UDC 541.64 https://doi.org/10.26577/2218-7979-2016-9-1-79-82

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The possibilities of use of the polyelectrolyte solutions in membrane technology for desalination

Abstract: The possibilities of use polyacrylic acid (PAA) solutions in membrane technology for water desalination have been investigated. To control changes in salt concentration (K_3 [Fe $(CN)_6$]), in aqueous solution, separated using standard dialysis membranes by UV spectroscopy. Thus optical density was examined at different concentrations of the solutions of the polymer (PAA), red blood salt, effect of pH on the degree of desalination. It was determined that the optimal concentration of polymer upon purification of water is PAA 10%. But with reduction of concentration of salt from 0,1mol/l to 0,001 mol/l the degree of desalination is increased. Upon use of solutions with lower pH values such as pH=3 the degree of desalination is decreased.

Key words: dialysis membrane, polyacrylic acid, optical density, water purification, degree of desalination.

Introduction

Many human activities, such as drinking, agriculture, sanitation and electricity generation require particularly significant amount of water. Fortunately, in many cases, centers of population are located near sources of useable water. However, oceans, which cover more than 70% of the earth's surface and contain 97% of the earth's water, have salt water [1]. Since this salty water is unsuitable for many applications, it must be purified before it used.

As the population on earth continues grow, the existing water supply will be more and more lack. Hence, the more water is required for satisfaction of requirements of mankind,the desalination of sea water will become more and more important source of useful water [2].

Membrane systems are attractive since they provide an absolute barrier for pathogens and remove the turbidity,thus, increasing the palatability of the water. Some membrane systems rely on thepower of gravity as a driving force, thereby avoiding the use of pumps and electricity [3].

The membrane technology allows to receive a water of high degree of purification. The complex process of purification allows to carry out for one technological operation the removal of excess content of salts from water, almost completely to expel from the composition of water the microbiological and organic components [4].

Membrane installations allow to receive best quality drinking water, and also to receive the desalinated water for various industries. While unlike traditional methods of purification the use of reagents (coagulants, flocculant, acids, alkalis etc.) is sharply reduced. Meanwhile, compactness and power intensityof installations allows to saveindustrial sites and cost of maintenance [5].

As the world's population continues to grow, existing water supplies will become increasingly insufficient. As more and more water is required to meet mankind's needs, desalination of sea water will become an increasingly important source of useable water. Any comprehensive plan addressing mankind's energy usage or ecologic impact must account for the effect of desalination; responsible development requires attention to the most energy-efficient methods of purifying water [6].

Materials and methods

In this work, the possibilities of use of polyacrylic acid solutions with the concentration of 5 w%, 10 w%, 15 w%, ($K_3[Fe(CN)_6]$) salt with concentration of 0,001 mol/l, 0,01 mol/l, 0,1 mol/l in membrane technologies for water desalination have been investigated. Also for the study of pH effect the solutions of salt with pH = 3, 4, 5, 6 values were prepared. Measurements were carried out via the device shown below (Figure 1). The tube (1) filled with aqueous solution of polyacrylic acid (PAA), the lower part is closed by a standard dialysis membrane (3) that non-permeable for macromolecules, but easily permeable for molecules of low-molecular substances. Changes in the concentration of salts in the «external» and «internal» solutions was controled by UV spectroscopy at a wavelength λ = 400 (UV-spectrometer, Specord Plus200, Germany).

