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## Photocatalytic efficiency of titania photocatalysts in saline waters

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**Abstract:** The photocatalytic efficiency of a recently synthesized TiO<sub>2</sub> powder, denoted P160, for the degradation of the Dye C.I. Reactive Orange 16 in natural and artificial seawater was investigated in comparison to its efficiency in deionized water and the efficiency of a standard TiO<sub>2</sub> powder, Degusa P25. It was shown that the photocatalytic efficiency of P160 was slightly higher than that of P25, probably due to slightly higher specific surface area, higher pore volume and larger pores of the powder P160. The efficiency of both photocatalysts in natural and artificial seawater was significantly lower than in deionized water. The overall rate of dye degradation for both types of photocatalysts was slightly higher in artificial seawater than in natural seawater, which shows the influence of organic compounds naturally present in seawater on the photocatalysts activity. A saturation Langmuir-type relationship between the initial degradation rate and the initial dye concentration indicated that adsorption plays a role in the photocatalytic reaction. The photodegradation rate constant, *k*, which represents the maximum reaction rate, had similar values for P25 and P160 in all types of water due to the similar properties of the photocatalysts.

**Keywords:** photocatalysis; titanium dioxide; dye degradation; seawater; Langmuir–Hinshelwood model.

### INTRODUCTION

The removal of organic pollutants from water is an important challenge for water treatment worldwide. In the last few years, seawater has become an important source for drinking water preparation mainly by reverse osmosis membrane filtration. However, the organic matter in seawater, which may deposit on the

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membrane surface and thus stimulate biofouling, should be removed in advance. The conventional treatment methods are unable to remove trace organic contaminants and large amounts of secondary pollutants are released into the environment. To overcome this, the semiconductor photocatalytic process has provided a satisfactory and economically viable solution by enabling complete mineralization of many organic pollutants into  $\text{CO}_2$  and  $\text{H}_2\text{O}$ .<sup>1,2</sup>

The semiconductor  $\text{TiO}_2$  has been widely used as a photocatalyst for inducing a series of reductive and oxidative reactions on its surface. The photo-induced reactions are basically initiated by band gap excitation to generate valence band holes ( $\text{h}^+$ ) and conduction band electrons ( $\text{e}^-$ ). In  $\text{TiO}_2$ -assisted oxidation processes of organic compounds, there are two important processes: the direct oxidation on the  $\text{TiO}_2$  surface by  $\text{h}^+$  and the indirect oxidation by reactive oxygen species, such as superoxide ( $\text{O}_2^{\bullet-}$ ), singlet oxygen ( $^1\text{O}_2$ ), the hydroxyl radical ( $^{\bullet}\text{OH}$ ), the hydroperoxyl radical ( $\text{HO}_2^{\bullet}$ ), and hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), which are formed *via* the reduction of  $\text{O}_2$  by  $\text{e}^-$  and by the reaction of  $\text{h}^+$  with hydroxyls or water at the  $\text{TiO}_2$  surface.<sup>3-5</sup> The efficiency of heterogeneous photocatalysis depends primarily on the properties of the photocatalyst, such as: the band gap energy, specific surface area, pore size distribution, crystal structure, crystal size, *etc.* However, the efficiency of a photocatalyst could greatly depend on environmental factors, in other words some components found in water that processed may affect the efficiency.<sup>6-10</sup> Previous investigations of the photocatalytic efficiency of some photocatalysts in saline waters showed that salinity generally decreases the efficiency.<sup>7,8,10-13</sup>

The aim of this work was to compare the photocatalytic efficiency of a recently synthesized<sup>14</sup>  $\text{TiO}_2$  powder P160 and a standard  $\text{TiO}_2$  powder Degusa P25 on the degradation of dissolved organic substances in saline waters, using artificial (ASW) and natural (SW) seawaters. Previous investigations<sup>14,15</sup> showed the very good photocatalytic efficiency of P160 on the degradation of dyes CI Reactive Orange 16 and CI Basic Yellow 28 in deionized water. In this paper, the efficiency of P160 and of P25 in saline waters were compared to the efficiency in deionized water (DIW) according to the degree of decomposition of the dye C.I Reactive Orange 16, as a model for dissolved organic substances, under UV irradiation at room temperature. Due to the natural decomposition of plants, fish and microorganisms, SW usually contains a complex mixture of organic constituents that could also react during photocatalytic experiments. ASW was used to assess the influence of the major seawater ions on the efficiency of the photocatalysts and to establish the relevance of ASW as a model for the study. The effect of the initial dye concentration on the initial reaction rate of photodecolorization by both photocatalysts in DIW, SW and ASW was also studied.

