Performance test of self-made fast film detection all-in-one machine under different pressure

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Abstract: Ultrafiltration membrane can remove colloid, virus and large molecules of organic matter, but it does not have the ability to remove small molecules of organic matter and ionic pollutants, and the nanofiltration membrane can effectively remove organic matter and inorganic salts and other pollutants. However, the research and application of nanofiltration advanced water treatment technology are still few in China. In this experiment, ultrafiltration membrane was combined with nanofiltration membrane to make a rapid detection instrument. The instrument was used to test key performance indicators such as desalination rate and water flux under different pressures, which proved that the instrument could quickly detect related indicators of the membrane and its efficiency could be doubled.

1. Introduction
China’s water pollution problem is serious, especially in recent years, new pollutants have been found, and the traditional coagulation - sedimentation - filtration treatment technology has been unable to meet the needs. Ozone-biological activated carbon technology can enhance the removal of organic pollutants, ammonia nitrogen, but there are problems such as the generation of bromate by-products. With the development of science and technology, membrane treatment technology is gradually emerging in the petrochemical industry and industrial water treatment, but there are some problems.

The membrane can be divided into many types by function. Ultrafiltration and nanofiltration membranes are more common. The function of ultrafiltration membrane is mainly to cut the molecular weight and the transmittance of pure water. Ultrafiltration technology can remove colloid, virus and large organic molecules, but it does not have the ability to remove small organic molecules and ionic pollutants, so the safety of water quality cannot be fully guaranteed. The performance of nanofiltration membrane is water flux and removal rate (also known as interception rate), and nanofiltration technology can effectively remove pollutants such as organic matter and inorganic salts, but the research and application of nanofiltration advanced water treatment technology in China are still few. It can be seen that each membrane has its unique advantages. If the ultrafiltration membrane is combined with the nanofiltration membrane, the advantages can be superimposed and the water treatment effect will be better. Therefore, it is very important for the basic detection of ultrafilter-nanofiltration double membrane combined process research, which will also provide reference for the promotion and application of nanofiltration water treatment technology.

The instrument used in this experiment is a self-made rapid detection instrument combining ultrafiltration membrane with nanofiltration membrane, and the instrument is used to detect the performance of membrane indicators under different pressure conditions, such as: desalination rate, water flux.
2. The experiment

2.1. Instruments and reagents

2.1.1. Instrument: self-made ultrafiltration and nanofiltration double membrane rapid detection instrument, Stopwatch, measuring cylinder.

![Diagram of integrated membrane performance test device](image)

2.1.2. Reagent: sodium chloride (analytically pure), hydrochloric acid (analytically pure), sodium hydroxide (analytically pure), deionized water (conductivity less than 10us/cm)
Reverse osmosis diaphragm: 10 kinds of different products from different enterprises

2.2. Experimental methods

2.2.1. The test conditions for the water flux and ion removal rate of the nanofiltration membrane are shown in Table 1.

| Test fluid type | Test solution concentration mg/L | pH    | Test temperature °C | Membrane velocity m/s |
|-----------------|-------------------------------|-------|---------------------|------------------------|
| NaCl            | 250±5                         | 7.5±0.5 | 25.0±0.2          | ≥0.45                  |
| CaCl₂           | 250±5                         | 7.5±0.5 | 25.0±0.2          | ≥0.45                  |
| MgSO₄           | 250±5                         | 7.5±0.5 | 25.0±0.2          | ≥0.45                  |
| NaCl            | 2000±20                       | 7.5±0.5 | 25.0±0.2          | ≥0.45                  |
| CaCl₂           | 2000±20                       | 7.5±0.5 | 25.0±0.2          | ≥0.45                  |
| MgSO₄           | 2000±20                       | 7.5±0.5 | 25.0±0.2          | ≥0.45                  |

2.2.1.1. Several membrane samples (not less than 4) shall be intercepted, and the samples shall be free from obvious defects such as wrinkles and damage. The size of the samples shall meet the requirements of the sealing ring that completely covers the evaluation pool of the reverse osmosis
membrane. The effective membrane area of the membrane in the evaluation tank is not less than 2.5x10^{-3} m^2.

2.2.1.2. Soak the sample in deionized water or distilled water for 30min.

2.2.1.3. According to the type of membrane, the corresponding concentration of sodium chloride aqueous solution was configured as the test solution. The solution concentration was shown in table 1, and use hydrochloric acid or sodium hydroxide to adjust the PH to 7.5±0.5. The solution concentrations are 2000mg/L and 32000mg/L respectively.

2.2.1.4. Install the reverse osmosis membrane sample into the reverse osmosis membrane evaluation pool, and the desalination layer shall be toward the inlet side of the evaluation pool.

2.2.1.5. Open the booster pump, slowly adjust the stop valve, and adjust the test pressure to 1.55MPa and 5.52MPa successively.

2.2.1.6. After stable operation at constant temperature and constant pressure for 30min, a certain amount of test liquid was collected with beaker, and the amount of water sample was not less than 150mL; Use the stopwatch and the measuring cylinder to measure the volume of the permeable fluid (no less than 30mL for a single pattern) in a given period of time.

2.2.2. Calculation method

2.2.2.1. Water flux
The calculation formula is

\[ F = \frac{V}{At} \]

Where \( F \) is the water flux, unit \([L/(m^2\cdot h)]\), \( V \) is the volume of transparent liquid collected, unit L, \( A \) is the effective membrane area, unit m^2, \( T \) is the Time spent collecting \( V \) volume of transparent liquid, unit h

2.2.2.2. Ion removal rate
The calculation formula is

\[ R = \left(1 - \frac{C_p}{C_f}\right) \times 100\% \]

Where \( R \) is the Removal rate, \( C_p \) is the chloride ion content in the permeable solution, mg/L, \( C_f \) is the chloride ion content in the test solution, mg/L.

2.3. Experimental results
When the pressure of the pressure gauge is adjusted to 1.55Mpa, the experimental data are shown in the following table 2.

| Model | Water flux m³/(m²·h) | Stable desalination rate % | Minimum desalination rate % | Water rate m³/d | Membrane area m² |
|-------|----------------------|----------------------------|----------------------------|-----------------|-----------------|
|       |                      |                            |                            |                 |                 |
When the pressure of the pressure gauge is adjusted to 5.52Mpa, the experimental data are shown in the following table 3.

| Model | Water flux m3/(m2-h) | Stable desalination rate % | Minimum desalination rate % | Water rate m3/d | Membrane area m2 |
|-------|----------------------|-----------------------------|-----------------------------|-----------------|-----------------|
| F     | 0.02574              | 99.7                        | 99.5                        | 18.9            | 30.6            |
| G     | 0.02687              | 99.7                        | 99.5                        | 22.7            | 35.2            |
| H     | 0.02755              | 99.8                        | 99.7                        | 24.6            | 37.2            |
| I     | 0.02755              | 99.8                        | 99.7                        | 24.6            | 37.2            |
| J     | 0.03819              | 99.8                        | 99.7                        | 34.1            | 37.2            |

3. Conclusion
The instrument can quickly detect membrane related indicators; especially key performance indicators such as desalination rate and water flux, and the detection efficiency can be more than doubled.

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