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Experimental Study on Reverse Osmosis System with Carbon Nano Tubes from Candle Soot

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Abstract

Conventionally, water Purification system contains two important purification stages, namely Carbon Filtration and Reverse Osmosis (RO). There has been significant research work reported in the literature on enhancing the RO water purification efficiency. Moreover, for obtaining desired quality of water as well as the production rates, the importance of system engineering is evident. We present two fold contributions in this field, (1) prepared and used candle flame soot as Nano carbon tubes as the adsorbents. An adsorption purification stage with carbon Nano tubes has been used before the RO stage in the water purification system. Experimental study of the purification system with and without Nano tube filtration stage has been presented. (2) Experimental study of transient analysis of RO system has been presented to understand the dynamics of the two stage process. The effect of feed pressure, water feed rate, and ratio of rejected and retentate flow rate have been investigated on the water quality.

Keywords: TDS (Total Dissolved Solids), Carbon Nanotubes, Reverse Osmosis.

1. Introduction

Current water shortage in many parts of the world requires the necessity of efficient purification methods for drinking water. Reverse Osmosis (RO) is widely popular and accepted water purification technique. In RO, the solvent is moved from high solute composition to low composition with the help of external pressure. This leads to the removal of dissolved solids making it suitable for drinking purpose. Moreover, because of the large surface area and the large chemical and thermal stability, carbon nanotube has obtained popularity in wastewater treatment. Recently, a review article (Liu et. al., 2013) summarized the applications of carbon nano tubes in water treatment. Usually, adsorption filtration by carbon nanotubes followed by RO increases lifespan of RO membrane and increases water purity as well. Moreover, for making the water purification process economically and technically attractive, operation conditions such as feed water flow rate, feed pressure, water recovery should be maintained at specific values. Thus, systems engineering plays a vital role in efficient operation of RO system (Sassi et. al., 2013). Hence, steady and transient analysis of the water purification process for various scenarios provides large insight in understanding the capacity and efficiency of the water purification system. We present two fold contributions in this field, (1) prepared and used candle flame soot as Nano carbon tubes as the adsorbents. An adsorption purification stage with carbon Nano tubes has been used before the RO stage in the water purification system. Experimental study of the purification system with and without Nano tube filtration stage has been presented. (2) Experimental study of transient analysis of RO system has been presented to understand the dynamics of the RO process. The effect of feed pressure, water feed rate, and ratio of rejected and Retentate flow rate have been investigated on the water quality.

Synthesis of carbon nano tubes from candle soot and experimental results are presented in Section 2. The transient analysis of RO system to study the effect of various parameters is presented in Section 3. Finally the work is concluded in Section 4.

2. Carbon Nanotubes (CNT) Synthesis Adsorption Stage

In a controlled flame environment, Single Wall Nano Tubes (SWNT) can be produced (Height et. al., 2005) by flame Synthesis method. Such nanotubes can be used in the adsorption stage before the RO stage. In this work, carbon nano tubes are prepared in the laboratory with controlled flow environment from candle soot. Cheaply available 100 candles were used to prepare soot by keeping aluminum foil sheets on the top as shown in the Fig. 1. Candle soot was collected on the aluminum foil, which consists of 5% CNT's. Crude CNTs were purified by centrifugation using Sulphuric acid. CNT's which were prepared by using above method were fabricated into a traditional carbon filtration tube. This 15% CNTs along with 85% Activated Carbon Tubes made the carbon filtration stage.

3. Results and Discussion

3.1 Steady State Analysis of the RO system with CNT

To confirm the efficacy of the CNT stage, we carried out the water purification of RO system with CNTs and compared the corresponding water quality with only activated carbon in Table 1. The feed water TDS was measured at 1000 PPM. The feed water was purified with Activated carbon adsorption stage followed by RO and was compared with CNT adsorption stage followed by RO. The water quality in terms of TDS was measured at steady state. While 42 PPM was the TDS of water after purification using activated carbon in the adsorption stage, the TDS of 28 PPM was noticed when using CNTs in the adsorption stage. Thus, a 50% improvement in TDS was observed with CNTs compared to that with the activated carbons. The significant improvement in water quality in presence of CNT adsorption stage motivated to carry out a transient analysis of RO system, which is discussed in the next section.