## EXPERIMENTAL

*Materials*

Recently synthesized powder P160<sup>14</sup> was used in the experiments, together with a commercially available photocatalyst powder Degussa P25, since it has become the standard for photoreactivity in environmental applications.<sup>16-19</sup> The specific surface area of P25 powder was 45.7 m<sup>2</sup>·g<sup>-1</sup>, the pore volume was 0.177 cm<sup>3</sup>·g<sup>-1</sup>, the average pore size was 7.57 nm, the crystalline size was 29.5 nm and it consisted of 72.7 % anatase and 27.3 % rutile,<sup>19</sup> while the point of zero charge, pH<sub>PZC</sub>, of P25 was 6.4.<sup>20</sup> P160 was synthesized by a non-hydrolytic sol-gel process combined with a solvothermal treatment.<sup>14</sup> Titanium isopropoxide, Ti(O<sup>i</sup>Pr)<sub>4</sub>, titanium tetrachloride, TiCl<sub>4</sub>, and carbon tetrachloride, CCl<sub>4</sub>, were mixed in the mole ratio 1:1:1 under a nitrogen atmosphere in a glove box. The obtained mixture was subjected to gelation in an autoclave at 160 °C for 3 h. The gel was dried at 100 °C under a nitrogen flow and calcined at 500 °C for 3 h. The thus obtained powder P160 consisted of pure anatase and its specific surface area was 52.8 m<sup>2</sup>·g<sup>-1</sup>, the average pore size was 11.1 nm, the pore volume was 0.209 cm<sup>3</sup>·g<sup>-1</sup> and the crystalline size was 26.4 nm.<sup>14</sup> The point of zero charge of P160, determined by a batch equilibration technique,<sup>21</sup> was 6.5. Scanning electron micrographs (SEM) of the titania powders, obtained using a Tescan Mira3 XMU microscope operated at 20 kV, are presented in Fig. 1.

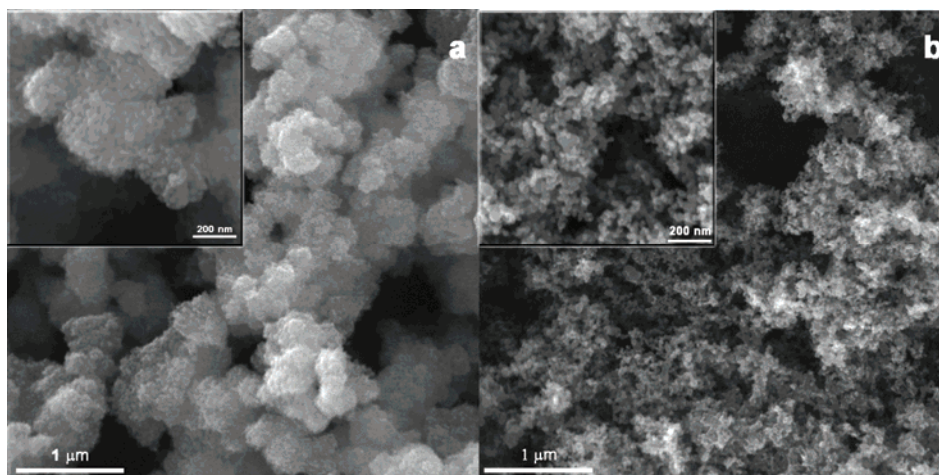


Fig. 1. Scanning electron micrographs (SEM) of a) P160 and b) P25.

The anionic dye C.I Reactive Orange 16 (RO16) was obtained from Bezema (commercial name Bezaktiv Orange V-3R) and used without further purification. Its molecular formula is C<sub>20</sub>H<sub>19</sub>N<sub>3</sub>O<sub>11</sub>S<sub>3</sub>.

The three types of water were used: deionized water (DIW) from a Millipore Waters Milli Q purification unit; natural seawater (SW), obtained off the coast of Greece and passed through 2 μm filter and artificial seawater (ASW).

*Analysis of natural seawater and preparation of artificial seawater*

The concentrations of major cations and anions in the natural seawater were determined on a Metrohm ion chromatography instrument, 861 Advanced Compact IC MSM II, and the results are presented in Table I. The instrument specifications were: conductivity detector with

chemical suppression; controlled flow ranging from 0.2 to 2.5 mL min<sup>-1</sup> and maximum pressure of 35 MPa. The columns specifications were: Metrosep A Supp 5–150 (for anion analysis), anion eluent – 3.2 mmol Na<sub>2</sub>CO<sub>3</sub>/1.0 mmol NaHCO<sub>3</sub>; Metrosep C2–150 (for cation analysis), cation eluent – 4 mmol tartaric acid/0.75 mmol dipicolinic acid; suppressor solution – 50 mmol H<sub>2</sub>SO<sub>4</sub>. Prior to the analysis, all samples were filtered through 0.45 µm filters and degassed in an S100 Elmasonic ultrasonic bath. The standard solutions were prepared with demineralized water and standard ion solutions.

