A novel aminated polymeric adsorbent for removing refractory dissolved organic matter from landfill leachate treatment plant

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Abstract

Refractory dissolved organic matter (DOM) from landfill leachate treatment plant was with high dissolved organic carbon (DOC) content. An aminated polymeric adsorbent NDA-8 with tertiary amino groups and sufficient mesopore was synthesized, which exhibited high adsorption capacity to the DOM (raw water after coagulation). Resin NDA-8 performed better in the uptake of the DOM than resin DAX-8 and A100. Electrostatic attraction was considered as the decisive interaction between the adsorbent and adsorbate. Special attention was paid to the correlation between porous structure and adsorption capacity. The mesopore of NDA-8 played a crucial role during uptake of the DOM. In general, resin in chloride form performed a higher removal rate of DOC. According to the column adsorption test, total adsorption capacity of NDA-8 was calculated to 52.28 mg DOC/mL wet resin. 0.2 mol/L sodium hydroxide solution could regenerate the adsorbent efficiently.

Key words: electrostatic interactions; chemically modified resin; coagulation; adsorption; pore structure

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Introduction

Dissolved organic matter (DOM) is ubiquitous in the water that is available in nature, containing mainly natural organic matter (NOM). NOM is often referred as a humic substance (HS, including humic acid and fulvic acid). DOM is a complex mixture of a variety of different polyfunctional organic components, which principally affects metal chelation, transporting of contaminants, and safety of drinking water. It is usually resistive to microbial degradation. Many investigations have focused on characterizing the chemical structure, molecular size, and formation source of DOM in aquatic environments due to its complexity (Imai et al., 2002; McDonald et al., 2004).

Landfill leachate is one of the wastewater with the highest content of DOM (Christensen et al., 1998; Nanny and Ratasuk, 2002). With increasingly stringent requirements for leachate pollution control, effective methods need to be developed, especially for the treatment of microbially refractory DOM, in the leachate.

Various adsorbents, including activated carbon, metal oxides, chitosan, mineral adsorbents, and polymeric adsorbents have been presented to adsorb DOM or HS from water in literature (Chen, 1999; Meier et al., 1999; Pelekani and Snoeyink, 1999; Bolto et al., 2001; Zhang and Bai, 2003). Among these adsorbents, macroporous resins and anion exchange resins, have been superiorly used for removing DOM from freshwater during the purification of drinking water, for their prominent adsorption efficiency and regeneration mechanism (Afcharian et al., 1997; Bolto et al., 2002). XAD-8 (DAX-8) is a non-ionic macroporous poly(methylmethacrylate) resin, which exhibits absolute retention of fulvic acid. It has been recommended by International Humic Substances Society (IHSS) to fractionalize DOM (Ma et al., 2001; Alberts and Takács, 2004). Moreover, since the 1970s, because of the aliphatic and carboxylic acid structures of DOM, anion exchange resins have been demonstrated to have strong potential in removing DOM. After comparing the performance of numerous anion exchange resins, Bolto (2004) found that the anion exchange resins showed a high efficiency (57%–91%) in UV254 removal of freshwater. Humbert (2005) also confirmed that anion exchange resins could eliminate both high and part of low molecular weight DOM effectively.

Chemically modified polymeric adsorbents are resins with functional groups such as phenolic hydroxyl, acetyl, sulfonic group or amino group, grafted on hypercrosslinked polymers (Alexandratos and Natesan, 1999; Cai et al., 2005). Among these, aminated hypercrosslinked polymers display a unique advantage in adsorption of aromatic sulfonates (Pan et al., 2005), phenol derivatives (Pan et al., 2003), and phenolic acids (Wang et al., 2005) due to the presence of electrostatic interactions, hydrogen-bonding interaction or π–π interaction between adsorbents.
and adsorbates. In recent years, more and more chemically modified resins have been synthesized and applied in different sewage control domains.

