CHAPTER 4

RECYCLING OF TEXTILE DYE USING DOUBLE NETWORK POLYMER FROM SODIUM ALGINATE AND SUPERABSORBENT POLYMER

4.1 INTRODUCTION

Industrial effluents are discharged into land and water from industries such as dying, paper, plastic, leather, food, mineral processing (Orthman et al. 2003) etc. without proper treatment leading to complex environmental pollution and health problems. Textile dying process generates huge quantity of toxic effluents which contains unabsorbed residual dyes and salts that spoils the environment enormously. Low biochemical oxygen demand and high chemical oxygen demand (Nasr et al. 2006) are the characteristics of dye effluent. Many synthetic organic dyes from effluent are highly toxic and endanger the aquatic life and environment (Sivaraj et al. 2001). The reactive dyes may be mutagenic and carcinogenic (Sivaraj et al. 2001) and can cause severe damage to the liver, digestive and the central nervous system of human beings and affect agricultural cultivation and underground water. Hence there is an urgent necessity to remove dyes from the effluent before being discharged into land and water using appropriate physico-chemical methods. Among them the adsorption technology which employs activated carbon (Nasr et al. 2006), natural clays (Tahir & Rauf 2006), modified clays (Baskaralingam et al. 2006), fly ash (Dhodapkar et al. 2006) etc. as adsorbents was generally considered to be a cost effective method to bring down the concentration of unabsorbed dyes in dye effluent (Tsai et al. 2004). In recent years SAPs
are progressively being used to remove the colors, toxic and heavy metal substances and other pollutants from waste water through adsorption mechanism which involves mass transfer from the liquid phase to the adsorbent and subsequent binding via physico-chemical interaction (Zheng et al. 2011, Wang & Liu 2013). For constant use, the mechanical strength of these SAPs must be good enough to withstand varying shearing forces. But unfortunately these polymers are not having enough mechanical properties for the continuous applications. It had been reported (Guilherme et al. 2005) that the mechanical properties of SAPs could be improved by double network formation through physico-chemical crosslinking in the presence of another preformed polymer (Yasuda et al. 2005). In this laboratory SAPs were synthesized for water conservation in agricultural applications and effluent water treatment, but their mechanical properties were not good for broader applications. Hence an attempt was made to widen its application by improving its mechanical properties by double network formation taking NaAlg as the second pre-formed polymer. The primary choice of NaAlg for double network formation (DNP) was due to the attractive combination of availability, price, and its performance in effluent water treatment. Besides, these possessed good water solubility, non-toxicity, biodegradability and biocompatibility (Nakajima et al. 2009).

DNPs were reported (Marandi et al. 2008) to be good candidate matrices for the removal of dye from the textile effluent. This was prepared by photo crosslinking of SAP and CaSO₄ induced ionic crosslinked NaAlg using 254 nm radiations. NaAlg, a natural ionic hydrophilic linear polysaccharide containing β-D-mannuronic acid and α-L-guluronic acid with –OH and –COO⁻ groups was commonly used in the synthesis of tough hydrogels for different applications (Guilherme et al. 2005). The sugar residues in NaAlg either could be arranged in blocks or randomly distributed (Wang & Liu 2013). Moreover, NaAlg grafted/crosslinked SAP was shown to be an excellent adsorbent for the
removal of colored materials and toxic heavy metal ions from industrial effluent (Kobašlija & McQuade 2006). Hence the present investigation involves the synthesis of a potential DNP by photo crosslinking of NaAlg on reported SAP (ANT) and its subsequent evaluation as adsorbents to remove the dyes from the textile dye effluent.

4.2 EXPERIMENTAL

Chapter 2

4.3 RESULT AND DISCUSSION

4.3.1 Yield, Dye Uptake and Reactant Composition for DNPs

The different compositions of reactants employed in DNPs synthesis are furnished in Table 4.1 along with the DNP yield (%) and RB 4 dye adsorbed in milligram per gram of DNP. The percentage yields of DNPs were found to be in the range of 70-89.