TABLE I. Ionic composition of SW

Ion	Concentration, mmol L <sup>-1</sup>
Cl <sup>-</sup>	564.1
Na <sup>+</sup>	488.9
K <sup>+</sup>	8.74
Mg <sup>2+</sup>	45.22
Ca <sup>2+</sup>	8.56
SO <sub>4</sub> <sup>2-</sup>	27.91

The quantities of salts for the ASW preparation were calculated according to the composition of SW given in Table I. The prepared ASW had the following composition: 488.9 mmol L<sup>-1</sup> NaCl, 8.74 mmol L<sup>-1</sup> KCl, 25.91 mmol L<sup>-1</sup> MgCl<sub>2</sub>·6H<sub>2</sub>O, 19.36 mmol L<sup>-1</sup> MgSO<sub>4</sub>·7H<sub>2</sub>O and 8.56 mmol L<sup>-1</sup> CaSO<sub>4</sub>.

#### *Photocatalytic degradation experiments*

A batch-type quartz reactor (cylindrical shape, inner diameter 4 cm, volume 50 mL) was used for the catalytic runs and the set up was in a closed housing to prevent the effect of external light. The reactor had water-cooling jacket, and the illumination was provided for by a Philips HPR 125 W lamp, having the strongest emission wavelength of 364 nm. The lamp was placed 100 mm from the surface of the reaction mixture. The catalyst was maintained in suspended form by using a magnetic stirrer (500 rpm).

The photocatalytic efficiencies of P25 and P160 were investigated in DIW, SW and ASW under the following experimental conditions: dye concentration in the range of 20–80 mg L<sup>-1</sup>, TiO<sub>2</sub> powders concentration of 1 g L<sup>-1</sup> and UV irradiation at room temperature.

In all the experiments, a suspension of 25 mg of TiO<sub>2</sub> powder and 25 mL of solution was mixed ultrasonically for 10 min, followed by magnetically stirring for 30 min in the dark, to attain adsorption/desorption equilibrium. The pH values of the suspensions were between 6.5 and 6.8 in DIW and ASW and about 7.7 in SW, for both photocatalysts. Then, the UV light was switched on to perform the photocatalytic reaction. The concentrations of dye in the starting solutions and of dye remaining in the solutions after stirring in the dark and after 5, 10, 15 and 30 min of irradiation were determined by UV–Vis spectroscopy (Shimadzu UV-160A 145 instrument). The solutions for analysis by UV–Vis spectroscopy were prepared by passing through a syringe filter (pore size of 0.22 µm) in order to remove the particles of the photocatalyst.

## RESULTS AND DISCUSSION

### *Comparison of the photocatalysts efficiency in different types of water*

The results of photodegradation of dye RO16 in DIW, SW and ASW by photocatalysts P25 and P160 are presented in the form of the dependence of the

normalized concentration,  $c/c_0$ , vs. time  $t$ , where  $c_0$  is the concentration of RO16 after adsorption in the dark and  $c$  is the concentration of RO16 after illumination time  $t$  (Figs. 2 and 3). The degradation efficiency of the photocatalysts can be assessed by using the expression:  $1-c/c_0$ .

The Langmuir–Hinshelwood (L–H) model was used to describe the kinetics of photodegradation of dye.<sup>22–25</sup> This model basically relates the degradation rate  $r$  and reactant concentration  $c$  in water after an illumination time  $t$ . The simple rate expression for the L–H model is given by Eq. (1):

$$r = -\frac{dc}{dt} = \frac{kKc}{1 + Kc} \quad (1)$$

where  $k$  is the rate constant, which is dependent on the diffusion of the reactant into the pores and the reaction at the interface,<sup>16</sup> and  $K$  is the Langmuir adsorption to desorption equilibrium constant. According to the L–H model, a limiting reaction rate ( $r = k$ ) is observed at high reactant concentrations ( $Kc \gg 1$ ). When the adsorption is relatively weak and/or the reactant concentration is low ( $Kc \ll 1$ ) and Eq. (1) can be simplified to pseudo-first order kinetics with an apparent first-order rate constant  $k_{app}$ .<sup>26–28</sup>

$$-\ln\left(\frac{c}{c_0}\right) = kKt = k_{app}t \quad (2)$$

The dependences of  $-\ln(c/c_0)$  vs. illumination time  $t$  for the data in Figs. 2 and 3 are linear (insets of Figs. 2 and 3), as confirmed by the correlation coefficient  $R^2$  values of  $\approx 1$  (Tables II–IV). The derived  $k_{app}$  values corresponding to their respective initial dye concentration,  $c_0$ , are also presented in Tables II–IV.

