DENSIOS-VISCOMETRIC STUDIES OF TiO$_2$-MCM-41 IN ETHANOLIC NICOTINAMIDE SOLUTIONS AND ITS APPLICATION IN DRUG DELIVERY OF IBUPROFEN

SRABANI SWAGATIKA$^{a}$, AGNIMITRA DINDA$^{a}$, SURESH KUMAR DASH$^{a}$, UPENDRA NATH DASH$^{a}$

$^{a}$Department of Chemistry, $^{b}$Department of Pharmacy, I. T. E. R., Siksha'O'Anusandhan University, Bhubaneswar, 751030, Odisha, India.

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ABSTRACT

Objective: To study the density, viscosity of the solutions of TiO$_2$-MCM-41 in the presence of nicotinamide as hydrotropic agent in ethanol solvent at different temperatures ranging from 298.15 K to 313.15 K at an interval of 5 K, and its application as a drug delivery system.

Methods: 10 and 15 weight percentages of TiO$_2$-MCM-41 were synthesized via co-condensation method using cetyl hexadecyltrimethyl ammonium bromide (CTAB) as structure directing agent, tetraethylorthosilicate (TEOS) as silica source and Degussa P-25 as titania source. The characterization of the prepared samples was done by powdered XRD, Fourier Transformed-Infrared spectroscopy (FTIR), scanning electron microscopy (SEM), and DSC. Its drug delivery activity was also studied taking Ibuprofen as test drug.

Results: Characterization result indicated that TiO$_2$-MCM-41 retained the mesoscopic morphology and porous structure. The results of density and viscosity measurements have been discussed in the light of molecular interactions. It was found that TiO$_2$-MCM-41 have lower density and viscosity in comparison to parent MCM-41, whereas (15) TiO$_2$-MCM-41 shows highest solute-solute interaction and lowest solute-solute interaction in ethanol in presence of nicotinamde and exhibited highest drug release capacity.

Keywords: TiO$_2$-MCM-41, Ethanol, Nicotinamide, Partial molar properties, Viscosity co-efficient, Drug delivery application.

INTRODUCTION

Nanoporous titania is a low-cost, high performance inorganic metal oxide having wide applications like photovoltaic, catalysis, photo catalysis, filtration, sensors, cosmetics, sunscreen lotions, semiconductor. Since its commercial production in the beginning of the twentieth century, it has attracted the attention of researchers for exploring its properties [1-5]. Recently, it has done miracle in the field of medical science, in the treatment of cancer as an improved drug delivery system (DDS) [2] due to its useful properties like water insolubility, non-toxicity, non-radioactivity, biocompatibility, chemical stability, mechanical suitability, etc. It can readily bind a variety of ligands to its surface. This property showed new light to the researchers for an improved drug delivery system for most water insoluble drugs. Incorporation of titania species into the system which would be helpful to understand the structural and characteristics properties of these materials providing better scope to use this inorganic mesoporous composite for carriers of partially insoluble drugs.

MATERIALS AND METHODS

Materials

Cetyl hex decyltrimethyl ammonium bromide (CTAB) (used as structure directing agent), Tetraethylorthosilicate (TEOS) (used as the silica source), ammonia solution (used as mineralizing agent) and nicotinamide used as (hydrotropic agent), sodium hydroxide-hexane solution (used as hydrolytic agent), sodium hydroxide-hexane were purchased from Merck and Degussa P-25 (as titania source) were purchased from Sigma-Aldrich. Ethanol was of AnalR grade and used after drying over molecular sieve over night. Deionized water (Sp. Cond. ~10$^{-8}$ S cm$^{-1}$) was used throughout the experiment. Ibuprofen (>99.5%) was provided from Aldrich.

Preparation of solution of TiO$_2$-MCM-41

The solutions of modified TiO$_2$-MCM-41 were prepared in 0.1 M nicotinamide in ethanol as solvent. The concentration of the solutions ranged from 40 ppm to 140 ppm, and the solutions were used on the same day.

