Treatment of Seawater using Solar Energy in A Re-Circulation Pipe Reactor

Manahel Al Araimi
Caledonian College of Engineering, Sultanate of Oman

B. M. Sangeetha
Caledonian College of Engineering, Sultanate of Oman

Feroz Shaik
Caledonian College of Engineering, Sultanate of Oman

Shamsa Al Saadi
Caledonian College of Engineering, Sultanate of Oman

L. Nageswara Rao
Caledonian College of Engineering, Sultanate of Oman

Abstract

Experimental investigations were carried out in a recirculation pipe reactor exposed to solar energy, to study the degradation of the pollutants present in the seawater. Titanium dioxide (TiO_2) was used as photocatalyst and the effect of degradation of pollutants was evaluated through percentage reduction of Chemical Oxygen Demand (COD), Total Organic Carbon, Total Inorganic Carbon (TIC), pH, Total Dissolved Solids (TDS) and Turbidity.

Keywords: Solar energy, Titanium dioxide, Desalination, Organic matter, Inorganic matter

I. INTRODUCTION

Desalination is process of removing mineral salt from sea or brackish water either by thermal or membrane techniques. This process is considered to be energy intensive and vital for fresh water supply especially in the water scarcity nations. In addition to mineral salts, there are lot of pollutants present in the feed water in trace amounts which needs to be removed before the water enters in to the main process otherwise it may leads to scaling or fouling of the system. The feed water is generally treated by conventional methods, which sometimes ineffective in removing the trace pollutants and here comes the application of advanced oxidation processes. Solar photo catalysis is an advanced oxidation process which is widely applied in water treatment processes and in the present study an attempt was made to study the application of solar nano photo catalysis for the treatment of pollutants present in seawater.

Various researchers [1-8] applied photocatalysis technology for the treatment of wastewater but not much reported on seawater treatment, which may be due to complexity of seawater composition. In the present investigation the application of solar nano photocatalysis for seawater treatment showed promising results and the technology can be developed for pretreatment of feed water to the reverse osmosis desalination process. Photo catalytic reaction is relatively lower in cost as it only needs photons/light, catalyst, and air for the reaction to take place. Nano-scale photocatalyst has more photocatalytic activity than the normal scale catalyst due its larger surface area for contacting between the reactants and it's having a smaller size will reduce the time needed for the carrier diffusing out of the photocatalyst pours to the photo catalyst surface. Using a concentrated light system that reflect the solar light onto the photocatalytic reactor by the use of a reflecting surface is more preferred because it requires smaller reactor volume, it operates at a higher flow rate, better mass transfer rates, and it can be even operated under cloudy conditions. When light illuminate the surface of the photo catalysts with band gap energy equal or higher than the semiconductors band gap, the semiconductor gets activated by the absorption of photons then the electrons get excited from the valance band to the conduction band resulting in the formation of a positive hole (p^+) in the valance band and an electron (e^-) in the conduction band. The positive hole can oxidize the pollutant directly or oxidize water to form ($HO^{\cdot}$) radicals. At the same time, the electron reduces the oxygen adsorbed to the photocatalyst which prevents the combination of electrons and the positive hole [1].

The reaction below explains the mechanism [1]:

$$\text{Photo catalyst} \longrightarrow e^- + p^+ \quad (1)$$

$$e^- + O_2 \longrightarrow O_2^- \quad (2)$$

$$p^+ + \text{Organics} \longrightarrow CO_2 \quad (3)$$

$$p^+ + H2O \longrightarrow HO^{\cdot} + H^+ \quad (4)$$

$$HO^{\cdot} + \text{Organics} \longrightarrow CO_2 \quad (5)$$

Photocatalytic reaction breaks down the pollutant molecules without any residue thereby eliminates the need of the removing sludge to landfill. The other advantage is that the catalyst lasts for long time and there is no need for adding chemicals in the process, which makes the operation simple and economical. Experimental investigations carried out by Radwan Al Rasheed [1] have proved that photocatalysis got the ability in oxidizing the pollutants which are present in seawater.