From the results presented in Figs. 2 and 3, it could be seen that the efficiency of photocatalytic degradation of RO16 by P25 and P160 in DIW, SW and ASW decreased as the initial concentration increased, which is in good agreement with decreasing trend of  $k_{app}$  values, shown in Tables II–IV. This could be explained in terms of saturation of the limited number of accessible active sites on the photocatalytic surface. When the dye concentration increased, the amount of dye adsorbed on the catalyst surface also increased (data not shown), resulting in a reduction in the light intensity reaching the photocatalyst,<sup>11</sup> since the absorption of RO16<sup>29</sup> well matches the absorption of titania<sup>19</sup> in the UV part of the spectrum. It is well known that the absorption edge of titania powders is about 400 nm,<sup>19</sup> while RO16 had three absorption bands in the UV region, centered at 388, 302 and 254 nm.<sup>29</sup>

Both photocatalysts showed their highest photocatalytic activity in DIW, where the dye concentration decreased more rapidly with time than in SW and ASW, as seen in Figs. 2 and 3. Consequently, the  $k_{app}$  values were much higher

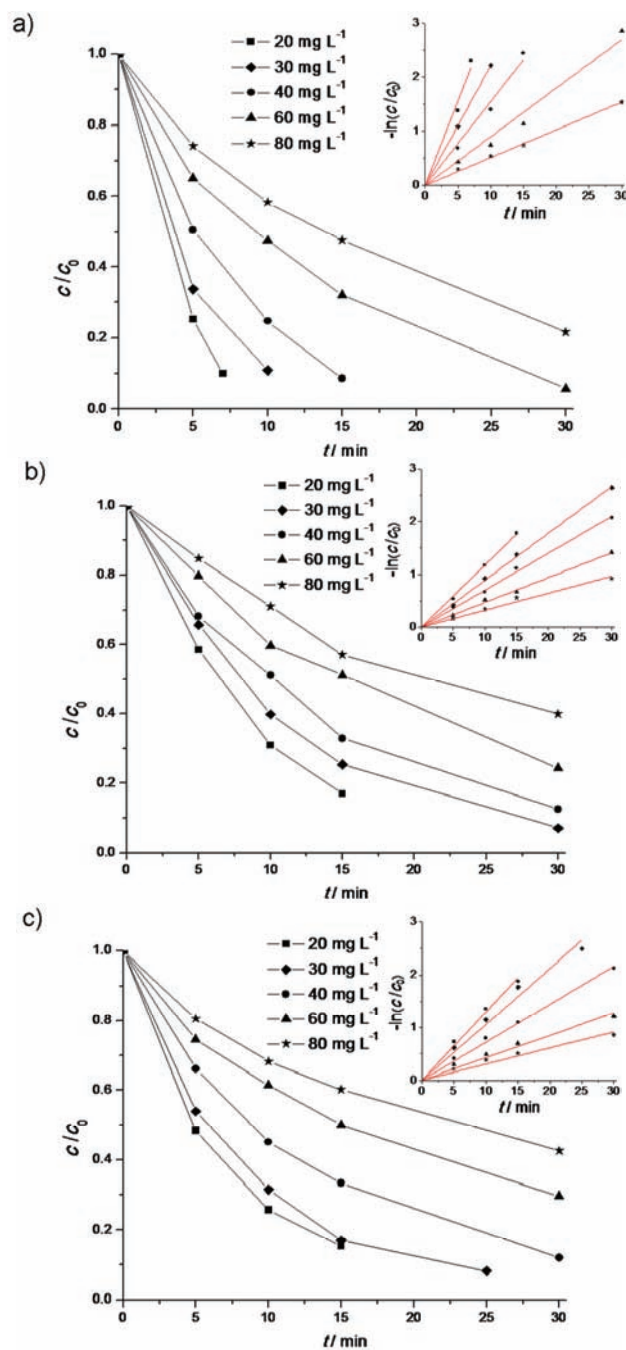


Fig. 2. Photocatalytic degradation of the dye RO16 by P25 powder in a) DIW, b) SW and c) ASW (UV irradiation at room temperature; the P25 concentration was 1 g L<sup>-1</sup>). The corresponding linear plots of the photocatalytic decolorization kinetics are given in the insets.

