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Experimental Studies For Treatment Of Seawater In A Re-Circulation Batch Reactor Using Tio$_2$ P25 And Polyamide

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ABSTRACT

A new method of degradation of the pollutants present in seawater using titanium dioxide(TiO_2P25) and Polyamide (PA) with a specific design of a reactor, which circulates the flow inside of it using a peristaltic pump, was considered. Experiments were carried out in a batch re-circulation reactor by varying the concentration of TiO_2 and PA.Samples were collected on hourly basis and the parameters total organic carbon (TOC), total inorganic carbon (TIC), chemical oxygen demand (COD), total dissolved solids (TDS) and the pH was evaluated to study the effect of degradation of pollutants present in the seawater by solar nano photo catalysis.

Keywords: Photocatalysis; Seawater treatment; Solar energy; Desalination.

1. INTRODUCTION

Water is essential for life, and due to the limited groundwater and rainfall in Oman the reliance is focused on desalination of seawater. There are many desalination plants in Oman and the expansion of these plants happens almost every five years due to increase in water demand to meet the rapid industrial and population growth. The idea behind implementation of nano photocatalysis technology is to use an environmental friendly method for degradation of the organics and inorganics which are present in the feed water to reverse osmosis desalination. This technology can limit the membrane fouling, since the pollutants will be degraded before they make it to the RO membrane, hence tackling the problem from the source not only reduce the maintenance cost but it will also provide a long life of the membrane. Fouling and scaling can be marked as the major problem in RO membrane, which affects the overall performance of the plant, where in case of fouling it can be due to the microorganisms which consists of bacteria that can settle on the membrane and grow, beside that the plugging of the suspended particles, organics and colloid. On the other hand, scaling can also result to membrane fouling due to the inorganics present in it such as calcium carbonate, calcium fluoride, barium sulfate and strontium sulfate. 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 applicationof solar nano photocatalysis for seawater treatmentshowedpromising 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 photocatalyst 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]:

$$\text{Photocatalyst} \longrightarrow e^- + p^+ \tag{1}$$

$$e^- + O_2O_2^- \longrightarrow \tag{2}$$

$$p^+ + \text{Organics} \longrightarrow CO_2 \tag{3}$$

$$p^+ + H_2O \longrightarrow HO^\cdot + H^+ \tag{4}$$

$$HO^\cdot + \text{Organics} \longrightarrow CO_2 \tag{5}$$

Photo catalytic 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 in a way that can improve the membrane life.

2. MATERIALS & METHODS

2.1 Materials:

Commercial type of TiO_2Aeroxide P25 from the Evonik industry powder was used. A fresh seawater samples was collected from Al-Seeb beach from around 1 km away from the shore. A transparent glass cylindrical tube reactor was used which had a diameter of 0.10m, thickness of 0.0015m and a length of 0.35m. The glass tube was provided with two holes at the bottom, one as inlet to the pump and the other as the outlet line. Silicon tube was used to connect between the cylindrical tube and the peristaltic pump. A solar parabolic trough collector was also used to maximize the sunlight concentration. Figure 1 shows the schematic diagram of the experimental set-up. It is batch re-circulation reactor, where the contents are well mixed by slow movement of the solution as well exposed to solar irradiation.