4.3.2 Mechanism of crosslinking

The Ca$^{2+}$ ionic crosslinking in NaAlg which occurred through (Lee & Mooney 2012) the α-L-guluronate (G-blocks) of NaAlg and the possible mechanism for photo crosslinking between ionically crosslinked NaAlg and SAP is presented in Figure 4.1. During irradiation of the SAP and ionic crosslinked NaAlg blend, carbon centered radicals might be formed by the preferential homolytic scission of C-H bond of methine carbon (Lee & Mooney 2012). This might have facilitated crosslinking via radical coupling. Moreover, during irradiation oxygen insertion reaction might also have occurred between the methine carbon and hydrogen ($\overset{\cdot}{C-H}$) leading to the formation of hydroperoxide ($\overset{\cdot}{C-O-O-H}$) weak links. Since this link which was
photolabile have generated oxygen centered radicals $\cdot O$ and $\cdot OH$ during photolysis which also had induced crosslinking (Figure 4.1).

Figure 4.1 Photo crosslinking mechanism between SAP and NaAlg
Table 4.1  Designation of DNP samples and their equilibrium dye and water uptake capacity

<table>
<thead>
<tr>
<th>DNP Sample code</th>
<th>SAP* Sample code</th>
<th>Weight % of SAP in mixture</th>
<th>Weight % of NaAlg in mixture</th>
<th>RB 4 sorption (mg/g)</th>
<th>Water uptake (g/g)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNP-1</td>
<td>ANT-31</td>
<td>67</td>
<td>33</td>
<td>301</td>
<td>678</td>
<td>86</td>
</tr>
<tr>
<td>DNP-2</td>
<td></td>
<td>50</td>
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<td>298</td>
<td>654</td>
<td>85</td>
</tr>
<tr>
<td>DNP-3</td>
<td></td>
<td>40</td>
<td>60</td>
<td>285</td>
<td>620</td>
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</tr>
<tr>
<td>DNP-4</td>
<td></td>
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<td>DNP-5</td>
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<td>29</td>
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<td>250</td>
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</table>

*In all experiments the [AA] and [KPS] were 1.27 M and 0.009 M respectively, and volume of experimental solution was 40 ml. # Physical blend of NaAlg and ANT-11 before irradiation.
4.3.3 Characterization of DNPs

4.3.3.1 FT-IR Analysis

Typical FT-IR spectra of SAP, NaAlg and DNP-16, RB 4 adsorbed DNP-16 and DNP-0 are displayed in Figure 4.2. Analysis of these IR spectra (Şolpan et al. 2008, Işıklan et al. 2010, Pawar & Edgar 2012) indicated the presence of SAP and NaAlg moieties in the photo crosslinked double network polymer. For example the absorption peaks at 1730 and 1547 cm$^{-1}$ attributed to the $>\text{C}=\text{O}$ stretching of ester group (TMPTA) and carboxylate anion (KA) respectively present in SAP were also present in DNP. The peak at 1655 cm$^{-1}$ indicated the presence of NIPAAm residue in SAP moiety. The IR spectra also showed a broad peak at 3502 cm$^{-1}$ (–OH), a peak at 1612 cm$^{-1}$ was endorsed to $\text{—COO}^-$, and a peak at 1029 cm$^{-1}$ corresponded to C$\text{—O}$ group which were characteristics of the polysaccharide (NaAlg). The characteristic peak of calcium alginate appeared at 810-813 cm$^{-1}$ (–Ca–O) in DNP-16 and DNP-0.
Representative IR spectra of virgin and desorbed RB 4 are given in Figure 4.3. The broad peaks at 3450 and 3458 cm\(^{-1}\) were attributed to the amino groups of virgin and desorbed RB 4 respectively. Peaks at 1720 and 1639 cm\(^{-1}\) indicated the presence exocyclic \(\text{>C=O}\) and endo cyclic \(\text{>C=N}\) groups in the dye. The characteristic peaks at 1140 and 674 cm\(^{-1}\) corresponded to \(\text{>C—N}\) and \(\text{>C—Cl}\) groups of dye.
4.3.3.2 TG Analysis

TG thermograms for representative DNP samples (DNP-16 and DNP-0 (physical blend of NaAlg and SAP before irradiation)) depicted in Figure 4.4 showed multistep degradation. The initial weight loss up to 100°C was attributed to the residual volatile matter such as moisture etc. present in the SAP. The initial onset degradation of DNP at a temperature around 225°C with considerable decomposition was ascribed to a complex process including dehydration of the saccharide rings, de-polymerization with the formation of water, CO₂ and methane (Wang & Wang 2010). The degradation step above
300°C was more likely due to the degradation initiated via the olefinic bond, decarboxylation of carboxylate anion and scission of crosslinks etc. The major degradation of DNP around 400°C corresponding to a weight loss of 50% was more likely attributed to the degradation of SAP moiety. Comparison of DTG curves revealed that the thermal stability of the photo crosslinked double network was greater than that of the physical mixture.