To date, although it is proved that DOM in low DOC content (DOC concentration usually < 10 mg/L) freshwater could be treated by resins distinctly (Bolto et al., 2004), wastewater containing DOM in higher DOC content water, such as landfill leachate or landfill leachate with primary treatment processes (DOC concentration usually > 500 mg/L), have not been thoroughly investigated. Rodríguez (2004) had depicted a landfill leachate after primary coagulation and has found activated carbon presented a higher adsorption capacity compared to XAD-8 resin, but its adsorption capacity is relatively low (38.12 mg COD/g activated carbon after 2 h contact). Therefore, it is essential to explore a new polymeric adsorbent, with an aim to remove DOM in high DOC content water, with higher adsorption capacity. Furthermore, the study has been focused on developing an adsorption mechanism of the resin in removing DOM, which is the main purpose of the current article.

1 Materials and methods

1.1 Synthesis of NDA-8 resin

The procedure of synthesis is in two steps: post-crosslinking and chemical modification. The chloromethylated low-crosslinked macroporous styrene-divinylbenzene copolymers (DVB content 6% and chlorine content 19.5%) were supplied by Langfang Electrical Resin Co., Ltd. (Hebei, China). Other reagents involved were purchased from Shanghai Chemical Reagent Plant. Three hundred gram copolymer beads were swollen in 1800 mL nitrobenzene for 12 h in a 2000-mL three-necked round-bottomed flask, which was equipped with a mechanical stirrer, a thermometer, and a reflux condenser. Under mechanical stirring, 90 g zinc chloride was added into the flask at 298 K. The mixture was stirred at 388 K in a set time to get post-crosslinked polymer beads with about 9.5% residual chlorine content. The chemical modification (amination) process of polymer beads was described elsewhere (Li et al., 2004). Finally, the aminated polymers were filtered and reserved for further use. The amination process and structure of NDA-8 were proposed as in Scheme 1.

1.2 Characterization of adsorbents

Commercial Purolite® A100 (Purolite, British), Supelite™ DAX-8 (Sigma-Aldrich, USA), and NDA-150 (Jiangsu N & G Co., Ltd., China) were used as references. Characteristics of the four polymeric resins are listed in Table 1. All resins were treated as follows before use: extracted by ethanol for 8 h in Soxlet apparatus and then dried under vacuum at 325 K for 3 h, followed by a rinse with two cyclic exhaustions using 0.1 mol/L sodium hydroxide and 0.1 mol/L hydrochloric acid. The amino resin (A100 and NDA-8) in chloride form or free amine form could be obtained with end of acid or alkali cycle, respectively. Before testing, all resins were washed with distilled water until the effluent was near neutrality and DOC could not be detected.

The surface area and pore size distribution of all resins were analyzed by ASAP2010 (Micromeritics, USA). The surface morphologies of NDA-8 resin were observed with a scanning electron microscope (SEM, JSM-5610LV, Japan). Infrared spectra of the polymeric adsorbents before

![Scheme 1](image)