Measurement of density

The density values of 0.1M nicotinamide in ethanol and the solutions of TiO$_2$-MCM-41 in 0.1 M nicotinamide in ethanol were determined by relative measurement methods by using specific gravity bottle of 25 ml capacity as described elsewhere[9]. At least five observations were taken and differences between any two readings did not exceed ± 0.02%. Measurement of density was done in the temperature range, 298.15K to 313.15K at 5 K intervals.
Measurement of viscosity

Viscosity measurements on the solutions were made at different temperatures ranging from 298.15K to 313.15K at an interval of 5K in a water thermostat maintained at appropriate temperatures varying within ±0.05K by using an Ostwald Viscometer as described elsewhere[9]. The viscosity values so obtained were accurate to within ±0.3×10⁻⁴ Cp.

The solutions of TiO₂-MCM-41 varied over a concentration range of 40 ppm to 140 ppm, i.e., 2.5×10⁻² to 8.5×10⁻² M.

**Ibuprofen loading and in vitro release measurements**

**Preparation of standard solutions**

In the purpose of calculating the amount of Ibuprofen loaded to MCM-41 and (xx) TiO₂-MCM-41, standard solutions were prepared in the concentrations of 2μg/ml-10μg/ml by appropriate dilutions. Absorbance measurements were recorded between 200-300 nm. The absorbance values at 222 nm were used for the all calculations of the concentration of Ibuprofen. The absorbance values and concentrations of these standard solutions were used to plot the calibration curve. A stock solution was prepared by dissolving 200 mg of Ibuprofen in 250 ml phosphate buffer, pH 7.4. Absorbance at the λ max = 222 nm was measured. A calibration curve was plotted between absorbance and concentration.

**In vitro release studies**

200 mg of MCM-41 Land (xx) TiO₂-MCM-41 were conformed into disks by applying pressure (1 ton) and soaked in solutions of ibuprofen in hexane (25 mg/ml) separately for 48 hours so that the absorption process reached 30 wt % with respect to the starting materials. The ibuprofen impregnated samples are designated as MCM-41-Ibu and (xx) TiO₂-MCM-41-Ibu. The concentration of the adsorbed ibuprofen in the samples was determined by UV-Vis spectrophotometer at a wavelength of 222 nm using Nanodrop spectrophotometer V-630.

The concentration of Ibuprofen (molecular mass=122.12 gm, structure is shown below) was calculated according to the standard curve prepared in the concentration range of 10 μg/ml.

![](image)

**Ibuprofen**

For in vivo release studies, 200 mg each of MCM-41, and (xx) TiO₂-MCM-41 were compressed into tablet forms having 13 mm diameter by applying 1 ton pressure. The drug release rate from the drug under sink conditions at 37±0.5°C was measured. The drug release was monitored by spectrophotometry as a function of time (for 6 hours) at a wavelength of 222 nm using Nanodrop spectrophotometer V-630.

**Theoretical aspects**

From the density (d), and viscosity co-efficient (η) data, the following parameters have been determined.

Apparent molar volume, \( V_v \) was calculated by the standard equation \( \text{(1)} \)

\[
V_v = 1000(c_d)\phi(d_c-d) + M d c^{-1}
\]

where \( c \) is the molar concentration, \( d_d \) is the density of the solvent, \( d \) is that of the solution and \( M \) is the molecular mass of TiO₂-MCM-41, as determined earlier [8].

Limiting apparent molar volume, \( V_v^\phi \) was determined by least square method [10] by fitting the \( V_v \) data to the Masson equation \( \text{(10)} \) by equation \( \text{(2)} \)

\[
V_v = V_v^\phi + S_c c^{1/2}
\]

Where, \( S_c \) is the slope of the \( V_v \) vs \( c^{1/2} \) plot.

Apparent molar expansibility \( E_v \) was calculated by using equation \( \text{(10)}(3) \)

\[
E_v = E_v^\phi + \phi \alpha_e (10)000 c^{-1}
\]

where \( \alpha_e \) and \( \alpha_0 \) are the co-efficients of expansion of the solution and solvent respectively, and were obtained from the usual relation [10].