Figure 4.4  TG/DTG traces of DNP-0 and DNP-16

4.3.3.3  Water Uptake and Dye Adsorption

Water and dye uptake (Table 4.1), and release profiles with respect to time for DNP-16 and DNP-0 are given in Figure 4.5. The maximum equilibrium water uptake by DNP-16 and DNP-0 were 810 and 698 g/g respectively. The adsorption capacity of RB 4 on DNP-16 and SAP were 439 mg/g and 321 mg/g respectively. Analysis of the adsorption profiles in Figure 4.5 revealed that the water and dye uptake rates were greater than the corresponding release rates. The decrease in the release rates of water and dye
might be due to the enhanced physico-chemical crosslinking through H-bonding with dye molecule. However, in the absence of salts the adsorption capacity of DNP-16 was 545mg/g (in the absence of co-ion). But at higher salt loading (Ionic strength = >0.2062 mole/dm^3) during dying the adsorption capacity decreased to 245 mg/g. The possible reason for low adsorption capacity at high ionic strength was due to the screening of electrostatic interaction of opposite charges by the salt on the adsorbent surface.

![Graph showing water uptake and dye sorption and desorption for DNP-0 and DNP-16](image)

**Figure 4.5** Water, RB 4 uptake and their release profiles for DNP-0 and DNP-16

### 4.3.3.4 Adsorption Isotherms

The adsorption data of RB 4 on DNP-16 were fitted to Langmuir and Freundlich isotherms [equations (2.4) and (2.5) respectively, where the terms have their usual meaning as discussed in chapter II] and the best fit for the adsorption of RB 4 on DNP-16 was found to be Langmuir isotherm based on the comparison of their correlation coefficient (R^2) of Langmuir and
Freundlich isotherms, and this indicated monolayer dye adsorption (Banerjee & Sharma 2013).

![Langmuir adsorption isotherm for RB 4 and DNP-16 system](image)

**Figure 4.6**  Langmuir adsorption isotherm for RB 4 and DNP-16 system

Langmuir isotherm parameters $q_m$ and $K_L$ were calculated from the slope and intercept values of the plot $1/q_e$ vs. $1/C_e$ (Figure 4.6) and these parameters are given in Table 4.2. The $K_L$ value was essentially equilibrium constant, the variation of $K_L$ with temperature could be used to estimate the enthalpy change accompanying adsorption, affinity between the adsorbent and adsorbate. The value $q_m$ was comparable to the adsorption capacities of some other adsorbent materials for RB 4. These figures indicated that the DNP-16 was a good adsorbent for recycling of the textile dye from effluent. This was also supported by the nearly identical values for the experimentally determined equilibrium dye adsorption and theoretically calculated Langmuir equilibrium RB 4 adsorption isotherm parameters.
Table 4.2  Langmuir and Freundlich adsorption isotherm parameters for DNP-16 and RB 4 system

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Adsorption isotherm parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNP-16</td>
<td>Langmuir</td>
</tr>
<tr>
<td></td>
<td>q_m (mg/g)</td>
</tr>
<tr>
<td></td>
<td>K_L (L/mg)</td>
</tr>
<tr>
<td></td>
<td>R^2</td>
</tr>
<tr>
<td></td>
<td>446</td>
</tr>
<tr>
<td></td>
<td>1.283</td>
</tr>
<tr>
<td></td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td>Freundlich</td>
</tr>
<tr>
<td></td>
<td>K_F (mg/g)</td>
</tr>
<tr>
<td></td>
<td>1/n</td>
</tr>
<tr>
<td></td>
<td>R^2</td>
</tr>
<tr>
<td></td>
<td>2.119</td>
</tr>
<tr>
<td></td>
<td>0.825</td>
</tr>
<tr>
<td></td>
<td>0.919</td>
</tr>
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</table>