3.2 Transient Analysis of the RO system with CNT

Maintaining the target process conditions in RO technology is very essential for the successful and economic operation of the RO desalination system. Frequent changes in feed water quality can significantly change the conditions in the RO membrane modules, which may adversely affect the water quality and production or membrane damage. Hence, the transient experiment analysis of the RO system with CNTs is carried out and presented here.

3.2.1 Effect of feed pressure on water quality

Increase in feed pressure improves purification efficiency at the cost of high energy requirements. The RO system was run at two different feed pressures, at 80 psi and 100 psi. At higher feed pressure, as expected water quality was improved. 27% improvement in TDS was observed at 110 psi compared to that at 80 psi at steady state. Also, the rate of improvement in the TDS is also found to be higher with the higher pressure.

3.2.2 Effect of Flow Rejecter (FR) Size

At higher flow rejection, the resistance for separation decreases and hence leads to better TDS removal. We conducted experiments at two different FR sizes, at 350 and 450 μm. No difference was noticed on the water quality at steady state for the two resistances. Though, the rate of improvement in the TDS was significantly high with 450 FR compared to that at 350 FR. Thus, the improved rate of improvement in TDS was observed at the cost of larger water loss.

3.2.3 Effect of Feed Flow Rate

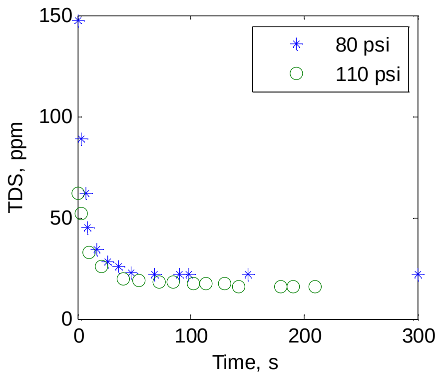

Fig. 1: Effect of feed pressure on TDS for the RO system

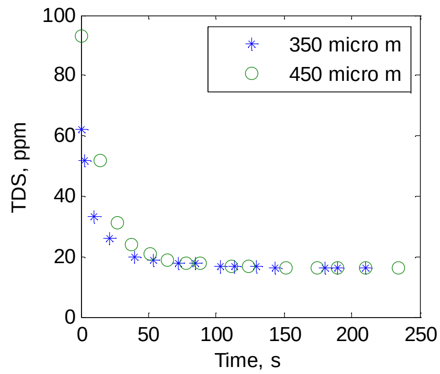

Fig. 2: Effect of flow resistance on TDS for the RO system

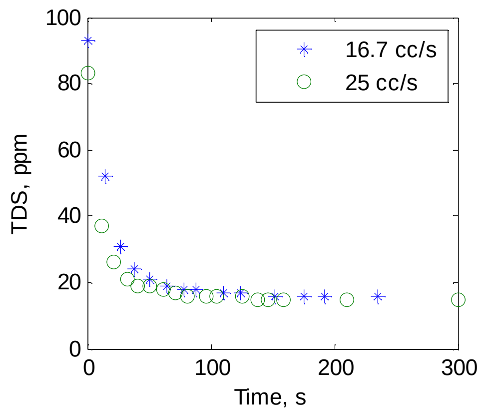

Fig. 3: Effect of feed water flow on TDS for the RO system.

The effect of feed flow rate on water quality was studied at two different values, 16.7 and 25 cc/sec. Observations similar to that with FR can be made here. No effect at steady state was observed, though the rate of improvement in TDS was better with larger feed water flow. Though, this trend is expected to be there upto a certain feed flow rate only, after which the TDS may deteriorate with further increase in water feed rates.

4. Conclusions

Carbon nano tubes material was prepared from the candle soot for its use in the RO system for water purification. An adsorption stage with CNTs followed by the RO stage was used in this work for steady and transient analysis. The experiments were conducted to study the effect of feed pressure, retentate/permeate ratio, and feed flow rate on the water quality. The increase in pressure, retentate/permeate ratio and feed flow enhanced the water purification efficiency. While increase in feed pressure resulted in the rate of improvement of TDS as well as the TDS value at steady state, the other two parameters had effects during transient conditions only. Thus, water purification efficiency was improved at the cost of high energy cost or water loss.

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