Limiting apparent expansibility \( E_v^\phi \) was determined by least square method [10] by fitting the \( E_v \) data to the Masson equation \( \text{(10)} \) by equation \( \text{(4)} \)

\[
E_v = E_v^\phi + S_v c^{1/2}
\]

where \( S_v \) is the slope of the \( E_v \) vs \( c^{1/2} \) plot.

The viscosity data of the solution were analyzed by Jones-Dole [11] empirical equation as follows

\[
\eta = \eta_0 + A_c c^{1/2} + B c (6)
\]

where \( \eta_0 \) is the relative viscosity, \( \eta \) is the viscosity co-efficient of the solution, \( A_c \) is that of the solvent, \( A_f \) is Falken-Hagen co-efficient and \( B \) is Jones-Dole co-efficient.

The constants \( A_f \) and \( B \) are the intercept and slope of the linear plots of \( \eta / \eta_0 - 1 \) vs \( c^{1/2} \), respectively, and were determined by least squares method [10].

The viscosity data have been analyzed on the basis of transition state theory from the relation [15]

\[
\mu\phi = \Delta\mu\phi^\star + \Delta\mu^\star (RT/\bar{V}) 1000B - (\bar{V}^\phi \bar{V} - \bar{V}^\phi)^{1/2} (7)
\]

Where, \( \mu\phi \) is the contribution per mol of the solute to free energy of activation for viscous flow of the solution.

\[
\Delta\mu^\star = 2.303 R T \log (\eta_0 \bar{V}^\phi / hN) (8)
\]

Where, \( h \) and \( N \) are Planck’s constant and Avogadro number, respectively.

\( \Delta\mu^\star \) is the contribution per mol of the solvent to free energy of activation for viscous flow of the solution.

\[
V_1 = M_{solvent} / d (9)
\]

\[
V_2 = V_v^\phi (10)
\]

**RESULTS AND DISCUSSION**

**Characterization of TiO₂-MCM-41**

The Scanning Electron Microscopy (SEM) indicated that the presence of 2D hexagonal long range mesoscopic morphology in TiO₂-MCM-41 (fig. 1). The uniform distribution of spherical particles resembling MCM-41[8] represents the siliceous material in the outer surface.
MCM-41 and (xx) TiO$_2$-MCM-41 were also characterized by XRD, FTIR and composite diffractogram which showed the retention of hexagonal siliceous structure and rutile phase of titania in the titania modified samples[13].

**Densiometric study**

The density of solvent (0.1M nicotinamide in ethanol) and those of the solutions of TiO$_2$-MCM-41 of different concentrations have been determined at four different temperatures varying from 298.15K to 313.15K. The density values of the solutions of the modified TiO$_2$-MCM-41 are given in table 1. As observed, the density values of solutions of the modified TiO$_2$-MCM-41 except at 40 ppm are lower than those of MCM-41[8] at the experimental temperatures. This is reflected in fig. 2 (a typical plot of density vs. concentration at 298.15 K). The lowering of density value of the modified MCM-41 with TiO$_2$(for both the compositions) at high concentrations with the solvent(ethanol with nicotinamide) interactions overcoming the solute-solute(i.e. TiO$_2$-MCM-41) intermolecular force of interaction in ethanolic nicotinamide solution, TiO$_2$ increases in volume and hence the density values decrease. The higher density values of (xx)TiO$_2$-MCM-41 than that of MCM-41 at 40 ppm may be due to the fact that dissolution of TiO$_2$-MCM-41 may be due to the fact that ethanol molecules along with the dissolved nicotinamide penetrate deep into the TiO$_2$-MCM-41 to produce a swollen gel, and secondly the strong TiO$_2$-MCM-41-solvent(ethanol with nicotinamide) interactions overcoming the solute-solute (i.e. TiO$_2$-MCM-41) intermolecular force of interaction transform the swollen gel into true solution thereby causing an increase in volume in the mixture. But, (15) TiO$_2$-MCM-41 showed a peculiar behavior where the density increases beyond 120 ppm, i.e., exhibits a second minima at 120 ppm. As usual, the formation of the swollen gel and the transformation of the swollen gel into true solution may be the plausible cause of the decreased and increased density values of the samples, respectively. However, the solutions of MCM-41 behave in a different manner, from those of TiO$_2$-MCM-41 showing an increased trend in its density values with concentration. It is seen that the density values for all the solutions decrease with increase in temperature.