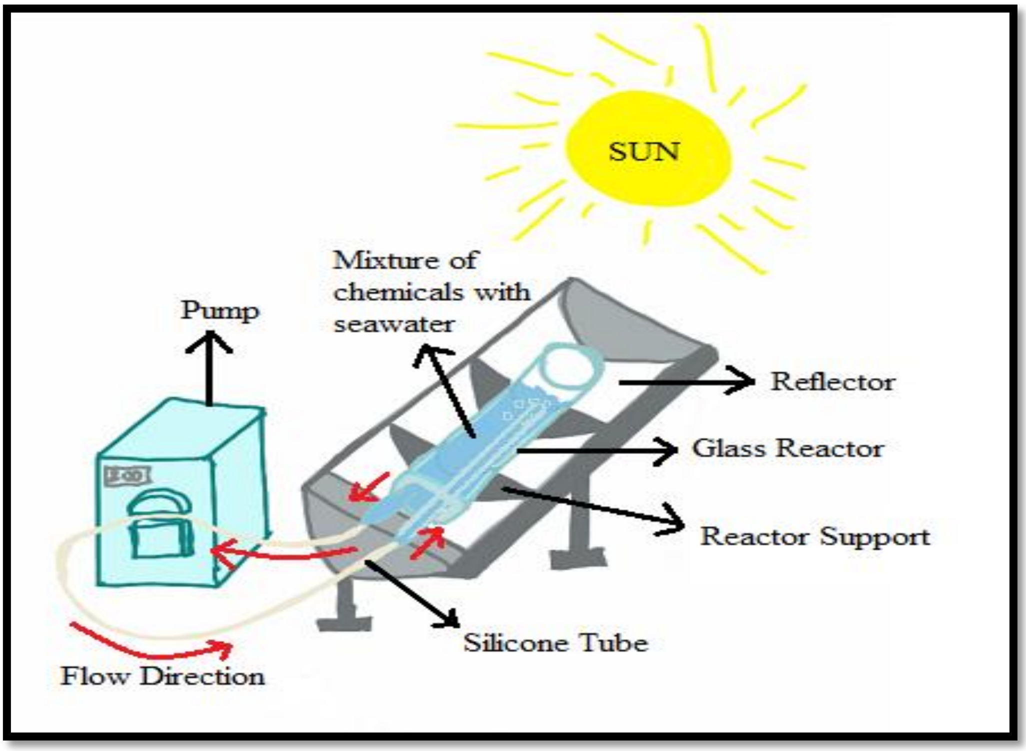

Figure 1: The schematic diagram of experiment setup

Polyamide was procured from Carl Roth GmbH Company, Germany.Shimadzu, Japan make saline water total carbon analyzer was used for TOC analysis of the samples.The COD was analyzed by using the Chemetrics Analyzer. TDS,and pH wereanalyzed by Eutech make water analysis kit.

2.2 Methodology:

Fresh seawater was collected for each experiment from Al-Seebcostal area, 1.5 L of seawater was used for each experiment with different concentrations of TiO_2.In the second set of experiments,0.5g of polyamide was added tostudy its effects on the degradation of pollutants in presence of TiO_2. After a proper mixing of the chemicals and seawater, the initial sample of was collected and then the reactor was exposed to the sun light (as shown in Figure1) in the college campus from 10:00 am to 3:00 pm. The samples were collected every one hour and analyzed.

3. RESULTS AND DISCUSSION

The first set of experiments was carried out with TiO_2 alone and the second set with TiO_2 in combination with PA. Figure 2 shows the percentage degradation of TOC at various concentrations of TiO_2. TiO_2 concentrations varied from 0.5 to 3.5g and it was observed that with increase in TiO_2 concentration, the reduction in TOC was increased. This may be due to the fact that higher concentration of TiO_2 results in more hydroxyl radical's generation, which oxidizes the pollutants present in the seawater, though the presence of chloride ion scavenges the hydroxyl radicals. A maximum of 48% reduction in TOC was observed at a dosage of 3.5g TiO_2.