**Table 1** Characteristic properties of NDA-8, A100, DAX-8, and NDA-150

<table>
<thead>
<tr>
<th>Property</th>
<th>NDA-8</th>
<th>A100</th>
<th>DAX-8</th>
<th>NDA-150</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>Amine-modified hypercrosslinked polystyrene-divinylbenzene</td>
<td>Polystyrene-divinylbenzene</td>
<td>Polymethylmethacrylate</td>
<td>Hypercrosslinked polystyrene-divinylbenzene</td>
</tr>
<tr>
<td>BET surface area (m²/g)</td>
<td>611.9 (73.1)</td>
<td>14.7 (16.5)</td>
<td>174.1 (124.7)</td>
<td>978.4 (88.6)</td>
</tr>
<tr>
<td>Average pore diameter (nm)</td>
<td>2.59 (5.00)</td>
<td>9.52 (7.00)</td>
<td>9.61 (10.70)</td>
<td>2.35 (4.12)</td>
</tr>
<tr>
<td>Micropore volume (cm³/g)</td>
<td>0.2225 (0.0094)</td>
<td>0.0339 (0.00283)</td>
<td>0.4159 (0.3307)</td>
<td>0.3051 (0.1233)</td>
</tr>
<tr>
<td>Total anion-exchange capacity (mmol/g)</td>
<td>0.1740 (0.0019)</td>
<td>0.0011 (0.0005)</td>
<td>0.0022 (0.00027)</td>
<td>0.2712 (0.0015)</td>
</tr>
<tr>
<td>Quaternary ammonium group (mmol/g)</td>
<td>2.53</td>
<td>4.55</td>
<td>0</td>
<td>ca. 0</td>
</tr>
</tbody>
</table>

Data in parentheses represent corresponding characteristics after DOM adsorption; NDA-8 and A100 are both in chloride form.
and after DOM adsorption were examined by a Nicolet170 SX IR spectrometer (Nicolet, USA) with a pellet of powdered potassium bromide.

1.3 Characterization of DOM

The wastewater employed was taken from a certain landfill site in Jiangsu Province, which was actually the water rejected by the nanofiltration membrane. The landfill leachate treatment process comprised of nanofiltration combined with the primary biological treatment. Accordingly, the DOM in the wastewater was basically non-biodegradable. The selected characteristics of the raw water are listed in Table 2. HS content of this wastewater was examined about 78% thereunder the method recommended by IHSS, details are not presented here.

Coagulation utilizing calcium hydroxide and amion polyacrylamide (PAM) were applied preferentially to reduce the load of the resin. It was verified in practice that coagulation by Ca(OH)$_2$ was an effective method in removing non-biodegradable organic compounds from the landfill leachate (Kargi and Pamukoglu, 2003; Kurniawan et al., 2006), and Ca(OH)$_2$ gave an outstanding performance in comparison with ferric salts here. PAM produced a coagulation-promotion effect and resulted in shorter sedimentation runs. The optimum coagulating reagent dosages were 18 g/L for Ca(OH)$_2$ and 1 mL/L for 0.1% PAM (W/W). However, a large part of DOM was also refractory to coagulation and still needed further treatment. The following DOM concerned referred to the water after coagulation.

DOC concentration measurements were conducted with DOC-5000A (Shimadzu, Japan). The concentrations of metals in water were quantified on ICP-AES J-A1100 (Jarrell-Ash, USA). The water after coagulation was freeze dried without further treatment, and infrared spectra of the DOM were also obtained.

Molecular size distributions of DOM in water were determined by Gel-Penetration Chromatography (GPC). The performed GPC was by Waters-515 (Waters, USA) with a Waters 2487 UV detector operating at 260 nm and a Waters 2410 differential refractometer detector. A Waters gel column was used for this study. Mobile phase was 0.1 mol/L sodium nitrate and polyethyleneglycol was chosen as molecular weight standard (600, 1000, 10000, 25300, and 89500 Da).

Table 2 Characteristics of the raw wastewater, water after coagulation, and resin adsorption

<table>
<thead>
<tr>
<th></th>
<th>Raw water</th>
<th>After coagulation</th>
<th>After adsorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD$_{0}$ (mg/L)</td>
<td>6634</td>
<td>4029</td>
<td>442</td>
</tr>
<tr>
<td>DOC (mg/L)</td>
<td>2742</td>
<td>1410</td>
<td>136</td>
</tr>
<tr>
<td>UV$_{254}$</td>
<td>76.59</td>
<td>29.78</td>
<td>2.34</td>
</tr>
<tr>
<td>Cr (mg/L)</td>
<td>0.84</td>
<td>0.21</td>
<td>0.04</td>
</tr>
<tr>
<td>Fe (mg/L)</td>
<td>13.32</td>
<td>0.41</td>
<td>nd</td>
</tr>
<tr>
<td>Mn (mg/L)</td>
<td>0.41</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>Zn (mg/L)</td>
<td>0.32</td>
<td>0.24</td>
<td>0.12</td>
</tr>
<tr>
<td>Cu (mg/L)</td>
<td>0.09</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>Ni (mg/L)</td>
<td>1.43</td>
<td>0.81</td>
<td>0.15</td>
</tr>
</tbody>
</table>

nd: not detected.