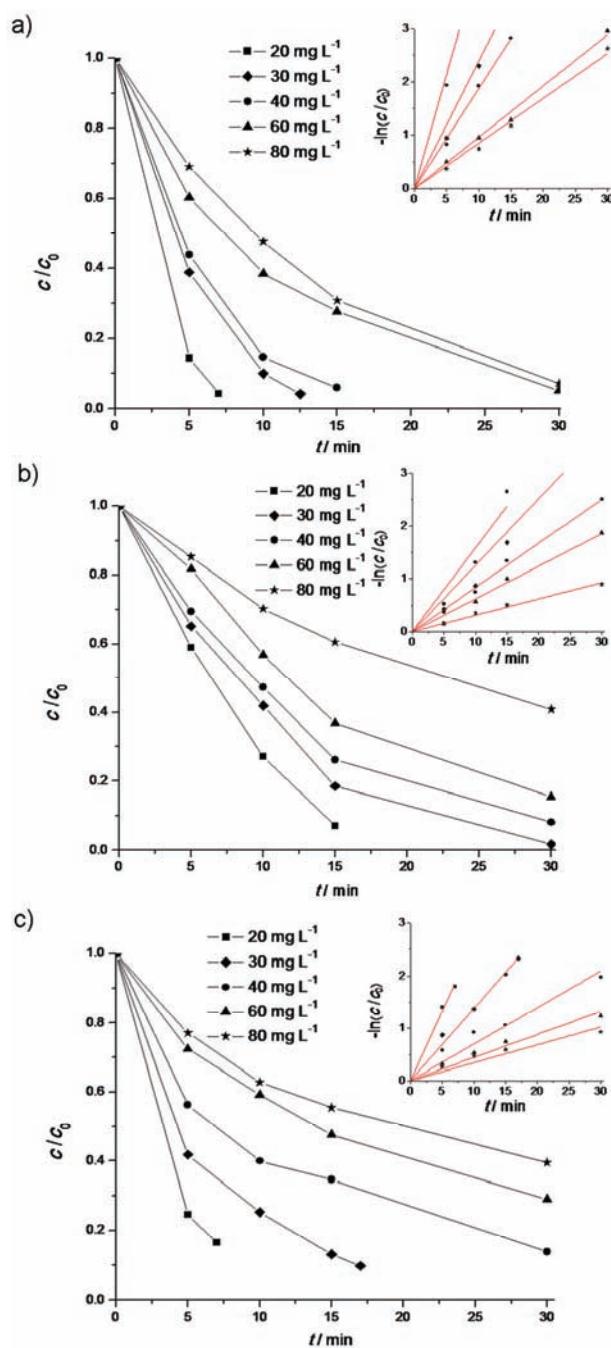


Fig. 3. Photocatalytic degradation of the dye RO16 by P160 powder in a) DIW, b) SW and c) ASW (UV irradiation at room temperature; the P160 concentration was 1 g L<sup>-1</sup>). The corresponding linear plots of the photocatalytic decolorization kinetics are given in the insets.

TABLE II. The  $k_{app}$  values for the photodegradation of RO16 by P25 and P160 in DIW in dependence on the initial dye concentration (UV irradiation at room temperature;  $TiO_2$  concentration was  $1 \text{ g L}^{-1}$ )

$c_0 / \text{mg L}^{-1}$	Type of titania			
	P25		P160	
	$k_{app} / \text{min}^{-1}$	$R^2$	$k_{app} / \text{min}^{-1}$	$R^2$
20	0.3109	0.9902	0.4267	0.9934
30	0.2207	0.9999	0.2389	0.9917
40	0.1545	0.9936	0.1874	0.9983
60	0.0898	0.9887	0.0962	0.9966
80	0.0512	0.9988	0.0846	0.9959

Table III. The  $k_{app}$  values of photodegradation of RO16 by P25 and P160 in SW in dependence on the initial dye concentration (UV irradiation at room temperature;  $TiO_2$  concentration was  $1 \text{ g L}^{-1}$ )

$c_0 / \text{mg L}^{-1}$	Type of titania			
	P25		P160	
	$k_{app} / \text{min}^{-1}$	$R^2$	$k_{app} / \text{min}^{-1}$	$R^2$
20	0.1173	0.9902	0.1590	0.9671
30	0.0890	0.9995	0.1260	0.9810
40	0.0700	0.9926	0.0827	0.9974
60	0.0470	0.9887	0.0620	0.9915
80	0.0322	0.9988	0.0310	0.9955

Table IV. The  $k_{app}$  values of photodegradation of RO16 by P25 and P160 in ASW in dependence on the initial dye concentration (UV irradiation at room temperature;  $TiO_2$  concentration was  $1 \text{ g L}^{-1}$ )

