

Sequencing batch reactor system for the co-treatment of landfill leachate and dairy wastewater

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Abstract

A two laboratory-scale aerobic sequencing batch reactors (SBR) were investigated to co-treat landfill leachate and the wastewater from industrial milk factory. The SBR reactor was operating in 24 h time cycle in the following sequential operation phases: aerobic fill, aerobic react, anoxic react, settle, draw and idle. Lab-scale plant was managed by means of different operative strategies in order to find out the optimal one in terms of nitrogen compounds and COD removal. It was found that it is possible to treat combined wastewater of landfill leachate and dairy wastewater. Moreover the treatment efficiency strongly depends on operating parameters i.e. phases duration, hydraulic retention time and organic loading. The most appropriate mode for co-treatment of landfill leachate and dairy wastewater is Mode I with aeration time of 19 h and anoxic phase of 2 h. The removal efficiencies of the SBR systems decreased with increased organic loading or decreased HRT. During co-treatment process of landfill leachate the best effluent quality was observed under organic loading of 0.8 kg BOD₅/m³ d and HRT of 10 days.

Keywords: Sequencing batch reactor (SBR); Landfill leachate; Dairy wastewater

1. Introduction

One of the most important problems with designing and maintaining a sanitary landfill is managing the leachate that is generated when

water passes through the waste. Depending on the type of waste deposited and the age of landfill, the leachate may be relatively harmless or extremely toxic. Generally leachate has a high chemical oxygen demand and high concentrations of organic carbon, nitrogen, chloride, iron, manganese, and phenols. Many other chemicals

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may be present, including pesticides, solvents, and heavy metals [1]. The generated leachate can cause considerable environmental problems and must be collected and appropriately treated before being discharged in the environment.

Leachate is often so polluted that it must be treated before it can be passed into a sewer or receiving water course. The problem with leachate treatment is that its composition changes in terms of strength, biodegradability, and toxicity as the wastes in the landfill age over time. Leachates produced in young landfills are usually high-strength wastewaters, characterized by low pH, high BOD₅ and COD values, as well as by presence of several hazardous compounds. However leachates from old landfill mainly contain refractory organic compounds and high concentration of ammonium, which constitute an environmental problem due to its fertilizing and toxic effects [2].

Several options have been applied for leachate treatment, presenting varying degree of efficiency. Current leachate treatment options include recycling and re-injection, on-site treatment, discharge to a municipal water treatment facility or a combination. The main applicable methods for leachate treatment are biological, chemical, membrane separation and thermal processes [3–5].

Today, landfill leachates are often treated with municipal sewage in the municipal wastewater treatment plants [6]. Because of stricter regulation for nitrogen discharge and problem with potential impact of recalcitrant leachate constituents on the biological treatment stage an increase of demands for separate treatment and disposal of landfill leachate is observed. The solution which can lead to disconnection landfill leachate from the municipal sewage treatment may be co-treatment with industry wastewater e.g. dairy wastewater.

The dairy industry generates strong wastewaters characterized by high biological and chemical oxygen demand concentration. Dairy wastewaters

are treated using physico-chemical and biological treatment methods [7]. Among biological treatment processes SBR processes have been extensively applied for treating municipal and hazardous wastes including the biological treatment of landfill leachate [8–10]. SBR has many positive processing characteristics. For example, combining the reactor and the settling tank in the same vessel easily controls performance with respect to reaction time and sludge solids maintenance and also allows flexibility of operation when carrying out different biochemical conversion reactions simultaneously.

This study was aimed at investigating the feasibility of nitrogen removal from ammonia-rich leachate with dairy wastewater by using an SBR system. The SBR reactor was operating in 24 h time cycle in the following sequential operation phases: aerobic fill, aerobic react, anoxic react, settle, draw, and idle. Lab-scale plant was managed by means of different operative strategies in order to find out the optimal one in terms of nitrogen compounds and COD removal. It was found that it is possible to treat combined wastewater of landfill leachate and dairy wastewater.

2. Materials and methods

Two laboratory scale-reactors were used for the examination of leachate and dairy co-treatment efficiency. The reactors were constructed from plexi glass; each reactor with 15 cm diameter, and 30 cm height had a total volume of 5 L. The reactors were supplied with oxygen by fine bubble air diffuser to keep dissolved oxygen concentration above 3 mg/L in the oxic phase. Magnetic stirrers were used for mixing. A set of two peristaltic pumps was used to feed and discharge the effluent, respectively, in both reactors. The reactors were operated at room temperature (18–20°C). The cycle time of the reactors was 24 h and consisted of five distinct modes: aerobic fill, aerobic react, anoxic react, settle and draw. In this study various operating

modes were investigated in order to improve treatment efficiency (Table 1).

The second SBR (SBR 2) system was operated at feeding condition of leachate dilution of 25% by volume with a dairy wastewater and with 4 g/L sludge concentration while the first reactor (SBR 1) was seeded with raw dairy wastewater. Dairy industrial wastewater collected from small milk factory in Lubliniec was used in his study. The COD strength of the dairy wastewater varied between 6000 and 7500 mg/L, while the BOD concentration was in the range of 4000–5000 mg/L. The total Kjeldahl nitrogen and total phosphorus of the fresh raw dairy effluent was about 80 mg/L and 25 mg/L respectively.