1.4 Batch and column experiments

Batch adsorption tests were performed as follows: 0.04, 0.08, 0.10, 0.15, 0.20, 0.25 g of the adsorbents were accurately weighted and introduced into a 250-mL conical flask directly. DOM water 100 mL with pH 2.5 was added to each bottle. The bottles were sealed and placed in a G-25 model incubator shaker (New Brunswick Scientific, British), shaken under 120 r/min for 96 h at room temperature (308 K).

Column test was carried out with a glass column (12 mm in diameter and 300 mm in length), 10 mL wet NDA-8 resin was enclosed, and a water bath was used simultaneously to maintain constant operating temperatures. The flow rate of the column was set to 2 BV/h (BV is the volume of resin bed) by a Lange-580 peristaltic pump (Lange, China). The total capacity $(Q_c)$ could be calculated based on Eq. (1):

$$Q_c = V(C_0 - C_a)/V_1$$

where, $C_0$ is the initial DOC concentration, $C_a$ is the average DOC concentration of the effluent, $V$ and $V_1$ represent the volume of the solution and wet resin, respectively, $Q_c$ means the total amount of adsorbed DOM until the effluent DOC concentration is equal to the initial DOC concentration.

The experiments were carried out thrice and analytical standard error was controlled to be less than ±3%.

2 Results and discussion

2.1 Characterization of DOM adsorption

2.1.1 Characterization by FT-IR

The chloride form (R–CH$_2$NH$^+$(CH$_3$)$_2$Cl–) and free amine form (R–CH$_2$N(CH$_3$)$_2$) are two forms of weak basic resins, where R represents the remaining part of the NDA-8, except the amine group. The free amine form of the NDA-8 with –CH$_2$N(CH$_3$)$_2$ group is supported by the absorbance bands at 2820 and 2770 cm$^{-1}$ (Fig. 1). However, after protonation of the amino group with hydrochloric acid, these two absorbance bands are replaced by 2470 and 2660 cm$^{-1}$, which are ascribed to –CH$_2$NH$^+$(CH$_3$)$_2$ bands stretching (Fig. 1).

2.1.2 Molecular size distribution

It is found that DOM exhibit a relatively narrow size range and low weight-averaged molecular weight (1074 Da) with only one peak from the GPC test (Fig. 2). The polydispersity value (1.14) of the DOM is noteworthy, even as, other DOM (HS) are usually > 1.5 (Chin et al., 1994; Maurice et al., 2002), this could be possibly attributed to effective biological degradation and molecular retention action of the nanofiltration membrane in the landfill leachate treatment process, as a result of which the impurities are removed and more homogeneous HS remains in the wastewater. The intensity of GPC/UV$_{254}$ profiles indicates that more than half of DOM in raw water is refractory to coagulation, which could be markedly eliminated by NDA-8 resin adsorption.
2.1.3 Surface morphology

Surface discrepancy of NDA-8 before and after DOM adsorption could be clearly viewed from the SEM images. Evidently, the surface of the resin is rugged and granular, but with the absorbed DOM, the surface of the resin appeared to be much smoother, revealing that layers of the DOM had been adsorbed on the surface of the resin (Fig. 3).