II. MATERIALS & METHODS

A. Materials:

Commercial type of TiO_2 Aeroxide P25 from the Evonik industry powder was used. A fresh seawater samples was collected from Al-Athaibah beach, Oman from around 1 km away from the shore. A transparent glass tube reactor was used which had a diameter of 0.02m and a length of 0.06m. The system tank holds 0.002 m^3 of seawater water along with 1.5g of the photo catalyst which is continuously re-circulated through the tubular reactor at constant flow rate with 170 rpm using a peristaltic pump. An aluminum sheet was used as a concentrator below the glass tube and the schematic diagram of the experimental set up was shown in Figure1.

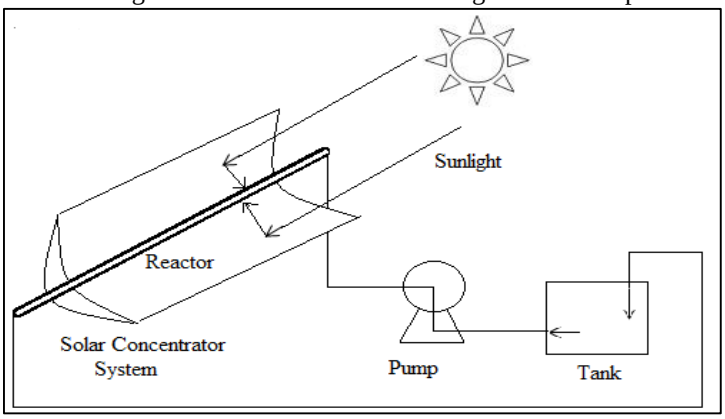

Fig. 1: Schematic of the Experimental Set-up

Shimadzu, Japan make saline water total carbon analyzer was used for TOC and TIC analysis of the samples. The COD was analyzed by using the Chemetrics Analyzer. TDS, and pH were analyzed by Eutech make water analysis kit.

B. Materials and Methods

Fresh seawater was collected for each experiment from Al-Athaibah costal area, 1.5 L of seawater was used for each experiment with different concentrations of TiO_2. The initial seawater sample was analyzed before adding the photocatalyst and then the reactor was exposed to the sun light (as shown in Figure1) in the Caledonian college of engineering campus, Oman from 10:00 am to 3:00 pm. The samples were collected every one hour and analyzed.

III. RESULT AND DISCUSSION

The TiO_2 concentration was varied from 1.5g to 4.5g with a continuous re-circulation. Figure 2 shows the variation of pH for different concentrations of TiO_2. It was observed that there is slight change in the pH during the reaction time.