The landfill leachate used for the experiments was obtained from Sobuczyna sanitary landfill site in southern Poland. The COD strength of the leachate varied between 3800 and 4250 mg/L, while the BOD concentration was less than 430 mg/L. This gives BOD/COD ratio of about 0.1 and means that most of the organic compounds in the leachate are non-biodegradable. One of the major pollutants in leachate was ammonium and its strength was 750–800 mg/L. The concentration of chloride was also high, on the level of 2300–2500 mg/L.

Both systems were inoculated with sludge collected from the municipal wastewater treatment plant in Czestochowa. A fraction (1/10) of the culture was removed from the reactor every day to adjust the sludge age 10 days.

Table 1
Experimental operating modes of SBRs

| Phase | Duration of phase (h) | | |
|-----------------|-----------------------|---------|----------|
| | Mode I | Mode II | Mode III |
| Aerobic fill | 2 | 2 | 2 |
| Aerobic react | 19 | 17 | 15 |
| Anoxic react | 2 | 4 | 6 |
| Settle and draw | 1 | 1 | 1 |

Samples were withdrawn from the reactor at the beginning and at the end of each cycle for analysis. The following parameters were analyzed: BOD₅, pH, nitrate, ammonia, total Kjeldahl nitrogen (TKN), and total phosphorus. All analyses were carried out according to Standard Methods [11]. Chemical oxygen demand (COD) was determined by the dichromate method using DR/4000 spectrophotometer (Hach Company, USA).

3. Result and discussion

In the first step of the experiment both reactors were in a start-up mode to allow the biological populations to adapt to the dairy wastewater. An adapted population has been indicated when effluent concentration was demonstrated to be stable. The reactors operated at organic loading rate of 0.5 kg BOD₅/m³ d, hydraulic retention time of 12 d and SRT of 10 days. The systems reached steady state within 10–11 d of acclimatization. Effluent COD, BOD, TKN, NO₃⁻, total phosphorus were approximately 85 mg/L, 65 mg/L, 15 mg/L and 1.0 mg/L and 10 mg/L respectively.

After acclimatization process three different operating modes has been studied. In Mode I the longest aeration time of 19 h and the shorter denitrification time were applied. It can be noted also that the SBR 2 system where co-treatment of landfill leachate and dairy wastewater was carried out reached steady state within 20 d. The results are shown in Table 2.

Although effluent TKN concentration in SBR 2 was almost 2 times higher as compared with SBR 1 the removal efficiency of the both systems was very similar. The reason was that in the second reactor the ammonia concentration in influent was high (200 mg/L) due to leachate addition. Also the higher concentration of organic compounds represented as COD and BOD was detected in SBR 2 effluent. These values of organic removal would be rather expected because in case of landfill leachate treatment

Table 2
Effluent quality and removal efficiency of SBRs system for operating Mode I

| SBR number | COD | | BOD | | TKN | | Effluent SS (mg/L) |
|------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|--------------------|
| | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | |
| SBR 1 | 85 | 98.6 | 67 | 97.9 | 15 | 80.1 | 10 |
| SBR 2 | 102 | 98.4 | 85 | 97.3 | 27 | 79.2 | 15 |

using exclusively biological method the residual COD cannot be further removed.

Results obtained for operating Mode II were presented in Table 3. In that step of this study the anoxic phase was extended up to 4 h in order to investigate denitrification efficiency under different processing conditions, at the same time was shortened to 17 h.

There was not observed improvement of dairy wastewater treatment efficiency in SBR 1 under next applied operation mode. Quality of reactor effluent was also the same as in case of Mode I. However it was found that treatment efficiency in SBR 2 operating at Mode II decreased. The effluent COD achieved value of

115 mg/L while TKN concentration increased to 35 mg/L. Lower removal of organic and ammonia can be explained by the fact that aeration time was not sufficient to allow complete nitrification and oxidation of organic contaminations in mixture of leachate and dairy wastewater. Probably the time for sufficient growth of nitrifying bacteria was quite short.

Confirmation of that thesis could be results obtained during the next step of this study where the operating Mode III was applied. As can be shown in Table 4 during lower aeration time of 15 h and longer anoxic phase of 6 h a worse treatment efficiency has been achieved in both bioreactors.