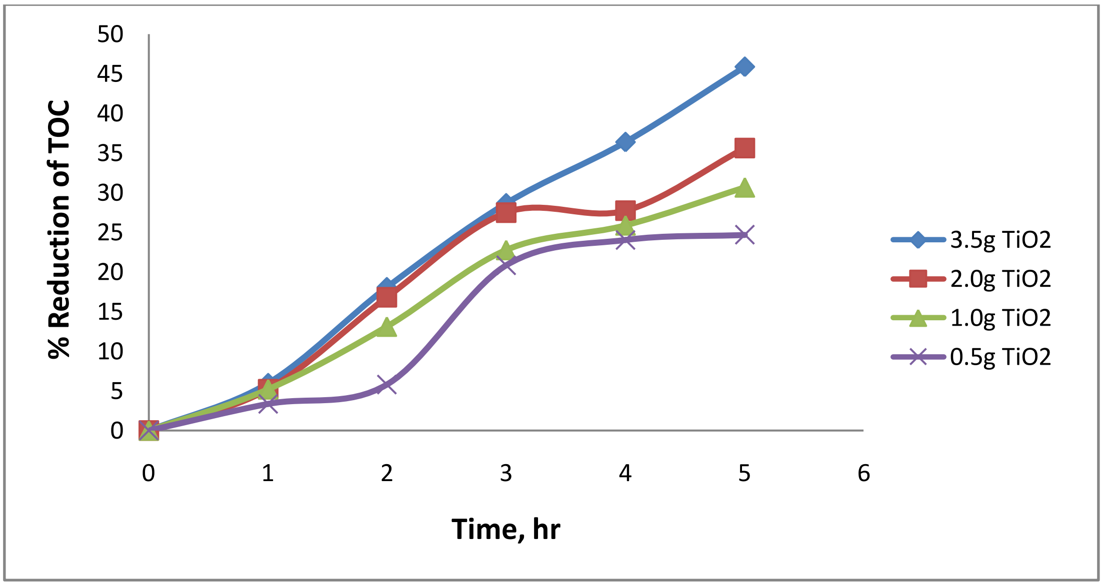

Figure 2: % Reduction of TOC at various concentrations of TiO_2.

Figure 3 & 4 shows the percentage reduction in TIC and COD for various concentrations of TiO_2 respectively. The decrease in TIC & COD followed similar trends to that of TOC and a maximum of 26% in TIC and 40% reduction in COD was observed at higher dosage of TiO_2.The maximum percentage reduction was with respective 5 hours of irradiation in the presence of solar energy.

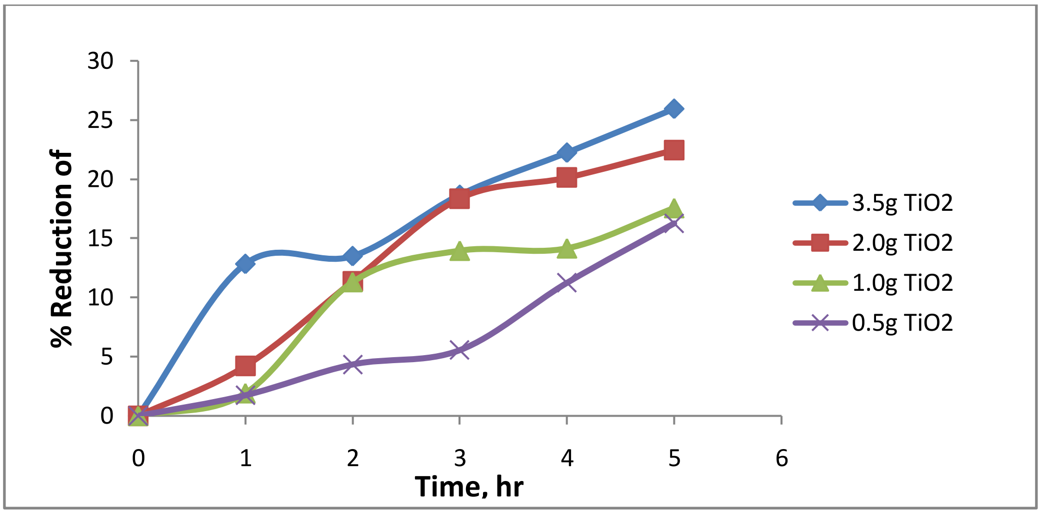

Figure 3: % Reduction of TIC at various concentrations of TiO_2.