2.2 Effect of resin form and initial solution pH

The chloride form of the resin shows a much better performance in removing DOC than the free amine form (manufacturing standard form) in extensive pH ranges (Fig. 4a). That is to say, form transformation of the resin should occur before use to achieve a preferable removal rate of the DOM. This discrepancy should be partly ascribed to more polar site of the chloride form than the free amine form resin. The charge of the protonated amino site shows a greater affinity for the hydrophilic part of the DOM. Figure 4a also shows that the removal rate of DOC is elevated at first until pH is close to 2.5, and then it is depressed dramatically with initial pH increasing from 2.0 to 12.9. Consequently, the optimal solution pH in the DOM adsorption is set at 2.5.

Tracking investigation of solution pH before and after DOM adsorption indicates that the final solution of pH increases when initial pH is below about 8.9 (6.3 for chloride form resin), but decreases above 8.9 for free amine form resin in the pH range 2.0–12.9 (Fig. 4b). There was a similar trend in the adsorption of humic acid by aminated polyacrylonitrile fibers (Deng and Bai, 2004). The main component of DOM is HS, which is one of phenolic acid

![Fig. 1 FT-IR spectra of (a) DOM-adsorbed NDA-8, (b) NDA-8 in free amine form, (c) NDA-8 in chloride form, and (d) DOM.](image1)

![Fig. 2 Molecular size distribution of the DOM in wastewater.](image2)

![Fig. 3 SEM images of (a) NDA-8 (×150), (b) NDA-8 (×20000), (c) NDA-8 (×80000), and (d) DOM-adsorbed NDA-8 (×100000).](image3)
The DOM has more acidic groups than HS on its aromatic framework. The result of acid-base titration shows that DOM is in high acidity (carboxylic groups of 10.94 mmol/g DOC and weak acidic groups of 2.03 mmol/g DOC). DOM also has a highly condensed aromatic structure as per 13C nuclear magnetic resonance report (details are not presented here). So DOM can also be deemed as phenolic acid derivative. The existence of phenolic and carboxylic groups can also be confirmed by FT-IR spectra at 3370 and 1720 cm\(^{-1}\) (line d in Fig. 1), respectively. Under the assumption of this precondition, K is used to represent the remaining part of the DOM except the phenolic and the carboxylic groups. Therefore, it is reasonable to assume the major reactions (Reactions (1)–(5)) referred to as electrostatic interactions.

\[
\begin{align*}
R-\text{CH}_2\text{N(CH}_3)_2 + \text{H}^+ &\leftrightarrow R-\text{CH}_2\text{NH}^+(\text{CH}_3)_2 \\
R-\text{CH}_2\text{N(CH}_3)_2 + \text{OOC–K–H} + \text{H}_2\text{O} &\leftrightarrow R-\text{CH}_2\text{NH}^+(\text{CH}_3)_2\text{OOC–K–OH} + \text{OH}^- \\
R-\text{CH}_2\text{NH}^+(\text{CH}_3)_2\text{OOC–K–OH} + \text{OH}^- &\leftrightarrow R-\text{CH}_2\text{NH} + (\text{CH}_3)_2\text{OOC–K–OH} + \text{Cl}^- \\
R-\text{CH}_2\text{NH}^+(\text{CH}_3)_2\text{Cl}^- + \text{OH}^- &\leftrightarrow R-\text{CH}_2\text{N(\text{CH}_3)_2} + \text{H}_2\text{O} + \text{Cl}^- \\
R-\text{CH}_2\text{N(\text{CH}_3)_2} + \text{H}^+ &\leftrightarrow R-\text{CH}_2\text{NH}_2(\text{CH}_3)_2
\end{align*}
\]

where, Reactions (1) and (5) indicate the protonation and deprotonation reactions of the amine group on NDA-8. Reaction (3) is the reaction mechanism based on ion exchange electrostatic interactions, whereas, Reaction (2) occurs by hydrolysis mechanism. Reaction (4) means the neutralization reaction of the resin at high pH value.

To comprehend the phenomena illustrated in Fig. 4b, the reactions mentioned earlier are explained as follows.