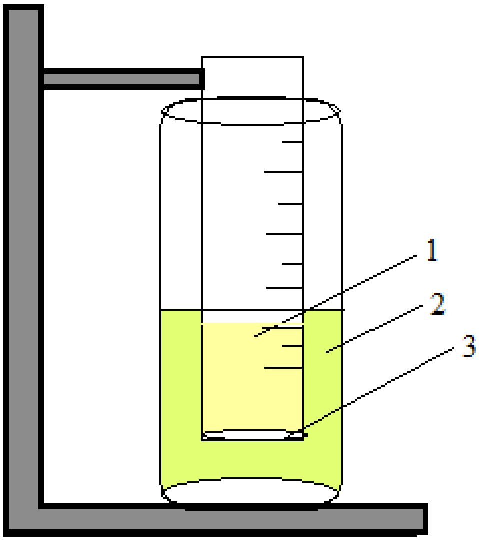

Figure 1 – The device for change of level of solution in internal and external solutions

1 – in an external vessel; 2 – in an internal tube: 3 – dialysis membrane

Result and their discussion

In the course of work, the effect of concentration of polymer on degree of water desalination (figure 2) was studied. It is necessary to emphasize that this experiment gives better result at high concentration ([PAA]=10%) of polymer comparable to concentration of macromolecules incrosslinked polymeric network of the same chemical nature.

It is quite explained as according to the classical theory of ideal solutions, the difference of osmotic pressure is defined by full number of the dissolved particles in each of unit ofthe system. The number of macromolecules having considerable molecular weight, remains small even at rather high mass concentrations of polymer. In case of suppression of ionization of carboxylic groups sharply decreases the quantity of osmotically active particles in solution.

However, at high concentrations ([PAA]=15%) of polymer considerable deviations from ideality as shown in the experiment are observed. At such concentrationsthe solution of polymer possesses the same degree of swelling, as the crosslinkedone. In a sense, the solution "swells" in the same way as the crosslinkednetwork (polymeric hydrogel), specifically,swells its constituent macromolecules, and partially permeable membrane plays the same role, as border of the sewed polymeric grid. In this regard, the optimal concentration of polymer upon water purification is PAA 10 w%.

This system has been used for the study of processes of swelling of PAA aqueous solution in solution ($K_3[Fe(CN)_6]$) salt. External solution contained 0,001 mol/l of salt in the initial state. "Internal solution" (i.e. the solution which contains in the internal tube, separated at the bottom from surrounding solution in a glass by the dialysis membrane) contains different concentration of PAA ([PAA]=5, 10, 15 w%). It should be noted that the system was set up in such a way that in the initial state the solution level in the tube ("internal solution") was 20 mm below than the level of solution in the external glass. In the initial statethe external solution had the volume of 100 ml, "internal"– 19 ml. After 50 hours the volume of internal solution increased from 19 ml to 39 ml. Accordingly, the volume of external solution in 50 hours decreased to 20 ml.

It is seen that at initial stages small increase in optical density of internal solution because of salt penetration was observed.But at later stages clarification of internal solution owing to pure penetration into him from external solution is observed. While, as seen from data of figure 2, there is an increase of optical density of external solution owing to loss of clear water by him.

Therefore, presence in "internal" solution of ionized macromolecules of PAA substantially interferes with penetration through the membrane ofsalt ions from external solution in "internal" solution. As the result of this phenomenon through the membrane from external solution by power of osmotic pressure generally clean watergets into internal solution.

Also during the experiment the effect influence of concentration of salt ($K_3[Fe(CN)_6]$) in external solution on the degreeof water desalination. With the reduction of concentration of salt from 0,1 mol/l to 0,001 mol/l in external solution the effect of cleaning amplifies. Really, apparently from data of figure 3, in big concentration of salt the optical density of internal solution changes a little, and only the optical density of external solution as a result of pure transition from its to internal solution increases.

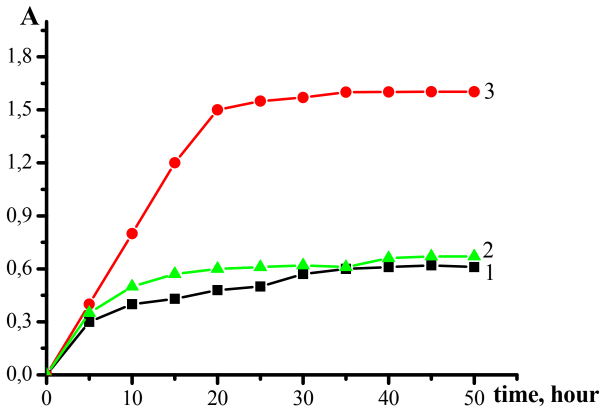

Figure 2 – The kinetics of change of optical density of the aqueous solution in the internal tube at different concentration of polymer