As can be seen from table 1 (displayed in fig. 2 at 298.15 K only) the density values for the (xx) TiO$_2$-MCM-41 decrease with increase in concentration, attain a minima at 80 ppm and then increase at 100 ppm followed by a decrease as the proportion of TiO$_2$-MCM-41 increases in the mixture. But, (15) TiO$_2$-MCM-41 showed a peculiar behavior where the density increases beyond 120 ppm, i.e., exhibits a second minima at 120 ppm. As usual, the formation of the swollen gel and the transformation of the swollen gel into true solution may be the plausible cause of the decreased and increased density values of the samples, respectively. However, the solutions of MCM-41 behave in a different manner, from those of TiO$_2$-MCM-41 showing an increased trend in its density values with concentration. It is seen that the density values for all the solutions decrease with increase in temperature.

Using the density values (d) of the solutions and solvent (d$_0$) in Equation (1), the apparent molar volume ($V_{app}$) and limiting apparent molar expansibility ($E_{app}$) and $S_v$ of MCM-41, and (xx) TiO$_2$-MCM-41 in 0.1 M nicotinamide ethanolic solutions at 298.15K, 303.15K,308.15K and 313.15K are given in table 2.

Using the density values (d) of the solutions and solvent (d$_0$) in Equation (1), the apparent molar volume ($V_{app}$) and limiting apparent molar expansibility ($E_{app}$) and $S_v$ of MCM-41, and (xx) TiO$_2$-MCM-41 in 0.1 M nicotinamide ethanolic solutions at 298.15K, 303.15K,308.15K and 313.15K are given in table 2.

<table>
<thead>
<tr>
<th>Temp(K)</th>
<th>Concentration (ppm)</th>
<th>40 ppm</th>
<th>60 ppm</th>
<th>80 ppm</th>
<th>100 ppm</th>
<th>120 ppm</th>
<th>140 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>298.15</td>
<td>0.8019</td>
<td>0.7992</td>
<td>0.7953</td>
<td>0.7963</td>
<td>0.7939</td>
<td>0.7956</td>
<td></td>
</tr>
<tr>
<td>303.15</td>
<td>0.7991</td>
<td>0.7974</td>
<td>0.7911</td>
<td>0.7922</td>
<td>0.7905</td>
<td>0.7919</td>
<td></td>
</tr>
<tr>
<td>308.15</td>
<td>0.7930</td>
<td>0.7904</td>
<td>0.7890</td>
<td>0.7881</td>
<td>0.7881</td>
<td>0.7889</td>
<td></td>
</tr>
<tr>
<td>313.15</td>
<td>0.7902</td>
<td>0.7863</td>
<td>0.7843</td>
<td>0.7905</td>
<td>0.7849</td>
<td>0.7853</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1: Values of densities, d (Kg/m$^3$) of (xx) TiO$_2$-MCM-41 in 0.1 M Nicotinamide in Ethanol at four different temperatures Density of (10) TiO$_2$-MCM-41 in 0.1 M nicotinamide in ethanol**

