Treatment of landfill leachate from a Swedish municipal waste landfill: The potential of biological nitrogen removal with sequencing batch reactor technology

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Abstract

This paper covers the start-up of a pilot-plant experiment where landfill leachate from a Swedish municipal waste landfill (Spillepeng) was treated using a sequencing batch reactor (SBR). The leachate was characterised by high COD and NH$_4$-N concentrations, low BOD/COD ratio, pH slightly over 7 and a high conductivity. During the studied period the mean temperature was 21°C, pH was 7.5 in the reactor, the hydraulic retention time reached 1.7 days and the sludge age was kept long due to the start-up and problems with loss of sludge.

The results show that the SBR-technique has a good potential in treating the leachate from the nitrogen fractions ammonium, nitrate and nitrite. The nitrification was easy to start-up and the reduction of ammonium nitrogen was found to be 97%. The denitrification was harder to start due to technical problems but complete denitrification was reached after 166 days.

Keywords: Landfill, landfill leachate, SBR, Sysav, biological nitrogen removal, pilot plant, pilot plant start-up

Introduction

Leachate from old landfills is often very rich in nitrogen, recalcitrant organic matter, heavy metals and salts. If the leachate seeps out from the landfill it could cause severe damage [Kurniawan et al., 2006].

The landfill Spillepeng is managed by Sysav$^1$, a Swedish waste management company. The landfill Spillepeng receive tonnes of waste each year and approximately 175 000 m$^3$ of leachate is produced during the decomposition of the waste [Andersson, 2007a, Anderson et al., 2007]. According to new regulations the leachate can no longer be sent to the local municipal WWTP and therefore the treatment of the produced leachate must be provide by Sysav on site [Andersson et al., 2007].

The choice of technique is based upon Sysav’s limited landfill area and the desire of using a technology that has been used in prior experiments treating landfill leachate [Andersson, 2007b].

After successful bench-scale experiments a pilot-plant was started 2nd of March 2007. In this paper the 166 first days of the start-up period for the pilot-plant experiments were examined and analysed.

$^1$SYSAV stands for Sydskånes avfalls aktiebolag
Goals
The goal with the pilot-plant experiments was to reach ammonium, nitrate and nitrite concentrations, measured as total-nitrogen, under 15 mg/l and hopefully reach and reduce recalcitrant compounds, measured as COD, down to 0.5 g/l in the effluent from the SBR.

Methods and material
The composition of the leachate
The composition of the landfill leachate used in the pilot-plant experiment is shown in Table 1. The leachate streams P2 and P6, later referred to as P2/P6, has its origins from bio cells. These bio cells contains mainly biodegradable waste such as household waste which was deposit 5-15 years ago [Andersson, 2007a].

Table 1: Average composition of the leachate P2/P6 spring 2007 and measurements from 2002 till 2007 (*).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>P2/P6</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.4</td>
</tr>
<tr>
<td>Conductivity, mS/cm</td>
<td>11</td>
</tr>
<tr>
<td>Chloride, mg/l</td>
<td>2769*</td>
</tr>
<tr>
<td>Alkalinity, meq/l</td>
<td>45</td>
</tr>
<tr>
<td>CODCy, mg/l</td>
<td>655* – 718</td>
</tr>
<tr>
<td>BOD7*, mg/l</td>
<td>56</td>
</tr>
<tr>
<td>BOD7/COD*</td>
<td>0.08</td>
</tr>
<tr>
<td>TOC, mg/l</td>
<td>297*</td>
</tr>
<tr>
<td>Total N, mg/l</td>
<td>325* – 344</td>
</tr>
<tr>
<td>NH4 – N, mg/l</td>
<td>265 – 273*</td>
</tr>
<tr>
<td>NO3 – N, mg/l</td>
<td>3.7</td>
</tr>
<tr>
<td>NO2 – N, mg/l</td>
<td>0.5</td>
</tr>
<tr>
<td>Total P, mg/l</td>
<td>2*</td>
</tr>
<tr>
<td>PO4 – P, mg/l</td>
<td>1.2</td>
</tr>
<tr>
<td>Suspended solids, SS, mg/l</td>
<td>81* – 95</td>
</tr>
<tr>
<td>VSS, mg/l</td>
<td>48</td>
</tr>
</tbody>
</table>

As Table 1 shows the leachate P2/P6 contains lot of nitrogen, as NH4-N, high concentration of COD and a low BOD/COD ratio. The pH of the leachate is slightly over 7 and the conductivity is also high. The age of the waste, the pH, high NH4-N, low BOD, high COD and low BOD/COD ratio all indicate that the leachate comes from a stabilized landfill [Tizaoui et al., 2006, Kurniawan et al., 2006].