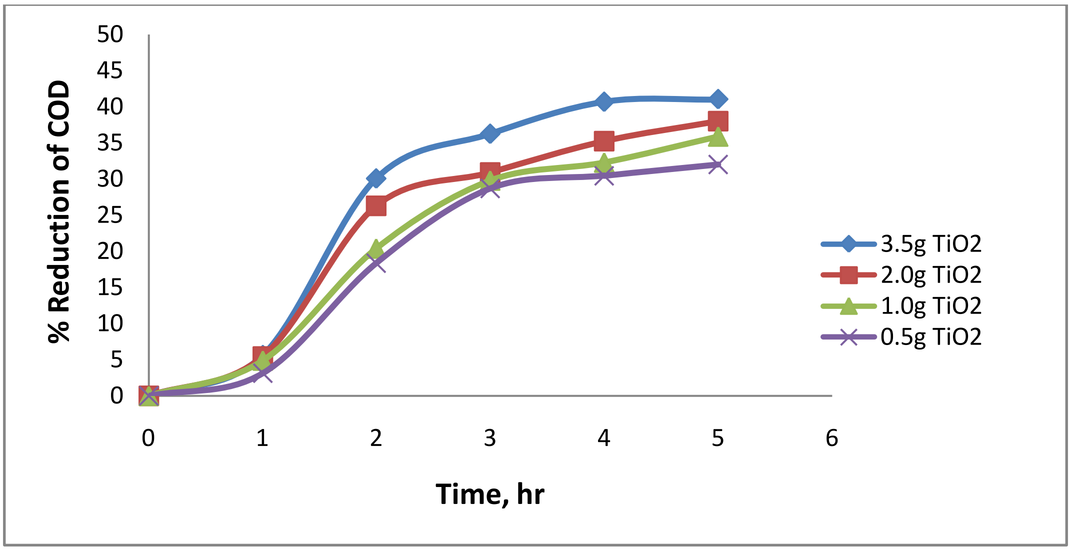

Figure 4: % Reduction of COD at various concentrations of TiO_2.

In the second set of experiments 0.5g of PA was added to study its effect on degradation of pollutants in the presence of TiO_2. Figure 5-7 shows the percentage degradation of TOC, TIC and COD respectively in the presence of 0.5g PA at various concentrations of TiO_2. The percentage reduction in all the three parameters was low compared to TiO_2 alone and this may be due to the fact that the presence of PA hinders diffusional rate of pollutants towards photo catalyst and also it might also impedes the formation of hydroxyl radicals.