<table>
<thead>
<tr>
<th>Temp(K)</th>
<th>Concentration (ppm)</th>
<th>40 ppm</th>
<th>60 ppm</th>
<th>80 ppm</th>
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<th>140 ppm</th>
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<td>0.7922</td>
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<td>0.7919</td>
<td></td>
</tr>
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<td>0.7904</td>
<td>0.7890</td>
<td>0.7881</td>
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<td>0.7889</td>
<td></td>
</tr>
<tr>
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<td>0.7863</td>
<td>0.7843</td>
<td>0.7905</td>
<td>0.7849</td>
<td>0.7853</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2: Values of parameter $V_{app}$ (m$^3$ mol$^{-1}$), $V_{app}$ (m$^3$ mol$^{-1}$), $S_v$ (m$^9$/2 mol$^3$/2K$^{-1}$), $E_{app}$ (m$^3$ mol$^{-1}$K$^{-1}$), $E_{app}$ (m$^3$ mol$^{-1}$K$^{-1}$) and $S_v$ (m$^9$/2 mol$^3$/2K$^{-1}$) for solutions of (xx) TiO$_2$-MCM-41 at different concentrations and temperatures**

<table>
<thead>
<tr>
<th>Temp(K)</th>
<th>$c\times10^7$ moldm$^{-3}$</th>
<th>$V_{app}\times10^7$</th>
<th>$V_{app}\times10^7$</th>
<th>$S_v\times10^9$[10]</th>
<th>$E_{app}\times10^5$</th>
<th>$E_{app}\times10^6$</th>
<th>$S_v\times10^9$</th>
</tr>
</thead>
<tbody>
<tr>
<td>298.15</td>
<td>2.423</td>
<td>-2.575</td>
<td>-2.484</td>
<td>5.397</td>
<td>2.677</td>
<td>0.788</td>
<td></td>
</tr>
<tr>
<td>303.15</td>
<td>3.635</td>
<td>-0.482</td>
<td>-3.732</td>
<td>4.386</td>
<td>5.313</td>
<td>0.862</td>
<td></td>
</tr>
<tr>
<td>308.15</td>
<td>4.847</td>
<td>+0.673</td>
<td>-2.271</td>
<td>5.481</td>
<td>0.063</td>
<td>0.907</td>
<td></td>
</tr>
</tbody>
</table>
A perusal of table 2 shows that the values of \( V_\phi^c \) are negative for all the three samples at the experimental temperatures. Since the \( V_\phi^c \) is a measure of solute-solvent interaction, the negative values of \( V_\phi^c \) indicate weaker solute-solvent interaction [8, 15]. The results indicate that the solute-solvent interactions vary irregularly with increase in temperature supporting to the fact the formation of the swollen gel and the transformation of the swollen gel into true solution are affected more or less with increase of temperature. As observed, the values of \( V_\phi^c \) are more negative for both the samples of TiO\(_2\)-MCM-41 than that of MCM-41. This point to the fact that the solute-solvent interactions in the former case are weaker as compared to the latter. In other words, the addition of TiO\(_2\) to MCM-41 favors the structure making effect of TiO\(_2\)-MCM-41 in ethanol-nicotinamide (hydrotropic agent) mixture.

The positive values of \( S_\phi \) at the experimented temperatures for TiO\(_2\)-MCM-41 indicate the presence of solute-solvent interaction. The positive values of \( E_\phi \) in TiO\(_2\) modified MCM-41 indicate a possible packing effect involving structure making in these samples.

### Table 3: Values of viscosities \( \eta \) (poise) and relative viscosities (\( \eta_r \)) for solutions of (xx) TiO\(_2\)-MCM-41 at different temperatures

<table>
<thead>
<tr>
<th>Temp(K)</th>
<th>( \eta \times 10^3 ) poise</th>
<th>( \eta_r \times 10^3 ) poise</th>
<th>( \eta_r )</th>
</tr>
</thead>
<tbody>
<tr>
<td>298.15</td>
<td>4.337</td>
<td>5.316</td>
<td>2.525</td>
</tr>
<tr>
<td>308.15</td>
<td>4.337</td>
<td>5.316</td>
<td>2.525</td>
</tr>
<tr>
<td>313.15</td>
<td>4.337</td>
<td>5.316</td>
<td>2.525</td>
</tr>
</tbody>
</table>

The viscosities \( \eta \) and relative viscosities (\( \eta_r \)) of solutions of (xx) TiO\(_2\)-MCM-41 in 0.1 M nicotinamide in ethanol are shown in Table 3. As observed from the table, the viscosity values follow the same trend as those of density for Titania modified samples.
Viscosity data were analyzed by means of Jones-Dole equation using equation 6. The values of viscosity co-efficients $A_F$, $B_J$ have been evaluated and are presented in Table.