4.3.3.5  Adsorption Kinetics

The rate of adsorption was an important parameter, and it was essential for column design and process optimization for successful commercial applications such as heavy metal removal, dye adsorption from effluent. Comparing the adsorption capacities (mg/g) of DNP-16 and DNP-0 for RB 4 measured as a function of time (Figure 4.7) revealed rapid dye adsorption during the initial 60 min of contact time, which subsequently slowed down over a longer period of time until the equilibrium was attained. During the initial 60 minutes contact time, 78% of equilibrium adsorption for DNP-16 was accounted. The rapid dye adsorption (Banerjee & Sharma 2013) was most probably due to the abundant availability of active sites on the adsorbent, whereas with the gradual occupancy of these sites, adsorption became less efficient after 60 minutes of contact time. The degree of dye adsorption was tested with the pseudo-first order and pseudo-second order kinetic models [equations (2.6) and (2.7) respectively] (parameters are given in Table 4.3) and the best fit kinetic model was found to be pseudo-first order by comparing the R^2 values of the plots ‘log (q_e - q_t) vs. t’ (Figure 4.7 for pseudo-first order (Banerjee & Sharma 2013).
Figure 4.7  Pseudo first order adsorption kinetic model

The rate constants of adsorption determined from the slopes of profiles in Figure 4.7 were decreased with temperature, indicating enhanced temperature did not favor the adsorption of RB 4. The extent of dye adsorption, and the amount of dye adsorbed per unit mass of the adsorbents \((q_e)\) decreased appreciably with temperature which might be attributed to the competing desorption process at enhanced temperature.
Table 4.3  Pseudo-first and second order adsorption kinetic parameters for DNP-16 and RB 4 system at different temperature

<table>
<thead>
<tr>
<th>Sample code</th>
<th>Kinetic model</th>
<th>T(K)</th>
<th>parameters ( (q_c = \text{mg g}^{-1}, \ \ k_1 = \text{min}^{-1} \ \text{and} \ \ k_2 = \text{gmg}^{-1}\text{min}^{-1}) )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNP-16</td>
<td>Pseudo-first order</td>
<td>303</td>
<td>( q_c = 439 ) [ k_1 = 4.2 ]</td>
<td>0.998</td>
</tr>
<tr>
<td></td>
<td></td>
<td>313</td>
<td>( q_c = 304 ) [ k_1 = 1.69 ]</td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td></td>
<td>323</td>
<td>( q_c = 282 ) [ k_1 = 1.31 ]</td>
<td>0.998</td>
</tr>
<tr>
<td></td>
<td>Pseudo-second order</td>
<td>303</td>
<td>( q_c = 77.23 ) [ k_2 = 5.23 ]</td>
<td>0.977</td>
</tr>
<tr>
<td></td>
<td></td>
<td>313</td>
<td>( q_c = 42.12 ) [ k_2 = 4.65 ]</td>
<td>0.974</td>
</tr>
<tr>
<td></td>
<td></td>
<td>323</td>
<td>( q_c = 31.72 ) [ k_2 = 4.50 ]</td>
<td>0.987</td>
</tr>
</tbody>
</table>

4.3.3.6  Thermodynamics of Dye Adsorption

The \( \Delta G^\circ \), \( \Delta H^\circ \) and \( \Delta S^\circ \) values for dye adsorption were measured as per the equation (2.8). The negative values of \( \Delta G^\circ \) namely, - 618, -1610 and - 2263 kJ mole\(^{-1}\) for the temperature 303, 313 and 323 K respectively indicated that the RB 4 adsorption on DNP was spontaneous. The average negative value of \( \Delta H^\circ \) (-2922 kJ mole\(^{-1}\)) for the above temperature indicated that adsorption was exothermic which might be due to the weak interactions between the
adsorbent and dye. The positive value of entropy (9.98 kJ mole\(^{-1}\)) was attributed to the increased volume of the system (adsorbent and dye solution) through swelling which might have enhanced the mobility of the adsorbed dye molecule.

