Efficient Turbidity Removal Using a New Gel Filtration Process

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Abstract

The removal of turbidity is a prime objective in the treatment of seawater, especially in the production of potable water. The water turbidity exists because of the colloidal particles or large-weight molecules that remain in suspension in the untreated solution. This study investigated the performance of a new gel layer for the treatment of highly turbid seawater. Based on the periodic turbidity values in the Arabian Gulf over the year, the chosen seawater samples had the turbidity values of 4.8 NTU, 76.1 NTU, and 99.7 NTU. The gel filtration layer showed promising adsorption capabilities and its physical appearance achieved a cohesive matrix form, which resulted in good mechanical strength. The proposed gel filter was effective enough for the removal of turbidity from the selected seawater samples with more than 98.5% efficiency.

Keywords: Hydrogels; Turbidity removal; Seawater; Gel filtration; Water treatment

1 Introduction

Water scarcity and contamination are worldwide concerns because of the limited freshwater resources. 97% of the available water on earth is considered saline water and only around 0.8% of the available water on earth is potable water which can be found in rivers, lakes, and underground aquifers (Gleick, 1993). The demand for freshwater is expected to increase by 20% to 30% by 2050 due to the rapid population growth and the large economic development (Boretti & Rosa, 2019). Thus, it is imperative that the focus is directed towards the innovation of strategies to obtain pure water at a low cost. One of the main impediments to desalinating seawater is the presence of organic, inorganic, and colloidal matter in the untreated water. These large-weight molecules and suspended colloidal particles are responsible for increasing the turbidity of the water. Water is defined as turbid when it is visually muddy or cloudy owing to the solid particles that remain suspended in the solution (Omar & MatJafri, 2009). More specifically, the turbidity of water is an optical property that causes the scattering and absorbance of light rather than transmitting through the solution without changing its direction (Malik, 2018).

The most widely used technologies for the removal of turbidity today remain to be sand filtration, coagulation-flocculation, and electrocoagulation (Shaikh et al., 2021). The coagulation processes induce the formation of flocks, leading the small particles to become larger and therefore settle down in the bottom of the reactor (Palta et al., 2014). However, the filtration process allows the selective permeation of water, whereas the large and colloidal particles get rejected (Nkwonta et al., 2010). Another reliable water remediation method is adsorption which is considered an effective technique that is inherently advantageous for the removal of both inorganic and organic pollutants (Ayawei et al., 2017). The investigation for efficient adsorbents attracted immense attention in the domain of water treatment. Hydrogels have emerged as promising materials with remarkable adsorption capabilities perceived by their low cost and high treatment efficiency (Van Tran et al., 2018). Hydrogels are three-dimensional (3D) cross-linked polymeric networks formed through the reaction of one or more monomers (Ullah et al., 2015). Hydrogels are highly swollen in water and thereby can imbibe large amounts of aqueous solution and entrap and immobilize the water contaminants due to their three-dimensional cross-linked structure. Therefore, for the first time, this work proposes a gel filtration layer for the treatment of highly turbid seawater.

2 Methodology

2.1 Seawater Turbidity

Seawater was collected from the bay of the Arabian Gulf in Doha, Qatar. The average turbidity values for Arabian Gulf seawater were highly variable throughout the year, and particularly low in the second half. The maximum turbidity observed was 99.7 NTU in March. Seawater possesses high turbidity values during the first quarter of the year with the average values of 3.4, 23.2, 8.3 and 4.7 NTU in the months of January, February, March, and April, respectively. Three seawater samples with different turbidity values were chosen to assess the performance of the gel filtration capabilities for the removal of turbidity. The selected samples represent the average turbidity over the year (4.8 NTU), the average of the maximum values throughout the year (76.1 NTU), and finally, the maximum turbidity value observed (99.7 NTU).

2.2 Gel Preparation and Filtration Setup

The aluminium hydroxide hydrate gel was prepared using stoichiometric ally reagents. Sodium bicarbonate and Aluminium Sulfate salts were purchased from ALPHA CHEMIKA. The following equation (1) describes the synthesis reaction of the aluminium hydroxide hydrate gel.

$$\mathrm{Al_2(SO_4)_3 + 6NaHCO_3 \rightarrow 3Na_2SO_4 + 2Al(OH)_3 + 6CO_2} \quad (1)$$

All chemicals were of analytical grade. At room temperature, 53.76g of sodium bicarbonate was dissolved in 560 mL of demineralized water. Additionally, 36.4g of aluminium sulphate was dissolved in 100 mL of demineralized water. The solutions were left under magnetic stirring for 45 minutes to ensure that both salts were completely dissolved. The aqueous aluminium sulphate solution was added slowly at a rate of 20 mL/min to the sodium bicarbonate solution. The reaction was given a sufficient time to assure that CO_2 was completely emitted. The gel solution was left for 14 days for polymerisation. After the 14 days passed, the water was removed and the gel was moulded in a Büchner funnel, allowing for the formation of the filtration media. As shown in Figure

1, the feed solution was then poured into the 3mm filtration layer, and the treatment was operated using gravitation energy only.