### Table 4: Values of parameters $A_F$ (dm$^3/2$ mol$^{-1/2}$), $B_J$ (dm$^3$ mol$^{-1}$), $\Delta\mu_{10*}$ (kJ mol$^{-1}$), and $B_J/ V_\phi$ for solutions of MCM-41, (xx) TiO$_2$-MCM-41 of different concentrations at different temperatures

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Temp (K)</th>
<th>MCM-41</th>
<th>(10)TiO$_2$-MCM-41</th>
<th>(15)TiO$_2$-MCM-41</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_F$</td>
<td></td>
<td>298.15</td>
<td>303.15</td>
<td>308.15</td>
</tr>
<tr>
<td>$B_J$</td>
<td>$10^5$</td>
<td>1.65</td>
<td>1.57</td>
<td>1.49</td>
</tr>
<tr>
<td>$\Delta\mu_{10*}$</td>
<td></td>
<td>67.30</td>
<td>68.17</td>
<td>69.02</td>
</tr>
<tr>
<td>$\Delta\mu_{15*}$</td>
<td>$10^3$</td>
<td>1.64</td>
<td>1.38</td>
<td>1.53</td>
</tr>
<tr>
<td>$B_J/ V_\phi$</td>
<td>$10^5$</td>
<td>-47.3</td>
<td>-35.4</td>
<td>-30.7</td>
</tr>
</tbody>
</table>

Identical conclusions in regard to solute-solute and solute-solvent interactions are obtained from the viscometric and apparent molar volume data. The negative value of coefficient $A_F$ in MCM-41 indicates the presence of weak solute-solute interaction, which may be attributed to the formation of a sheath of ethanol molecules around the solute resulting in the weakening of solute-solute interaction. The positive and highest value of $A_F$ in (15) TiO$_2$-MCM-41 except at 303.15K may be ascribed to the increased solute-solute interactions with increase in titania modification. The positive and highest value of $B_J$ in MCM-41 indicates the presence of solute-solvent interaction owing to the structure making tendency of the solute in the solvent [16, 17]. The behavior of $\Delta\mu_{10*}$ is similar to $B_J$. The $\Delta\mu_{15*}$, the Gibbs free energy of activation for viscous flow of solution is also larger than the free energy of activation for viscous flow of solution ($\Delta\mu_{10*}$) for MCM-41 which suggests that there is strong interaction between the solute and solvent molecules in the ground state than in the transition state. The reverse case is for TiO$_2$-MCM-41. The solvation can be judged from the hydration number ($B_J/ V_\phi$) as given in table 4. These negative values indicate that the MCM-41 molecules are less solvated. The $B_J/ V_\phi$ becomes positive for (xx) TiO$_2$-MCM-41 This indicates that TiO$_2$-MCM-41 is more solvated than MCM-41.

### Ibuprofen loading and release

Loading of Ibuprofen into mesoporous materials was confirmed by FTIR analysis (Fig. 4) using Jasco FTIR (Model 4100,Japan). The presence of carboxyl vibration bands at 1718 cm$^{-1}$, and C-H stretching vibrations in the 2950-2850 cm$^{-1}$ range from the alkyl groups of ibuprofen, confirmed drug loading into the host matrix. The broad band between 3100-3600 cm$^{-1}$ is due to physically adsorbed water whose intensity is decreased after drug loading which may be due to hydrogen bonding with carboxyl group of Ibuprofen. The peaks between 1620-1601 cm$^{-1}$ are due to H-O-H stretching vibration in the Si-O-Si structure. The peak at about 950 cm$^{-1}$ is observed for (xx) TiO$_2$-MCM-41, which is often used as evidence for the vibration of Ti-O-Si confirming to silica-titania inorganic network. A prominent peak near 1680 cm$^{-1}$ is observed in drug loaded samples which may be due to carbonyl group present in Ibuprofen. The compatibility of (xx) TiO$_2$-MCM-41 in Ibuprofen drug was evaluated through DSC analysis using Mettler Toledo DSC1 instrument. The curves of drug loaded (xx) TiO$_2$-MCM-41 and blank Ibuprofen are presented in Figs 5 and 6 respectively. It was evident from the DSC profile that all the samples exhibited sharp exothermic peaks near 77°C which correspond to the reported melting temperature of the drug.