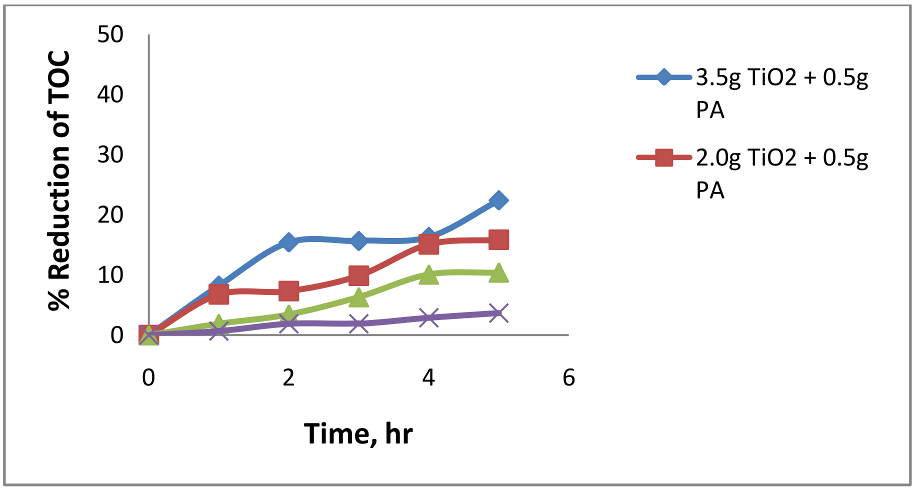

Figure 5: % Reduction of TOC at various concentrations of TiO_2 with 0.5g PA

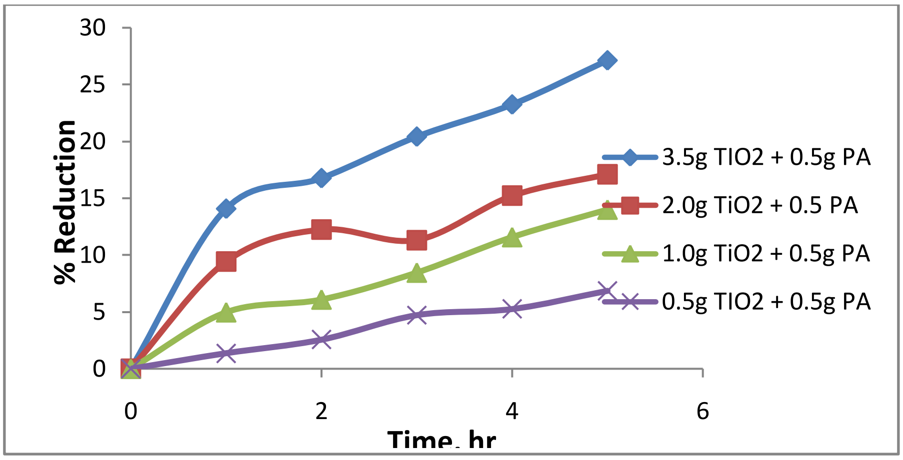

Figure 6: % Reduction of TIC at various concentrations of TiO_2 with 0.5g PA

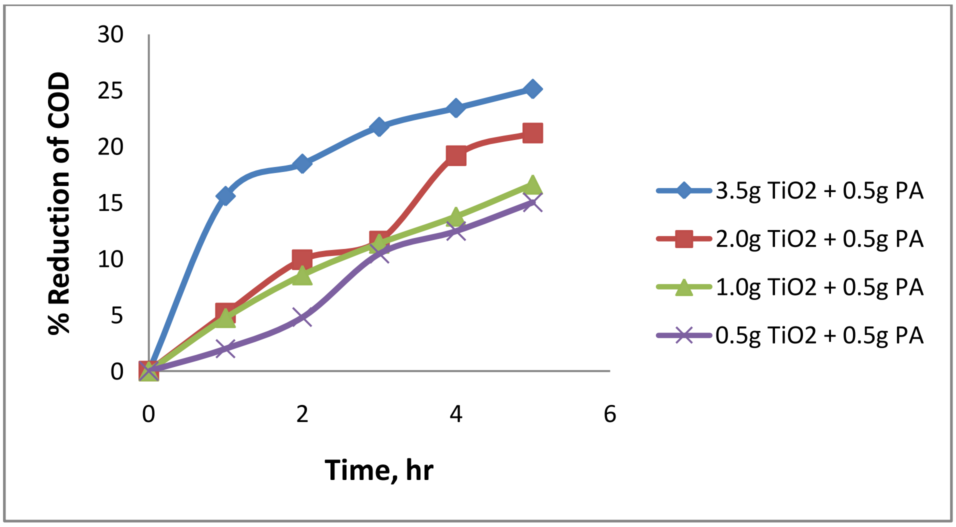

Figure 7: % Reduction of COD at various concentrations of TiO_2 with 0.5g PA

A maximum reduction of 23% in TOC, 28% TIC and 25% of COD was observed in the presence of PA at higher dosage of TiO_2. Figure 8 shows the percentage reduction of pH at various concentrations of TiO_2, decrease in pH attributes to the formation of mineral acid by products during photo catalysis. Figure 9 shows the degradation of TDS, where the effect of TiO_2 dosage is marginal.