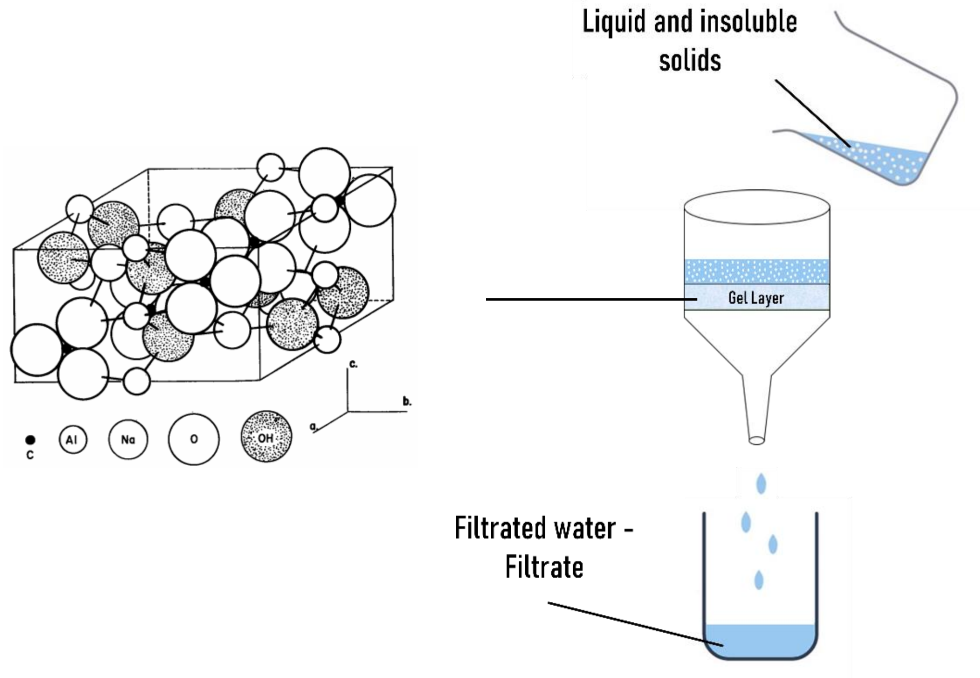

Fig. 1: Schematic drawing of the gel filtration procedure for the treatment of high turbidity seawater

3 Results and Discussion

3.1 Removal of Turbidity

After moulding the gel material in a Büchner funnel and adjusting the thickness to 3 mm, the turbid seawater was poured into the filtration layer. As mentioned previously, three seawater samples with the NTU values of 4.8, 76.1, and 99.7 were tested in the gel filtration treatment. The filtration system was operated under the gravity force only, and the filtrate of all samples was visually clear and transparent.

Table 2 shows the NTU values of the raw and treated seawater using gel filtration along with the turbidity removal percentages for the different types of feed water. The gel filtration layer showed a remarkable capacity for the elimination of turbidity to values lower than 1 NTU (>98.5% removal efficiency). The high turbidity removal potential could be attributed to the great adsorption features of the gel layer (Malekizadeh & Schenk, 2017). According to Malekzadeh et al. (2017), aluminium hydroxide hydrate gel holds great physical adsorption and mechanical straining properties.

Table 2: Turbidity Removal by gel Filtration

Feed water Sample	SW	SW	SW	Demineralized water
Before filtration	4.8 NTU	76.1 NTU	99.7 NTU	1 NTU
After filtration	0 NTU	1 NTU	1 NTU	0 NTU
% Removal	100%	98.6%	98.9%	100%

4 Conclusion

This study proposed a new gel filtration layer for the removal of turbidity from seawater. To reveal the gel filtration turbidity removal capacity, three different solutions were tested with 4.8, 76.1 and 100 NTU turbidity values. The gel filtration process removed more than 98.5% of the turbidity in the seawater, achieving 1 NTU turbidity in the filtrate. Future work includes comparing the proposed gel filtration system with other popular methods used for the removal of turbidity as well as studying the washing and recyclability aspects of the gel filtration layer.

Acknowledgement

This report was made possible by a UREP award [UREP26-012-2-006] from the Qatar National Research Fund (a member of the Qatar Foundation). The statements made herein are solely the responsibility of the authors.

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Cite as: Talhami M., Khatib W., Dahdal O., Hassan M. & AlHawari A., "Efficient Turbidity Removal Using a New Gel Filtration Process", *The 2nd International Conference on Civil Infrastructure and Construction (CIC 2023)*, Doha, Qatar, 5-8 February 2023, DOI: https://doi.org/10.29117/cic.2023.0158