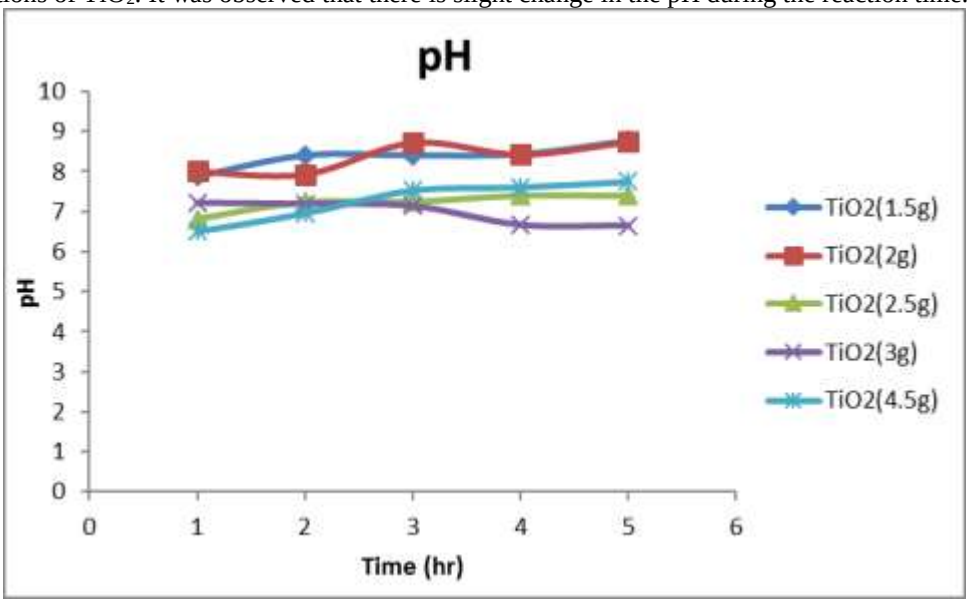

Fig. 2: Variation of pH for different concentrations of TiO_2

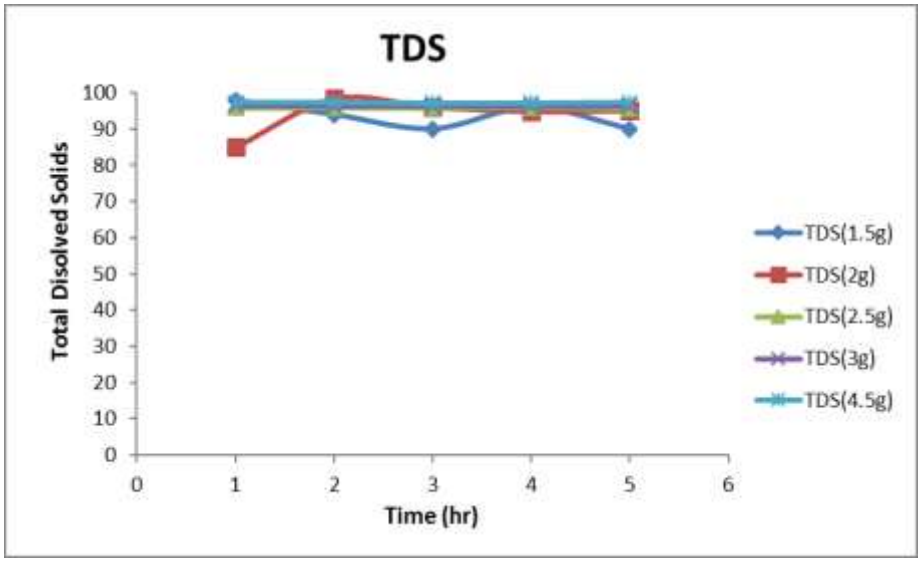

Fig. 3: Variation of TDS with different concentrations of TiO_2

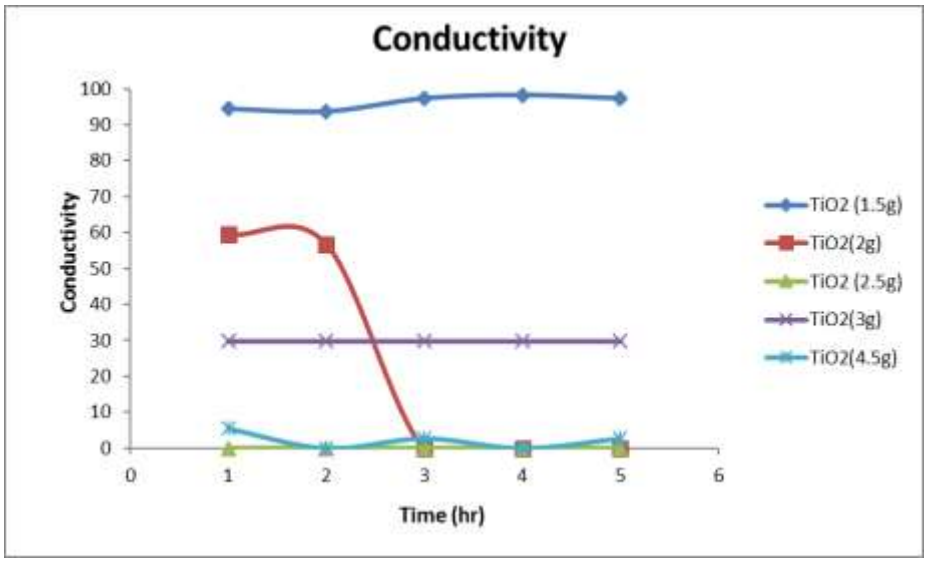

Fig. 4: Variation of Conductivity with different concentrations of TiO_2

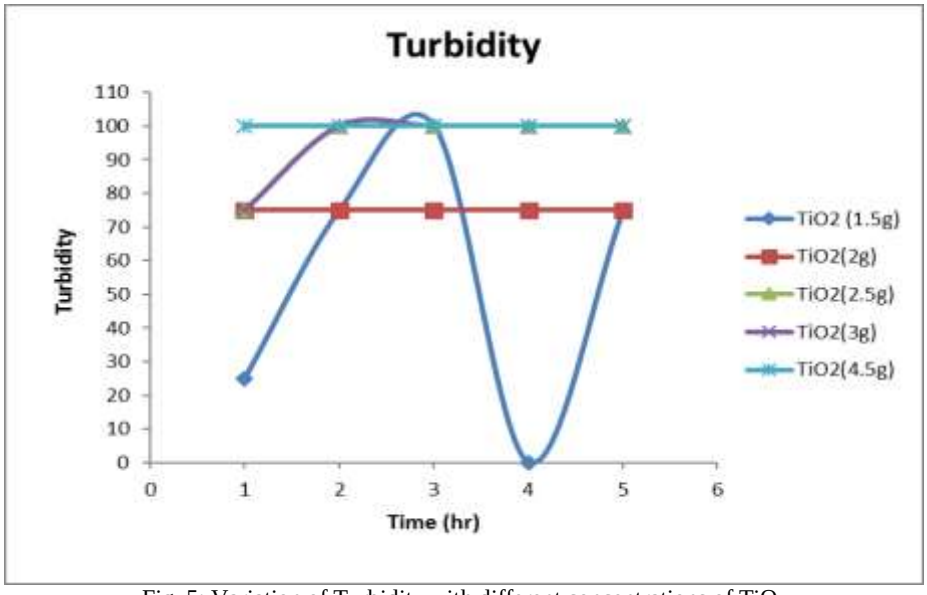

Fig. 5: Variation of Turbidity with different concentrations of TiO_2

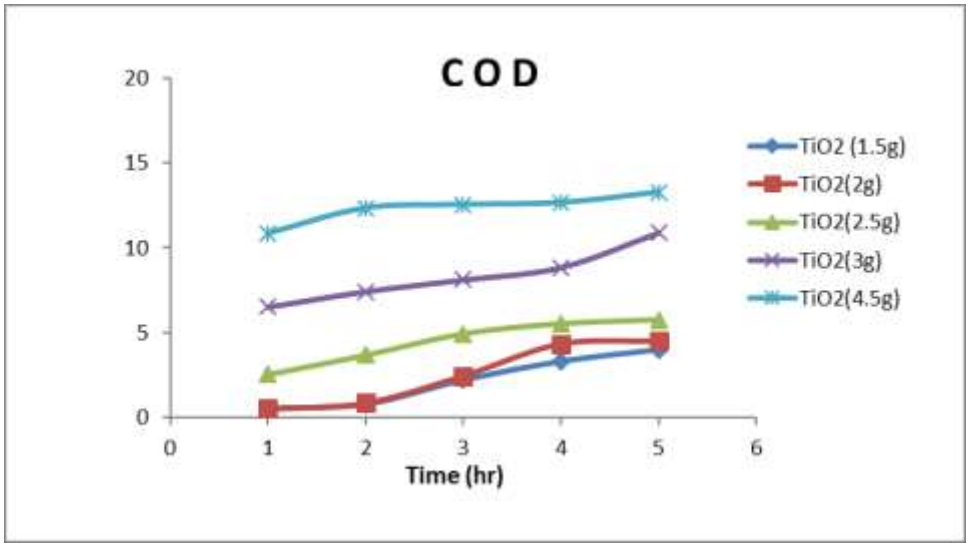

Fig. 6: Variation of COD with different concentrations of TiO_2

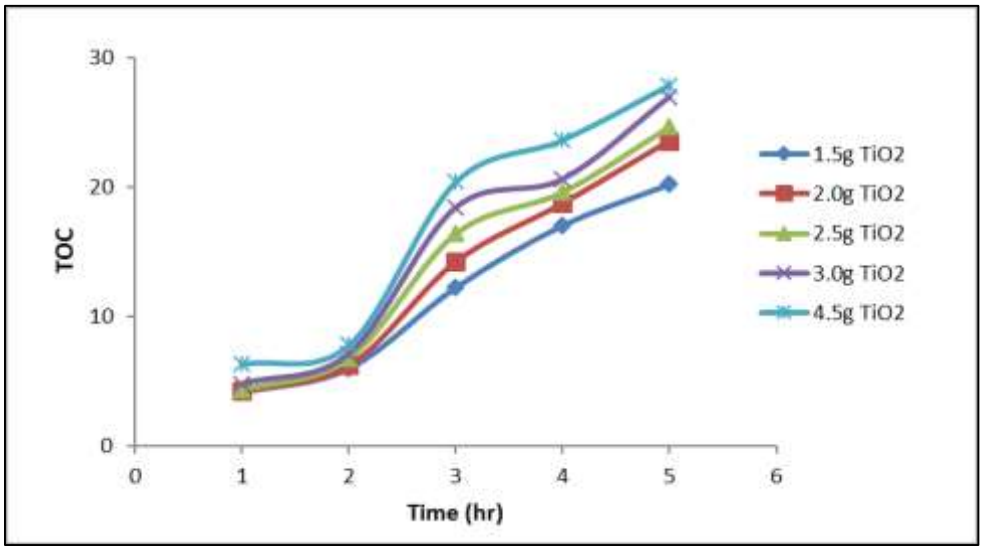

Fig. 7: Variation of TOC with different concentrations of TiO_2

IV. CONCLUSION

Water desalination by using solar energy is of great significance in the future, by replacing fossil fuel that is used in water desalination plants by solar energy. Major desalination processes consume a large amount of energy derived from oil and natural gas in the form of heat and electricity, while emitting harmful CO_2. Solar desalination has emerged as a renewable energy technology and a promising technology to produce fresh water. It is considered less expensive than other operations, and is also considered to be environmentally friendly and will be used heavily in the future because of the high cost of fossil fuels, which is used in large plants for water desalination.

The report explains in detail, "Continuous pre-treatment for seawater desalination using solar energy". The aim of this experiment is to determine the mass of the titanium dioxide that contributes to the desalination of certain amount of water and to test the effect of titanium dioxide in sea water desalination process and to treat the seawater by applying solar energy for water desalination. The device used in this project is a pump connector to solution which is (2 liter of sea water and titanium dioxide) through a tube of silicon, which works to pull the solution and was passed through a glass tube which was exposed to the sun for 5 hours continuously and for each hour, a sample was taken to measure different parameters such as (conductivity, pH, TOC, COD). The effect of titanium dioxide on sea water was analysed. The best result was obtained on the fourth day which was 4.5 g of titanium dioxide that showed a considerable reduction of chemical oxygen demand and organic matter. It was also observed that a greater amount of titanium helped in reducing organic matter on exposure of the solution to solar light.

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