1 – C(PAA) = 5 w%; 2 – C(PAA)= 15 w%; 3 – C(PAA)=10 w%

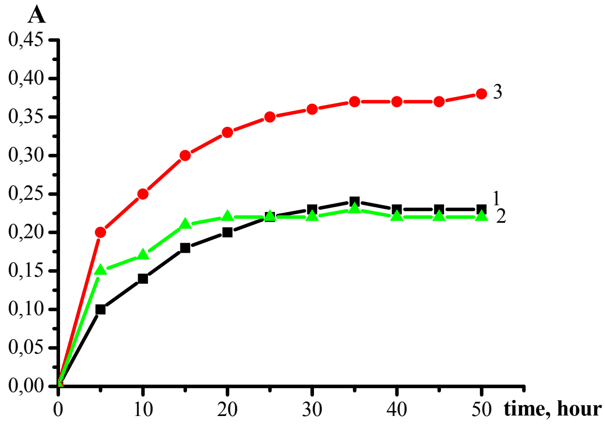

Figure 3 – The kinetics of change of optical density of the aqueous solution in the internal tube at different concentration of salt

1 – C($K_3[Fe(CN)_6]$)=0,1 mol/l; 2 –C($K_3[Fe(CN)_6]$)=0,01 mol/l; 3 –C($K_3[Fe(CN)_6]$)= 0,001 mol/l

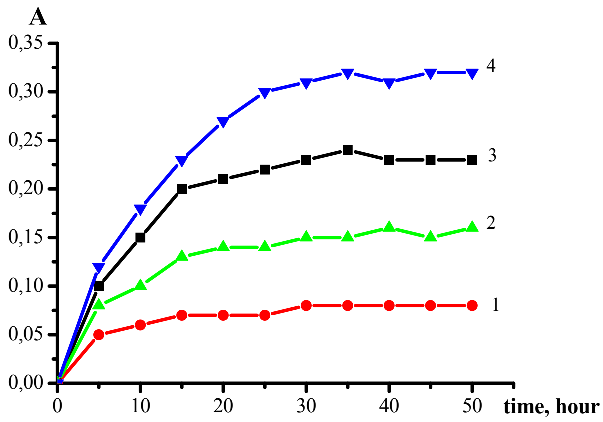

Figure 4 – The kinetics of change of optical density of the aqueous solution in the internal tube at different pH

1 –pH=3; 2 – pH=4; 3 – pH=5; 4 – pH=6

Besides, in this work the effect of pH on the degree of water desalination was investigated. It was observed that upon transition to solutions with lower pHthe degree of water desalination decreases. Optical density increases in internal solution, but remains during the long time (two days) is much lower than the optical density of external solution. Besides, decrease of pH the effect decreases owing to suppression of ionization of the PAA carboxyl groups and decrease of osmotic "activity" of PAA solution (Figure 4).

Conclusion

Thus, in this work the possibility of use the solutions of polyelectrolytes in membrane technology for desalinationhave been investigated. By UV-spectroscopy technique were studied absorbance of the solution at different concentrations of polymer [PAA]=5w%, 10 w%, 15w%. It was assumedthat existence into"internal' solution of ionized macromolecules of PAA significantly interferes with the penetration through the membrane of ions of salt from external solution into "internal" solution. As the result of this phenomenon through the membrane from external solution bypower of osmotic pressuresolution generally clear water gets into internal.It wasshown that optimal concentration of polymer upon water purification is 10 % PAA. While with reduction of concentration of salt from 0,1 mol/l to 0,001 mol/l in the solution the degree of desalination amplifies. And upon transition to solutions with lower pH (pH=3) the effect of degree of desalination decreases.

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