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Review

Characterization and biological treatment of pre-treated landfill leachate

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ABSTRACT

Characterization and biological treatment of leachate generated by Borg El-Arab landfill has been carried out. Intensive monitoring of the leachate indicated that it is moderately biodegradable. The BOD/COD ratio is in the range of 0.33–0.45. The ratio of COD:N:P was 100:39:0.3 indicating high nitrogen and low PO_4-P content. Three experimental sets of treatment schemes were conducted: aerobic, anaerobic and combined anaerobic/aerobic. To assess the impact of the applied organic load on the performance of the treatment processes, the leachate was diluted using sewage. Three different leachate concentrations were used, 5.9%, 25% and 50%. These correspond to average COD values of 1166, 4207 and 7830 mgO_2/l, respectively. Each treatment scheme was fed with the three dilutions. The same sets of experiments were repeated after pre-treatment using air stripping to remove ammonia nitrogen. The results obtained indicated that ammonia stripping for 6 h after adjusting the pH of the leachate (1:1) at 10, coupled by aerobic treatment via activated sludge for 24 h achieved the best results. Ammonia removal was more than 90%. Corresponding COD and BOD removal values reached 64.4 and 67.2%, respectively.

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1. Introduction

Solid waste generation is a growing global issue due to the large increase in solid waste production. This increase in waste quantity requires improving and expanding the solid waste management options. The sanitary landfill method continues to be used in different countries for the treatment and final disposal of solid waste due to its economic advantages (Sinan Bilgili et al., 2007). At a sanitary landfill site, the waste is placed on the land and extended in thin layers (cells). These layers are then compacted to decrease their volume and are covered periodically with a proper earth material. The degradation of the organic fraction of the wastes in the landfill, in combination with the percolating rain water produces a highly contaminated liquid called "leachate" (Castrillón et al., 2010). Composition of the landfill leachates presents variations depending on the constituents of the landfill solid wastes, the type of the microbial flora, characteristics of the soil, and the pattern of the rainfall and the age of the landfill (Castillo et al., 2007). Landfills are classified into three categories: young (less than 5 years), medium (5–10 years), and old (more than 10 years) (Farah Naz and Christopher Lan, 2012). Generally, treatment of municipal landfill leachates presents technical problems because of its high chemical oxygen demand (COD) (6000–15,000 mg/l), ammonium ion content (500–3000 mg/l) and also due to the presence of toxic compounds of organic and inorganic origin (Kargi and Yunus Pamukoglu, 2003). Usually integration of physical, chemical and biological methods is used for the efficient treatment of landfill leachate, since it is difficult to obtain satisfactory results by using any one of those methods alone. Sedimentation, air stripping, adsorption and membrane filtration are the main physical methods used for leachate treatment (Calli et al., 2005; Zgajnar Gotvajn et al., 2009; El-Gohary et al., 2013). Biological treatment methods (aerobic, anaerobic and anoxic) are widely used for the removal of biodegradable compounds. Advanced chemical treatment is used with the biological methods to remove non-biodegradable compounds from the leachate (Kurniawan et al., 2006; Ismail et al., 2011; El-Gohary et al., 2013). Sometimes leachate is treated jointly with municipal wastewater in conventional wastewater treatment plants. However, this may cause problems due to the presence of harmful constituents, including ammonium nitrogen, which is usually present in high concentrations in mid to old-age landfills. Its high concentrations could harm aerobic activated sludge organisms, due to its toxic effect as well as a low C/N ratio. These are the reasons, why combination of several treatment methods is usually applied (Zgajnar Gotvajn et al., 2009). The aim of the present study was the removal of organic matter and ammonia via biological treatment (Aerobic and Anaerobic) at the optimum mix ratio of leachate: municipal wastewater.

2. Materials and methods

2.1. Sampling of leachate

Leachate samples were collected from Borg Al Arab landfill site, the largest and first controlled landfill site in Egypt. Raw landfill leachate was taken from the main collection pumps and transported in ice box to the laboratories for analysis.