Table 3
Effluent quality and removal efficiency of SBRs system for operating Mode II

| SBR number | COD | | BOD | | TKN | | Effluent SS (mg/L) |
|------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|--------------------|
| | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | |
| SBR 1 | 84 | 98.7 | 68 | 97.8 | 14 | 80.2 | 10 |
| SBR 2 | 115 | 97.9 | 85 | 97.3 | 35 | 78.0 | 16 |

Table 4
Effluent quality and removal efficiency of SBRs system for operating Mode III

| SBR number | COD | | BOD | | TKN | | Effluent SS (mg/L) |
|------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|--------------------|
| | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | |
| SBR 1 | 114 | 98.1 | 98 | 97.8 | 17 | 78.2 | 13 |
| SBR 2 | 168 | 97.2 | 145 | 95.3 | 50 | 71.0 | 25 |

Table 5
Effluent quality and removal efficiency of SBR I system under various HRTs of 10, 8, and 7 days

| HRT (d) | Organic loading (kg BOD ₅ /m ³ d) | COD | | BOD | | TKN | | Effluent SS (mg/L) |
|---------|--|--------------------|----------------|--------------------|----------------|--------------------|----------------|-----------------------|
| | | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | |
| 10 | 0.8 | 87 | 98.8 | 69 | 98.6 | 15 | 80 | 15 |
| 8 | 1.0 | 90 | 98.7 | 72 | 98.6 | 17 | 78 | 20 |
| 7 | 1.2 | 120 | 98.3 | 95 | 98.1 | 19 | 75 | 23 |

The COD effluent from SBR 2 was almost 50% higher than from SBR 1 and achieved value of 168 mg/L. Significant decrease of total nitrogen removal in the reactor seeded with mixture of landfill leachate and dairy wastewater was observed, where TKN effluent was 50 mg/L. Moreover the effluent COD, BOD and TKN concentration far exceeds the standard for direct discharge to a natural body. Although effluent quality of SBR 1 was also worse than in previous experiment the treatment efficiency was quite good.

It was assumed that the most appropriate mode for co-treatment of landfill leachate and dairy wastewater is Mode I with aeration time of 19 h and anoxic phase of 2 h. Increase of aerobic react with at the same time decrease duration of denitrification step had negative impact of treatment efficiency.

In the next step of this study the SBR systems with industrial wastewaters were operated under operating Mode I and different hydraulic retention time of 10, 8, and 7 days. The results are shown in Tables 5 and 6.

The SBR 1 system with dairy wastewater under the organic loading of up to 0.8 kg BOD₅/m³ d reached steady state within 10 d of acclimatization while it was delayed to about 12 d under the organic loading of 1.2 kg BOD₅/m³ d. Also, the effluent qualities of the system were less stable when the organic loading was increased.

The removal efficiencies of the SBR I system were high however insignificantly decreased with increase in organic loading or decreased HRT, as shown in Table 5.

The TKN removal efficiency of the system under the lowest organic loading of 0.8 kg BOD₅/m³ d was about 6% higher than under the highest organic loading of 1.2 kg BOD₅/m³ d. The BOD₅ and COD removal was over 98% under all organic loadings applied. The highest effluent SS concentration was observed in the system under organic loading of 1.2 kg BOD₅/m³ d when achieved value of 23 mg/L.

The SBR 2 system with dairy wastewater and landfill leachate under the organic loading of up

Table 6
Effluent quality and removal efficiency of SBR II system under various HRTs of 10, 8, and 7 days

| HRT (d) | Organic loading (kg BOD ₅ /m ³ d) | COD | | BOD | | TKN | | Effluent SS (mg/L) |
|---------|--|--------------------|----------------|--------------------|----------------|--------------------|----------------|-----------------------|
| | | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | Effluent (mg/L) | Removal (%) | |
| 10 | 0.5 | 110 | 98.2 | 85 | 97.3 | 51 | 70 | 20 |
| 8 | 0.6 | 125 | 97.9 | 114 | 96.3 | 60 | 63 | 23 |
| 7 | 0.9 | 160 | 97.3 | 140 | 95.5 | 75 | 52 | 26 |

0.5 kg BOD₅/m³ d reached steady state within 13 d of acclimatization while it was delayed to about 18 d under the organic loading of 0.9 kg BOD₅/m³ d. Similarly as in system SBR 1 the removal efficiencies of the SBR 2 system decreased with increase organic loading or decreased HRT, as shown in Table 6.

The TKN removal efficiency of the system under the lowest organic loading of 0.5 kg BOD₅/m³ d was over 25% higher than under the highest organic loading of 0.9 kg BOD₅/m³ d. For the system under the highest organic loading the worse COD and BOD₅ removal efficiency was observed. Effluent COD and BOD₅ concentration achieved value of 160 mg/L and 140 mg/L respectively.

4. Conclusion

The landfill leachate obtained from an old-aged municipal landfill site was co-treated with dairy wastewater using sequencing batch reactor process. The SBR method offers an attractive alternative in dealing with the high-strength wastewater. Based on the results of this study, the following conclusions are drawn:

- It is possible to treat combined wastewater of landfill leachate and domestic sewage.
- Treatment efficiency is significantly affected by the various operating modes. The most appropriate mode for co-treatment of landfill leachate and dairy wastewater is Mode I with aeration time of 19 h and anoxic phase of 2 h.
- The removal efficiencies of the SBR systems decreased with increase organic loading or decreased HRT. During co-treatment process of landfill leachate the best effluent quality was observed under organic loading of 0.8 kg BOD₅/m³ d and HRT of 10 days.

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