4.3.3.7 Water and Dye Release Studies

The mechanism of water and dye released from swelled and dye adsorbed DNP-16 was analyzed using the power law Hosseinzadeh (2010) equation 1.26. The values of diffusion exponents (n) were found to be in the range 0.3–0.38 and 0.39–0.43 for water and dye solutions respectively. This implied that the release mechanism appeared to be Fickian.

4.3.3.8 SEM

The surface morphological features of the freeze dried SAP and DNP-16, and DNP-0 after swelling in water and dye solution was analyzed by SEM and the representative SEM micrographs are shown in Figure 4.8. Analysis of these SEM images revealed the formation of pores during freeze drying and porous network structure (Figure 4.8 a & b)) in irradiated samples. The porous morphology was more likely due to water evaporation. The shapes of the pores are irregular and interconnected. The massive distribution of pores in the freeze dried samples indicated water uptake throughout the material and the presence of void volume. The unequal pore sizes inferred that the crosslinking may not be uniform throughout the material. The porous structure appeared to be more compact in DNP-16 than in SAP (ANT-11) Figure 4.8(a & d) perhaps due to intermolecular crosslinking. These pores may be the areas, where the water permeation occurred and interaction sites were available to form secondary bond with dyes, metal ion, drugs etc. (Atta et al. 2010, Pourjavadi et al. 2010) Analysis of Figure 4.8c also confirmed the adsorption of RB 4 on DNP-16. Hence, the porous structure appeared to be the
predominant cause for the high swellability and dye adsorption. The porosity and network structure revealed by SEM micrographs corroborated a three dimensional structure for DNP.

Figure 4.8 SEM micrographs of equilibrium swelled, freeze dried DNP-16(a), DNP-0(b), DNP-16(c, RB 4 adsorbed) and ANT-11 (d)

4.3.3.9 Mechanical Properties

The physico-chemical crosslinked SAP shattered into pieces under modest compression (Figure 4.10c) due to its brittleness nature. But the photo crosslinked DNP was able to withstand cycles of compression and regained its original shape on relieving the compression and this is displayed in Figure 4.10 (b and d). Moreover the crosslinked DNP could able to hold water and water
soluble material through adsorption even under compression unlike ANT-11. This demonstrated that DNP was having significantly improved mechanical properties in terms of elongation and modulus, and Figure 4.9 showed typical compressive stress-strain curve of DNP-16 and SAP. The representative DNP-16 gel showed a compressive elastic modulus 750 MPa, which was very much greater than that of SAP (73 MPa). The ultimate stress and the strain at the breaking (failure) point of DNP-16 and SAP were 36.4 (at 354% elongation) and 3.54 MPa (at 3.5% elongation) respectively. Hence the adsorbent could be persistently used for textile effluent treatment process.

![Stress-strain curve for DNP-16 and ANT-11](image)

**Figure 4.9** Stress-strain curves for DNP-16 and ANT-11
Figure 4.10 Photographs of (i) SAP before compression (a) and after compression (c) and (ii) DNP-16 with 90% water content during compression (b) and after compression (d)

4.3.3.10 Reusability of Recycled Dye and Adsorbent

The most important requirement for the adsorbent is its reusability even after several adsorption-desorption cycle. This was tested by the constancy of its adsorbent capacity during the repeated cycle of its usage. It was observed that the initial adsorption capacity of DNP-16 for RB 4 was 439 mg/g. The adsorption capacity remained nearly constant after five adsorption-desorption cycles demonstrating that DNP-16 could be repeatedly used for the removal of dye from dye effluent in commercial effluent treatment plants due
to the improved mechanical properties of DNP-16 over SAP. Moreover, the molar extinction coefficient values at 573 nm (λmax) for the virgin (865520 L/mole.cm) and recovered dye (865531 L/mole.cm) were nearly identical supporting the original chemical nature of the recovered dye. Besides, IR spectra of virgin RB 4 and desorbed RB 4 were identical even after five adsorption-desorption cycles demonstrating that the dye remained stable structurally and hence the recovered RB 4 could be reused for dying fabrics.