For free amine form resin at \(pH < 8.9\), the surface complexation during the adsorption process may be composed of two steps: the resin is protonated through Reaction (1) initially, and then the surface complexation is formed through Reaction (3). Owing to the incomplete protonation process at higher pH, there is part of the \(-\text{CH}_2\text{N(\text{CH}_3)_2}\) group remaining on the resin and Reaction (2) will act as a supplementary reaction. Both Reactions (1) and (2) will cause an increase in the final pH value.

For chloride form resin at \(pH < 6.3\), the change tendency of pH value is similar to the free amine form resin, but with a smaller variation amplitude. In fact, the variation of pH also comes from the \(-\text{CH}_2\text{N(\text{CH}_3)_2}\) group. Washing the chloride form resin to neutral with water, before use, will cause the pH to increase. Consequently, a small fraction of the \(-\text{CH}_2\text{N(\text{CH}_3)_2}\) group on the resin is washed back and obtained to affect pH variation. This is supported by FT-IR spectra, \(2770\text{ cm}^{-1}\) assigned to the stretching vibration of \(-\text{CH}_2\text{N(\text{CH}_3)_2}\) group is detected from the chloride form resin (Fig. 1c).

For chloride form resin at \(pH > 6.3\), the final pH value decreases for the chloride form resin, which might be owing to the consumption of \(\text{OH}^-\), according to the neutralization reaction (Reaction (4)) and deprotonation reaction (Reaction (5)).

For free amine form resin at \(pH > 8.9\), the decrease of pH after adsorption may be related to the structure or speciation variation of the DOM in this pH range.

In addition, the hydrogen-bonding interaction between the \(-\text{CH}_2\text{N(\text{CH}_3)_2}\) group on the resin and \(\text{HO–K–COO}^-\) would play a role during the adsorption process as long as the phenolic group on the DOM was without dissociation. The reaction equation could be expressed as Reaction (6):

\[
R-\text{CH}_2\text{N(\text{CH}_3)_2} + \text{HO–K–COO}^- \leftrightarrow R-\text{CH}_2\text{N(\text{CH}_3)_2} \cdot \text{HO–K–COO}^-
\]

The line a in Fig. 1 shows the FT-IR spectra of the chloride form resin after uptake of the DOM. Peak at \(2770\text{ cm}^{-1}\) has vanished, which is in hypothesis of shifting to a lower wavenumber and being overlapped by bands of \(-\text{CH}_2\text{N(\text{CH}_3)_2}\) signal. The clue indicates that the hydrogen-bonding interaction does exist in the adsorption process. Additionally, the hydrophobic interaction resulting from the nonpolar moiety of DOM is another adsorption enhancement here. Previous research (Bolto et al., 2002, 2004) had paid attention to the non-ion interactions (hydrogen-bonding interaction and hydrophobic interaction) in the adsorption of DOM by anion exchange resins. These interactions participated partially and not
wholly in the adsorption process. In general, the DOM adsorption by NDA-8 was a complicated process.

It can be concluded that electrostatic attraction according to Reaction (3) is much more pronounced for chloride form resin at pH 2.5, which is another reason for the advantage of chloride form resin in the uptake of the DOM compared with free amine form resin. The correlation between the amount of DOM adsorbed and initial solution pH could also be explained by the electrostatic interactions resulting from positive surface charge of NDA-8 and anionic DOM, that is, with initial pH increasing, much more R–CH₂NH⁺(CH₃)₂ deprotonated, resulting in an overall decrease of electrostatic attractive effect, and a subsequent decrease of adsorption capacity.

2.3 Batch adsorption

Figure 5 shows the result of the batch adsorption experiment. Compared with other resins, NDA-8 displays an absolute advantage in retaining DOM from landfill leachate, whereas, NDA-150, A100, and DAX-8 ranks next to the fourth.