2.2. Chemical analysis

All analyses were carried out according to American Standard Methods for Water and Wastewater Examination, (APHA, 2005). The analyses covered: pH, total chemical oxygen demand (COD), 5-days biochemical oxygen demand (BOD_5), total suspended solids (TSS), total Kjeldahl nitrogen (TKN), Ammonia, total phosphorus (TP), Nitrite (NO2–N) and Nitrate (NO3–N). The landfill leachate used during this study represents a homogenous mixture of old and freshly produced leachate from the landfill body. The composition of the leachate obtained from Borg Al Arab landfill is presented in Table 1. Available data indicate that leachate under consideration is moderately biodegradable (BOD/COD ratio is in the range of 0.33–0.45). The ratio of COD:N:P was 100:39:0.3 indicating high N and low PO4-P content.

2.3. Biological treatment

2.3.1. Experimental set-up

Three biological batch-scale treatment schemes were investigated: a) anaerobic, b) aerobic and c) anaerobic/aerobic. Each treatment scheme consisted of three identical reactors operated in parallel. To study the impact of the applied organic load on the performance of the treatment processes, the leachate was diluted using sewage. Each reactor of the three treatment schemes was fed using one of the following dilutions: 1:16, 1:3 and 1:1 (leachate: municipal wastewater).

2.3.2. Anaerobic treatment

Three glass bottles were used as anaerobic reactors for leachate fermentation. Each reactor had 5 l of total volume with an effective volume of 3 l. The reactors were operated at room temperature (25 °C) and shaken continuously. The reactors were inoculated with digested sludge from a wastewater treatment plant in Cairo. Anaerobic conditions have been established initially by bubbling nitrogen for 5 min for each batch test. Each reactor was fed in a batch mode with one of the dilutions mentioned above each 24 h. The produced biogas was collected in calibrated 500 ml bottles connected to the digestion reactor via a syringe and a silicon tube. Calculated sludge retention time (SRT) ranged from 32 to 36 d for the three dilutions investigated. After two months of operation, the treatment efficiency was stabilized and monitoring of the performance was conducted.

2.3.3. Aerobic treatment

The set-up of aerobic treatment consisted of three Plexiglas reactors operated in parallel. All reactors were cylindrical shaped with interior diameter of 5.5 cm and height of 58.5 cm. The working volume of leachate was fixed at 2 l per reactor. Wastewater in the reactors was aerated with the aid of an air pump and diffusers. The three aerobic reactors were fed with the same set of dilutions used for anaerobic treatment (1:16, 1:3 and 1:1). The three reactors were inoculated with acclimatized activated sludge (3 g/l). Activated sludge was obtained from a wastewater treatment plant in Cairo. DO was adjusted to be around 2 mg/l. The pH of the raw leachate ranged from 8.1 to 8.7. Therefore no adjustment was required. For comparison, the hydraulic retention time was

Table 1
Physicochemical characteristics of sanitary landfill leachate.

Parameter	Unit	Max	Min	Average
PH	–	8.7	8.1	8.4
COD_{tot}	mgO_2/l	17150	13300	15225
COD_{sol}	mgO_2/l	16250	10250	13250
BOD_{tot}	mgO_2/l	6600	4820	5710
BOD_{tot}/COD_{tot}	–	0.45	0.33	0.39
TSS (105C°)	mg/l	1220	657	938.5
VSS (550C°)	mg/l	890	320	605
TKN	mgN/l	6543	5264	5903.5
Organic Nitrogen	mgN/l	1030	364	697
Ammonia	mgN/l	5936	4480	5208
NO_2	mgN/l	0.1	N.D	0.05
NO_3	mgN/l	0.1	N.D	0.05
Phosphorus $_{tot}$	mgP/l	80	16.4	48.2