$c_0 / \text{mg L}^{-1}$	Type of titania			
	P25		P160	
	$k_{app} / \text{min}^{-1}$	$R^2$	$k_{app} / \text{min}^{-1}$	$R^2$
20	0.1299	0.9969	0.2651	0.9973
30	0.1062	0.9917	0.1380	0.9964
40	0.0723	0.9980	0.0699	0.9774
60	0.0426	0.9908	0.0441	0.9841
80	0.0306	0.9831	0.0341	0.9683

for the photodegradation of the dye in DIW than those in SW and ASW. The observed decrease of dye photodegradation efficiency in salt waters was explained by the fouling effects of the inorganic ions on the photoactivity of titania. Several mechanisms for the fouling effects of inorganic ions on the photoactivity of titania were proposed.<sup>8</sup> These include UV screening, competitive adsorption to surface active sites, competition for photons, surface deposition of precipitates and elemental metals, radical and hole scavenging and direct reaction with the photocatalyst.



Furthermore, according to the  $k_{app}$  values for the photodegradation of the dye in saline waters, it could be seen that the photocatalytic efficiency was higher in ASW at lower concentrations (20 and 30 mg L<sup>-1</sup>), while at higher concentrations, the efficiency was slightly higher in SW for both photocatalysts. It could be assumed that the better efficiency in ASW than in SW was because SW contains some other ions (carbonate and bicarbonate) and organic substances besides the major cations and anions (Table I). It was reported that carbonate and bicarbonate both act as electron scavengers and thus they are expected to be responsible for the observed lowering of the degradation rate.<sup>12</sup> However, when the photocatalysis occurs in an air atmosphere, oxygen is a more powerful scavenger of electrons formed in TiO<sub>2</sub> after illumination than carbonate and bicarbonate ions. In addition, the reaction rate constants of hydroxyl radicals with carbonate and bicarbonate ions are much smaller than the values given for the other ions.<sup>30</sup> Therefore, it is likely that the organic substances present in SW influenced the activity of the titania powders by adsorption onto their surface and the resulting blocking of the active sites. The differences in the photocatalytic activities in ASW and SW may also be the result of the different pH values of the suspensions during the reaction. The pH values of the suspensions in SW were higher than  $pH_{PZC}$  of the titania, while in the case of suspension in ASW, the pH values were approximately equal to the  $pH_{PZC}$ . Accordingly, the adsorption of the dye anions should be less favorable at the negatively charged titania surface in SW than in ASW. However, the adsorption in SW was comparable (for P160) and even higher (for P25) than in ASW, which suggests that the organic substances present in SW strongly influenced dye adsorption onto the titania powders. These results show that, besides the major ions, organic compounds naturally present in seawater had a large influence on the photocatalytic activity of the titania powders. Consequently, the artificial seawater that contained only the major seawater ions cannot be used as a model for the prediction of the activity of the photocatalysts in natural seawaters.

By comparing the photocatalysts P25 and P160, it could be observed that P160 had a slightly better photocatalytic efficiency than P25 in all three types of water. The values of  $k_{app}$  in all three types of water for P160 were higher than those for P25 (with experimental uncertainty for the higher concentration of the dye). It is well known that the efficiency of semiconductors is influenced by many factors, such as crystalline structure, particle size, specific surface area, adsorption capacity, and prevention of electron-hole pair recombination reactions. In comparison with P25, the P160 powder had a slightly higher specific surface area, higher pore volume and larger pores, which contributed to its better photocatalytic efficiency with respect to P25. On the other hand, the P25 crystallites were slightly larger than those of P160 were and P25 contained 72.7 % anatase and 27.3 % of rutile, while P160 contained pure anatase. These features

should contribute to a better photoactivity of P25. It was shown<sup>31</sup> that, in comparison to pure anatase, mixed-phase titania catalysts show greater photoeffectiveness in the UV region due to stabilization of the charge separation by electron transfer from rutile to anatase, which slows recombination. Despite the fact that P160 contained pure anatase, its photocatalytic efficiency was slightly higher compared to that of P25, probably due to its higher specific surface area and larger pores. For the same quantity of adsorbed dye, the surface coverage would be higher in the case of the TiO<sub>2</sub> with a lower specific surface area, which causes a greater reduction of the light intensity reaching the photocatalyst and, consequently, lower photocatalytic activity. In addition, different types of aggregation of the primary particles of P160 and P25 (Fig. 1) caused the powders to have different pore volumes and pore sizes. The pore size is a very important parameter for photocatalysis, because large dye molecules cannot enter small pores and, in that way, the surface of such pores is inaccessible for reaction.