Equipment and operation parameters
The leachate was treated in the SBR using the following 8-hour-cycle: filling, aeration and stirring (nitrification), only stirring (denitrification), aeration to remove or oxidise any excess carbon source, sedimentation and decanting. In this way three cycles a day can be made.
To start-up the nitrification, sludge from Klagshamns WWTP, Malmö, Sweden, was used as inoculum in the pilot-plant and when the nitrification was established and stabilized the denitrification was initialized by adding ethanol as carbon source.
The equipment, used for treating the leachate, consists of a reactor with the effective volume of 2.8 m³. The total volume (actually 3 m³) was not used due to problems related with foaming and overflows. Figure 1 shows three pictures of the equipment.
Figure 1: Pictures of the pilot-plant reactor and the surrounding equipment. The upper left picture shows the inside of the reactor without leachate and shows the funnel through which the water was decanting. The upper right picture shows the inside of the reactor while treating the leachate. (Photographers: Sysav and Erika Heander)

Figure 1 shows the reactor with surrounding equipment, and the inside of the reactor without and with leachate. The filling of influent leachate, dosage of phosphor and carbon source is done from above while the decanting the effluent was done through the funnel. This solution led to problem with sludge loss, from the funnel, and therefore a pump was installed which empties the reactor from above. Inside the reactor the aeration and stirring equipments can be seen. The reactor also has a sludge outlet placed quite narrow the bottom of the reactor.

**Analyse methods**

During the pilot-plant experiment ammonium, nitrate, nitrite, COD, O$_2$, pH, SS, VSS and SV was measured approximately three times a week. Ammonium, nitrate, nitrite, COD (total and soluble) and PO$_4$-P was measured with Dr. Lange cuvettes LCK 303/304, 341/342, 339, 138, 349 and 114 which were analysed with Dr. Lange ISis 9000. The temperature and pH was measured with WTW pH 330 pH Meter and the oxygen concentration with an online meter (Lange sc100). Suspended solids and volatile suspended solids was analysed using standard SS-EN 872-1, at a laboratory in Lund, and SV was analysed onsite.

**Reliability of the analysis**

The analysis has been made as soon as possible, after sampling, to minimize the risk of biological activity in the samples. Sludge samples for analysing SS and VSS has been kept in the fridge due to longer time lapse between sampling and analyse.

**Results and discussion**

The results show that the SBR-technique has a good potential in treating the leachate from the nitrogen fractions ammonium, nitrate and nitrite. Under the 166 days the pilot-plant SBR was studied complete nitrification and denitrification was accomplished.
During the experiment period the mean temperature was 21°C, the pH was 7.5 and the SBR was operated with a hydraulic retention time at 1.7 days. The sludge age was kept long due to the start-up and problems with loss of sludge. Figure 2 shows the concentration of ammonium in influent leachate and nitrogen fractions in effluent leachate.

Figure 2: Concentration of ammonium in influent leachate and nitrogen fractions in effluent leachate

Figure 2 shows that the influent leachate (the leachate to be treated) had ammonium concentrations between 125 - 329 mg NH$_4$-N/l.

The nitrification was easy to start-up, after 6 days complete nitrification was reached and ammonium reduced to values below 2 mg NH$_4$-N/l. This means that the SBR reduce the ammonium nitrogen with 97% efficiency. The denitrification was started day 98 but the start-up period was longer due to technical problems with the addition of carbon source but complete denitrification was reached after day 166 days (68 days after start of dosing).

To convert nitrate into nitrogen gas 5 - 5.6 g COD, as ethanol, was added for each removed g NO$_3$-N. Normally, design values for denitrification with ethanol, is 4-4.5 g COD/g NO$_3$-N. In this case more carbon was added due to technical problems with the dosage pump and because of that the leachate don’t contains so much internal carbon source which could be used for denitrification.

Some accumulation of nitrite occurred during the start-up, day 14, 56, 110 and day 157. The problems occurred when the treated volume was increased or when the oxygen concentration dropped below 2 mg O$_2$/l during nitrification. Several solutions such as increasing the aeration, to aerate the leachate for a whole day, decrease the volume to be treated or prolong the aeration time all reduced the nitrite in the reactor.

Total nitrogen was not measured during the start-up period but if complete nitrification and denitrification is accomplished the total fraction of NH$_4$-N, NO$_2$-N and NO$_3$-N can be lower than the goal of 15 mg total nitrogen/l in the effluent leachate.
Figure 3: Suspended solids and volatile suspended solids during the pilot-plant experiments

Figure 3 shows the suspended solids and volatile suspended solids in the reactor during the pilot-plant experiments. Instead of an increasing SS, sludge loss occurred at the beginning of the experiment. The addition of carbon source and the installation of the pump which empties the reactor from above led to a higher sludge concentration and day 161, 2 g SS/l was reached.

The organic matter was also measured during the experiment period and the results are shown in Figure 4.

Figure 4: The organic matter measured as total COD in the influent leachate and total and soluble COD in the effluent leachate and also the difference

Figure 4 shows the organic matter measured as total COD in the influent leachate and total and soluble COD in the effluent leachate and the difference between total COD in the influent leachate and the total COD in the effluent. The leachate contains a lot of recalcitrant organic matter but still the SBR-technique could remove approximately 120 mg COD/l each cycle. Even though the SBR-technique removes organic matter the removal was not enough to reach the goal below 500 mg COD/l.
Conclusions

From the examination the following conclusions can be drawn:

- The SBR-technology has a good potential in removing ammonium, nitrate and nitrite from the leachate stream P2/P6
- Compared to waste water more ethanol per g nitrate removed is needed to treat the leachate. The design value during this pilot-experiment was 5 - 5.6 g COD/g NO₃-N to reach complete denitrification
- The goal values for total nitrogen can probably be reached if complete nitrification and denitrification is accomplished.
- The SBR technology can reduce COD but the goal value was not reached

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References