![Fig. 4: FTIR image of mesoporous (xx) TiO$_2$-MCM-41 and drug loaded (xx) TiO$_2$-MCM-41](image-url)
The Ibuprofen loading was calculated by Beer-Lambert law \[18-20\]. % of Ibuprofen loaded in the samples (MCM-41 and (xx) TiO₂-MCM-41) were shown in table 5 and fig. 8. From the table, it is found that MCM-41 shows maximum drug loading capacity, and it decreases for the samples coated with TiO₂. This may be due to the reduced specific surface area and pore volume due to titania deposition which results in a decrease in the Ibuprofen loading amount. FTIR study(fig. 4) shows that more silanol(Si-OH) groups are present on the surface of MCM-41 in comparison to titania modified MCM-41, thereby forming more hydrogen bonds with the carboxyl group of Ibuprofen and showing maximum drug loading capacity(Fig.7).

Table 5: Loading of Ibuprofen

<table>
<thead>
<tr>
<th>Samples</th>
<th>Drug loading (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCM-41</td>
<td>34.22</td>
</tr>
<tr>
<td>(10) TiO₂-MCM-41</td>
<td>23.90</td>
</tr>
<tr>
<td>(15) TiO₂-MCM-41</td>
<td>19.86</td>
</tr>
</tbody>
</table>

Fig. 8 shows the percentage of ibuprofen release as a function of time for MCM-41, and (xx) TiO₂-MCM-41 samples loaded with ibuprofen and immersed into buffer solution. It is found that (15) TiO₂-MCM-41 shows highest drug releasing capacity among the three.

This may be due to the weak interaction of drug and TiO₂-MCM-41 which results in the increase in drug releasing rate as shown in table 6 and fig.9.

Table 6: Release of Ibuprofen

<table>
<thead>
<tr>
<th>Time in min</th>
<th>MCM-41</th>
<th>(10) TiO₂-MCM-41</th>
<th>(15) TiO₂-MCM-41</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>0.901</td>
<td>1.037</td>
<td>1.258</td>
</tr>
<tr>
<td>30</td>
<td>1.582</td>
<td>1.871</td>
<td>2.619</td>
</tr>
<tr>
<td>45</td>
<td>2.143</td>
<td>2.807</td>
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<td>3.385</td>
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<td>3.283</td>
<td>3.759</td>
<td>4.610</td>
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<td>5.308</td>
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<td>9.459</td>
<td>10.139</td>
<td>10.820</td>
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<tr>
<td>300</td>
<td>16.417</td>
<td>17.761</td>
<td>19.768</td>
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<tr>
<td>360</td>
<td>21.861</td>
<td>23.375</td>
<td>25.502</td>
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</table>

Fig. 9: In vitro release of ibuprofen from MCM-41 and (xx) TiO₂-MCM-41 in Phosphate buffer

It should be pointed out that the TiO₂-MCM-41 system still shows an appreciable Ibuprofen storage capacity and release rate, suggesting its potential application in the area of drug delivery and release.

CONCLUSION

Among the three samples; [MCM-41, (xx) TiO₂-MCM-41], (15) TiO₂-MCM-41 shows highest solute-solvent interaction and lowest solute-solute interaction in ethanol in presence of nicotinamide and exhibits the highest drug releasing capacity.

CONFLICT OF INTERESTS

Declared None
REFERENCES