*The influence of initial dye concentration on the initial photodegradation rate*

The effects of the initial dye concentration  $c_0$  (after 30 min in the dark) on its initial photodegradation rate  $r_0$  with P25 and P160 in DIW, SW and ASW are demonstrated in Fig. 4. Values of  $r_0$  (in mg L<sup>-1</sup> min<sup>-1</sup>) were obtained according to the results presented in Figs. 2 and 3, as the dye concentration decay at 5 min of photoreaction. It could be observed from Fig. 4 that the initial degradation rate increased with increasing initial dye concentration and then remained almost constant. According to the L-H model<sup>32,33</sup> (Eq. (1),  $r = r_0$  and  $c = c_0$ ), such a dependence of  $r_0$  on  $c_0$  indicates that the oxidation rate is first-order at lower concentrations and becomes zero-order at higher concentrations, when the reaction rate becomes independent of the dye concentration (meaning a saturation-type Langmuir kinetics). Such a Langmuir-type relationship between the initial degradation rate and concentration indicates that adsorption played a role in the photocatalytic reaction.

It is well known that photocatalytic reactions can occur independently of the degree of adsorption of organic compounds on TiO<sub>2</sub> both in the dark or during the photocatalytic process. The radical species produced during irradiation can react with dye on the surface of the TiO<sub>2</sub> but also in the bulk of the solution. It was suggested<sup>34</sup> that in the case of radical formation on a UV-illuminated TiO<sub>2</sub> surface, adsorption of the organic compound would increase the reaction rates, but it is not a prerequisite for the reaction to occur since the reactive OH· radicals and other oxidizing species can diffuse into the solution bulk where they react with the organic pollutant. In the present case, the adsorption was included in photocatalytic process: for both photocatalysts and for all types of water, the reaction rate increased as the adsorption increased, but in the case of a particular photocatalyst for different types of water, the highest adsorption did not mean the

highest reaction rate. For example, in the case of P25, the adsorption for all initial concentrations was higher in SW than in ASW, but reaction rates were lower. Thus, the adsorption plays a role in the photocatalytic reaction, but it is not the main factor that influences the reaction rate and the efficiency of the photocatalyst.

From Fig. 4 it is obvious that the highest values of initial reaction rate for both photocatalysts were observed for in DIW, than in ASW, and the lowest in SW, as was found for the efficiency of the photocatalysts according to the overall reaction rate for the different dye concentrations.

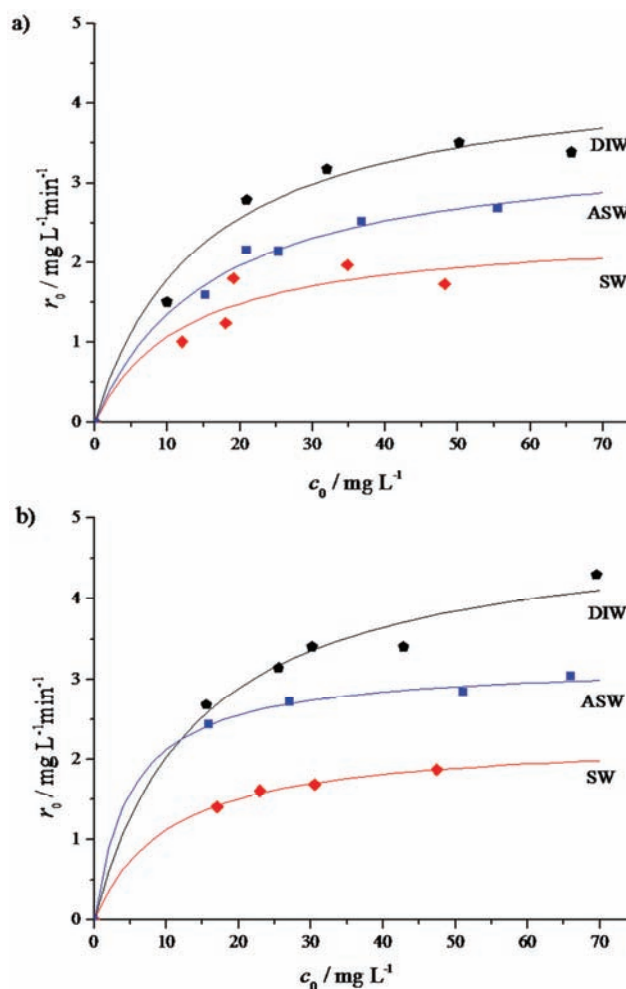


Fig. 4. Effect of the initial RO16 dye concentration on its initial photodegradation rate by a) P25 and b) P160 in DIW, SW and ASW (UV irradiation at room temperature; the RO16 concentration was in the range of 20–80  $\text{mg L}^{-1}$ ; the  $\text{TiO}_2$  concentration was 1  $\text{g L}^{-1}$ ).