DAX-8 could retain fulvic acid completely by non-ion interactions between its framework and DOM. However, without electrostatic attraction, only a small quantity of the DOM could be retained in the adsorption process. Thus, electrostatic attraction plays a decisive role in DOM adsorption.

Nevertheless, anion-exchange capacity of A100 was higher than NDA-8, if only electrostatic attraction occurred in adsorption. The DOM removal effect of A100 should be better than NDA-8. But in fact, that was not true. As narrated earlier, weight-averaged molecular weight of the DOM was over 1000 Da. Mesopore could be considered as the appropriate matching pore for the DOM. The porous structure discrepancy of NDA-8 and A100 lay in the mesopore volume. The mesopore volume of NDA-8 was 6.5 times higher than A100. In the pore filling process by DOM, non-ion interactions embodied by plenty of mesopores in NDA-8 resulted in a higher removal rate of DOM, whereas, non-ion interactions embodied by A100 were much smaller in the adsorption process. The adsorption effect of the mesopore brings on the variation of the resin surface, which could be compared directly to the SEM images (Figs. 3c and 3d). The micropores of the adsorbents were almost blocked by large molecules of DOM and there was little micropore volume left after the DOM adsorption (Table 1).

Furthermore, NDA-150 has the same framework, but a higher mesopore volume compared to NDA-8. It is concluded that less retaining capacity of NDA-150 compared to NDA-8 is due to the absence of an anion-exchange capacity, whereas, more retaining capacity than A100 is due to its rich mesopore. Consequently, just because of the abundant ion-exchange capacity and mesopore, NDA-8 stands head and shoulders above the other three in uptake of this refractory DOM. By means of actual calculation, the amount of DOM retained by NDA-8 can reach 51.86 mg DOC/g resin (about 137.7 mg COD/g resin) after 2 hours contact.

2.4 Column adsorption and desorption

Although the satisfactory adsorption capacity for NDA-8 in retaining the DOM from landfill leachate has been proved in batch experiment, a bench scale column adsorption and desorption test should be conducted to guide industrial application. The results of mini-column adsorption and desorption of the DOM on NDA-8 are shown in Fig. 6. Total adsorption capacity is calculated through data in Fig. 6 and Eq. (1), which is 52.28 mg DOC/mL wet resin.

Sodium hydroxide solution of 0.2 mol/L is used to desorb DOM on NDA-8, at the flow rate of 1 bed volume (BV)/h, nearly 100% regeneration efficiency is achieved. After 20 BV of DOM is adsorbed by NDA-8 resin, the effluent is collected and analyzed. Selected characteristics of the effluent are also shown in Table 2. As illustrated in Table 2, the DOM can be removed completely. It is also shown that not only could DOC be removed by NDA-8 to a great extent, but the content of heavy metals could also be cut down simultaneously, as it has the same effect as coagulation.
3 Conclusions

A new aminated polymeric adsorbent NDA-8 was synthesized and exhibited a developed mesoporous structure. The DOM from the landfill leachate treatment plant possessed a non-degradable characteristic and a relatively narrow size range with a low weight-averaged molecular weight about 1074 Da.

The dominating mechanism in uptake of the DOM by NDA-8 was based on ion exchange electrostatic interactions, whereas, the hydrogen-bonding interaction and hydrophobic interaction were also functionally important. The mesopore was chiefly occupied during adsorption of the DOM, which led to higher adsorption capacity of NDA-8 than A100.

The resin required a switch to chloride form and the DOM solution pH value had to be adjusted to 2.5 before contact, to obtain an optimum removal rate. DOC could reach a removal rate of 90.4% under this condition in the column experiment. Total adsorption capacity of NDA-8 in retaining DOM was calculated to be 52.28 mg DOC/mL wet resin, and the desorption process depended on 0.2 mol/L sodium hydroxide solution, which could achieve nearly 100% regeneration efficiency.

Acknowledgments

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