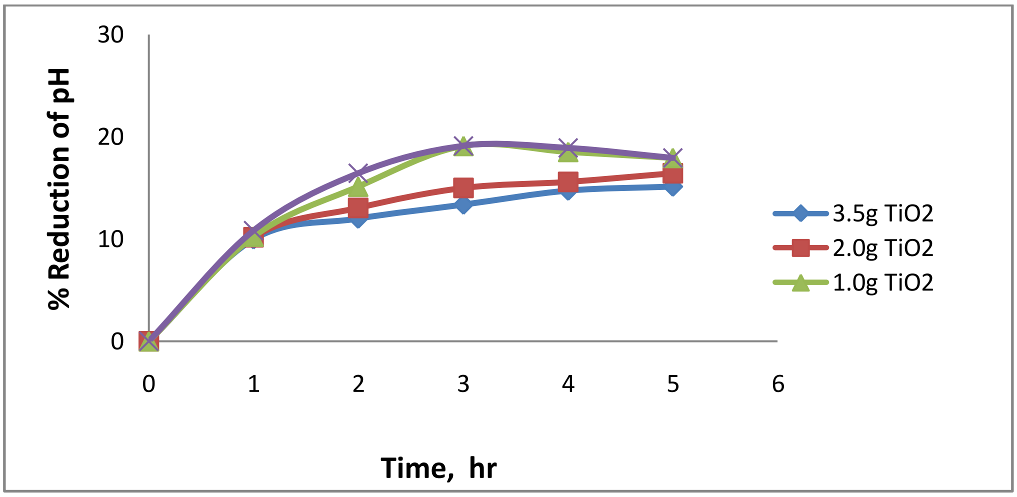

Figure 8: % Reduction of pH at various concentrations of TiO_2.

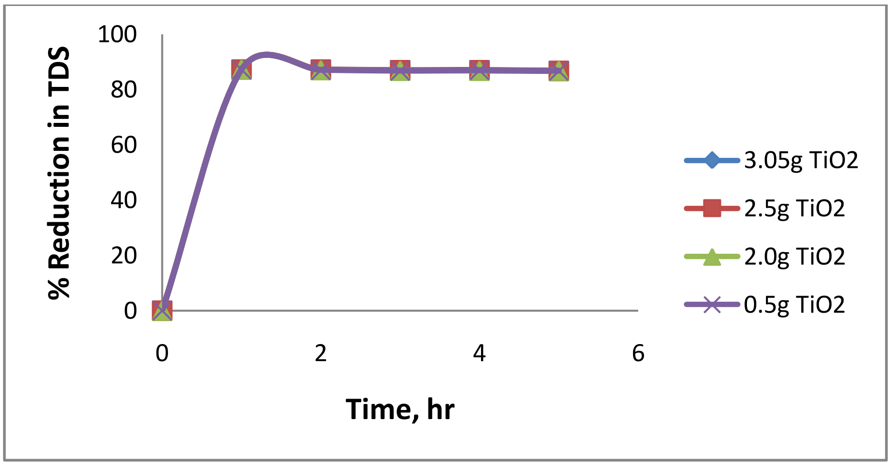

Figure 9: % Reduction of TDS at various concentrations of TiO_2.

4. CONCLUSION

Experimental investigations were carried out in a batch re-circulation reactor for the treatment of seawater using nano photo catalyst TiO_2 P25, with and without the presence of PA. From the results obtained it was observed that the total organic carbon, total inorganic carbon and chemical oxygen demand was appreciably reduced which indicates that this technology can be applied as a pre-treatment process for feed water to reverse osmosis desalination. The presence of PA hinders the diffusional rate of pollutants towards photo catalysts and hence the reduction in TOC, TIC and COD are slightly less compared to of TiO_2 alone. The parameters TIC, COD, pHand TDS showed similar trends as TOC, while percentage reduction increases with increase in photo catalyst dosages in all parameters except TDS, where the dosage effect is marginal.

5. ACKNOWLEDGMENT

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