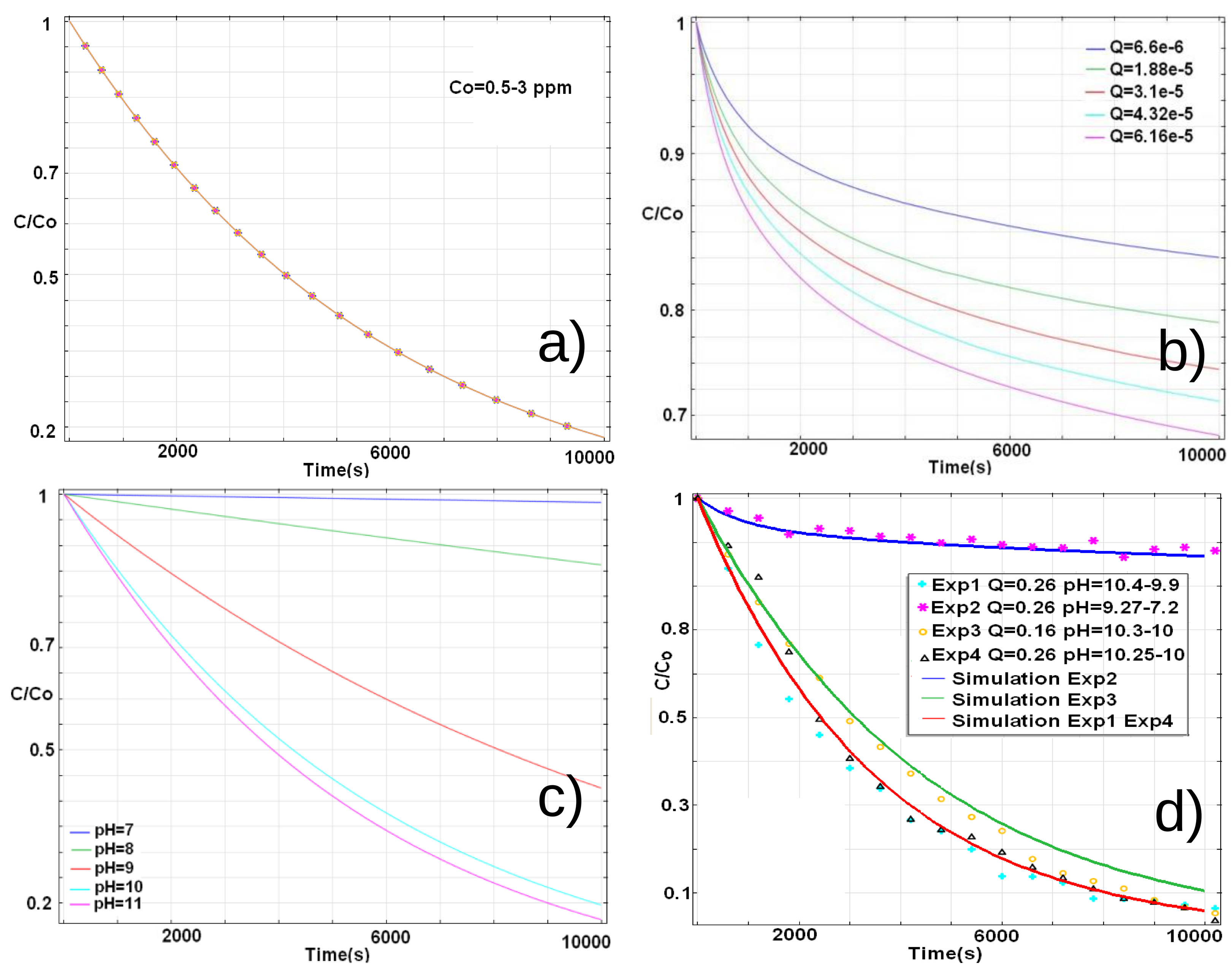

Figure 7. Evolution of cconcentration in the feeding tank at different conditions.

Conclusions: This model can be used to evaluate the hollow fiber membrane contactors performance for ammonia removal from aqueous solutions under different processing conditions and to define the operational parameters necessary to remove ammonia efficiently. More rigorous approaches will be taken in to account in further works where the model include the solution for the hydrodynamics inside the membrane contactor.

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References:

1, Mandowara and Bhattacharya, J. of Envir. Manag., 92, 121-130 (2011)
2, Mandowara and Bhattacharya, Compu. and Chem. Eng., 33, 1123–1131 (2009)
3, Agrahari et al., J. of Memb. Sc., 390–391, 164–174 (2012)
4, Hasanoglu et al., Chem. Eng. J., 160, 530–537 (2010)

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