![Graph](image)

**Figure 4.11  Solid state visible absorption spectra of fabric dyed with virgin and recovered RB 4**

The solid state visible absorption spectra of cloth dyed using virgin and recovered dye (Figure 4.11) were nearly identical corroborating the chemical stability of the dye during dye recovery processes in column mode. The constant color fastness properties of the dyed fabric with RB 4 and recovered RB 4 indicated that the chemical nature of recovered dye remained same, and the dyed fabrics showed good color fastness under sunlight and in soap solution.
4.3.3.11 Factors Affecting Dye Adsorption

4.3.3.11.1 DNP Composition

The quantum of dye adsorption by DNP-16 was analyzed as a function of its composition, using the profile (Figure 4.12) constructed by plotting weight percentage of SAP and NaAlg in the blend versus amount of dye adsorbed. As the % of NaAlg increased there was an increase in the dye uptake initially and with the further increase in NaAlg content the dye uptake decreased. DNP with increased % of SAP displayed an initial increase in dye uptake which then decreased for enhanced % of SAP. These observations on the degree of dye adsorption with the change in composition of DNP could be attributed to the poor crosslinking due to increased viscosity of the medium, variation in photo crosslinking, physico-chemical crosslinking and electrostatic repulsion between carboxylate anion as well.

![Figure 4.12 Effect of weight % of SAP and NaAlg in RB 4 uptake](image)

Figure 4.12 Effect of weight % of SAP and NaAlg in RB 4 uptake
4.3.3.11.2 Irradiation Time

Duration of irradiation had also affected the dye adsorption on DNP for a given composition, and adsorption versus irradiation time curve for a representative DNP-16 is shown in Figure 4.13. The DNP-16 (24 h irradiated) had absorbed 810 g/g of water under ambient conditions. However, it had adsorbed 478 mg/g of dye in distilled water. For irradiation time greater than 24 h both water uptake and dye adsorption were reduced (30 h) and this could be attributed to extensive crosslinking.

![Figure 4.13 Effect of irradiation time on RB 4 uptake](image)

4.3.3.11.3 pH Values

The pH of dye effluent was one of the major factors affecting the dye adsorption behavior of an adsorbent and the effect of pH on adsorption of RB 4 on DNP-16 over a pH range of 2-10 are given in Figure 4.14. The functional groups on the surface of an adsorbent could be altered by the variation in pH of dye effluent taken for treatment process. It was obvious that
the adsorption capacity increased with increasing pH of dye effluent, and significant enhancement was observed till it reached a pH value of 6. Further increase of pH beyond 8 has reduced the dye adsorption due to the electrostatic repulsive force between adsorbent and adsorbate. At lower pH, most of the carboxyl groups on the surface of the adsorbent exist in the form of $-\text{COOH}$, and simultaneously the competition between hydrogen ion and the cationic RB 4 to enter the solution phase has increased. This could result in the reduction of dye desorption. At pH 6, the adsorption capacities increased hardly owing to the buffer action of $-\text{COOH}$ and $-\text{COO}^-$ groups (Liu et al. 2011).

![Graph: Effect of pH on RB 4 uptake of DNP-16](image.png)

**Figure 4.14** Effect of pH on RB 4 uptake of DNP-16
4.4 CONCLUSIONS

DNP of different composition were synthesized through photochemical crosslinking of NaAlg and SAP at 254nm. TG analysis and the mechanical properties of DNP revealed that, it was sufficiently thermally stable in air and can withstand usual environmental conditions. SEM micrographs of swelled, and freeze dried DNP-16 revealed network formation and RB 4 adsorption. The nearly identical visible absorption spectra of the dyed fabrics for virgin and recovered RB 4, and the constant color fastness properties of the dyed fabric with these dyes indicated that the chemical nature of recovered dye remained intact. DNP-16 was evaluated as an adsorbent in column mode for textile effluent treatment taking RB 4 as a typical reactive dye, and the adsorption capacity of DNP-16 was 439 mg/g. In every adsorption-desorption cycle almost constant amount of dye was recovered. The equilibrium dye adsorption profile at different concentrations of dye implied predominantly Langmuir adsorption isotherm. The kinetics data of adsorption supported pseudo-first order model. The dye adsorption-desorption followed a Fickian mechanism. Evaluation of $\Delta G^0$, $\Delta H^0$ and $\Delta S^0$ for dye adsorption indicated that adsorption was spontaneous and exothermic for the chosen double network polymer. This study demonstrated that DNP-16 could serve as a potential adsorbent for the effective recycling of dyes from the textile effluent in commercial effluent treatment plants.