The experimental data presented in Fig. 4 were fitted to a hyperbolic function, expressed by Eq. (3):<sup>35</sup>

$$Y = \frac{abx}{1+bx} \quad (3)$$

in which  $Y = r_0$ ,  $x = c_0$ ,  $b = K$  and  $a = k$ .

The parameters  $K$  and  $k$  were estimated by an optimization procedure using MATLAB and are presented in Table V.

TABLE V. The parameters  $k$  and  $K$  obtained by fitting the experimental data of the photocatalytic degradation of the dye by P25 and P160 in DIW, SW and ASW (UV irradiation at room temperature; RO16 concentration was in the range of 20–80 mg L<sup>-1</sup>; TiO<sub>2</sub> concentration was 1 g L<sup>-1</sup>); *MSE* – mean standard error

Type of water	Type of titania					
	P25			P160		
	$k / \text{mg L}^{-1} \text{min}^{-1}$	$K / \text{L mg}^{-1}$	<i>MSE</i>	$k / \text{mg L}^{-1} \text{min}^{-1}$	$K / \text{L mg}^{-1}$	<i>MSE</i>
DIW	4.4364	0.0669	0.0487	4.9546	0.0695	0.0362
ASW	3.5383	0.0622	0.0119	3.1995	0.1964	0.0035
SW	2.4275	0.0786	0.0631	2.2746	0.0975	0.0005

The results given in Table V show that the values of the photodegradation rate constant  $k$  for both types of photocatalysts were higher in DW than in saline waters, which indicates that inorganic ions have inhibiting effect on the photo-activity of both titania samples. In addition, the values of photodegradation rate constant for both photocatalysts were lower in natural seawater than in artificial seawater. The value of  $k$  of the photocatalytic decolorization of the dye in DIW with P160 was slightly higher than with P25, probably because of the higher surface area and larger pores. However, the values of  $k$  for P160 in ASW and SW were lower than those for P25 in these waters, which indicates that influence of inorganic ions in ASW and SW was more pronounced for P160 than for P25.

#### CONCLUSIONS

The efficiency of recently synthesized TiO<sub>2</sub> powder P160 in the degradation of the dye C.I. Reactive Orange 16 in deionized and saline waters under UV irradiation is comparable and even slightly better than the efficiency of a standard TiO<sub>2</sub> powder Degusa P25. The higher specific surface area, higher pore volume and larger pores of P160 with respect to P25 contributed to its better photocatalytic efficiency. Water salinity decreased the efficiency of P160 to approximately the same extent as the efficiency of P25 was decreased. Some organic compounds naturally present in seawater have a large influence on the efficiency of both photocatalysts; hence, artificial seawater that contains only the major ions of seawater cannot be used as a model for the prediction of photocatalyst activity in natural seawaters. The dependence of the initial degradation rate on the initial

dye concentration followed the Langmuir–Hinshelwood (L–H) model. The photodegradation rate constant  $k$ , which represents the maximum reaction rate, has similar values for P25 and P160 in all types of water due to similar properties of the photocatalysts.

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## ИЗВОД

ЕФИКАСНОСТ ФОТОКАТАЛИЗАТОРА НА БАЗИ  $\text{TiO}_2$  У СЛАНИМ ВОДАМА

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Фотокаталитичка ефикасност  $\text{TiO}_2$  праха P160, синтетизованог нехидролитичким сол–гел поступком, испитивана је у процесу разградње боје C.I. Reactive Orange 16 у природној и лабораторијски припремљеној морској води у поређењу са ефикасношћу у дејонизованој води, као и у поређењу са ефикасношћу комерцијалног фотокатализатора Degussa P25. Показано је да је ефикасност P160 мало већа од ефикасности P-25 због веће специфичне површине, већих пора и веће запремине пора. Ефикасност оба катализатора у природној и лабораторијски припремљеној морској води значајно је мања него у дејонизованој води. Просечна брзина разградње боје за оба фотокатализатора је у малој мери већа у лабораторијски припремљеној него у природној морској води, што показује утицај органских компоненти присутних у природној морској води на фотокаталитичку ефикасност. Зависност почетне брзине разградње од почетне концентрације боје се покоравала Ленгмир–Хиншелвудовом моделу, што указује на то да адсорпција има улогу у фотокаталитичкој реакцији разградње боје. Слична својства фотокатализатора су узроковала блиске вредности константе брзине фотокаталитичке разградње,  $k$ , која представља максималну брзину реакције, за P25 и P160 у свим испитиваним врстама воде.

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