Bio-chemical treatment of landfill leachates with high load of organic and nitrogen compounds

Ophir Zisman[1], Ariel Kushmaro[2], Asher Brenner[1]

[1]Dept. of Civil & Environmental Engineering, [2]Dept. of Biotechnology Engineering
Faculty of Engineering Sciences, Ben-Gurion University of the Negev, ISRAEL

Abstract

This research tested biological treatment of landfill leachates over a period of 8 months, in order to remove organic and nitrogen compounds and to decrease emissions of H_2S and VOC. The biological treatment was conducted in a sequencing batch reactor (SBR), with aerobic/anaerobic/anoxic stages. The reactor was supplied with sludge from 2 industrial sources, and the microbial population of the sludge was examined in order to better understand the processes occurring inside the reactor. The results show that biological treatment is feasible for the removal of biodegradable organic matter, with a mean BOD_5, COD and TOC removal of 84.5%, 42.7% and 40.9% respectively. However, aiding processes should be incorporated to improve organics removal. The removal of high ammonia concentrations cannot be achieved by biological nitrification (removal of 23.2% was achieved). In laboratory conditions, a chemical precipitation (Struvite) of the leachates with $MgO+H_3PO_4$ or with $MgCl_2 \cdot 6H_2O+Na_2HPO_4 \cdot 7H_2O$ in equal molar ratio of $Mg:NH_4:PO_4$ demonstrated high removal of ammonia (76.8±6.4% and 80.7±4.5%, respectively). Incorporation of an anoxic stage in reactor operation enables to achieve efficient denitrification (80.0%) to remove nitrates present in the raw leachates.

Background

Dudaim landfill

Dudaim landfill is located about 10 km northwest of Be'er-Sheva and occupies 470 dunam. It started its activity in the year of 1990 as a local municipal solid waste disposal site serving Be'er-Sheva and the nearby local and regional councils. Dudaim was upgraded according to stringent environmental requirements and expanded to serve as a significant central waste site, due to a governmental decision of shutting down Hiriya (Tel-Aviv) and unregulated garbage dumps and despite attempts to foil the idea by Be'er-Sheva residents (Not In My Back Yard syndrome). Dudaim currently collects more than 1,000 tons of solid waste per day. One ton of solid waste is estimated to generate approximately 0.2 m^3 of leachates. The base and sides of the tip are engineered using a composite clay and high-density polyethylene liner overlain with a sand leachates collection layer to avoid a possibility of liner shrinkage resulting in a crack formation, following leachate migration to pollution of ground-waters. Leachates collection system allows the leachates to be recycled back to the waste body in the tip (thus reduces both the time required for a sealed tip to become stable, and the final volume of leachates drained due to increased evaporation loss). It also serves to supply humidity for biodegradation of organic material, and to improve generation of biogas or to be removed using evaporation treatment in the leachate's evaporation lagoon. As a result of height differences between the bottom of the tips and the leachates evaporation lagoon, leachates are pumped to the leachates evaporation lagoon via pumping stations.

Objectives

The aims of this study were based on the problem of volatile compounds present in Dudaim landfill. The leachates evaporation lagoon in Dudaim works smoothly, however, due to its large surface area and the possibility of VOC, sulfur compounds and ammonia present in the lagoon, odor nuisances are produced. Hence, efficient removal of these compounds and of compounds responsible for generating them should be achieved in the raw leachates, before decantation in the evaporation lagoon. Therefore, the main aim of this study was to examine the possibility of bio-chemical treatment of landfill leachates in order to remove organic and nitrogen compounds and to decrease emissions of H_2S and VOC.

Materials and Methods

Leachates characteristics

	Units	Settling Chamber	Evaporation Lagoon
pH	-	7.83-8.23 (8.12)	8.18-8.39 (8.30)
TSS-105	mg L^{-1}	17.5-340 (116.4)	150-650 (350.8)
VSS	mg L^{-1}	12.5-330 (93.4)	72.5-213 (143.9)
TDS	mg L^{-1}	15,600-34,000 (23,962)	50,800-58,700 (55,120)
TOC	mg L^{-1}	1,380-8,950 (4,672)	5,496.2-9,751 (7,715)
NH_4-N	mg	2,060-3,748 (2,611)	814-1,517 (1,222)
PO_4-P	mg L^{-1}	18.1-63.2 (33.8)	72.6-86.4 (79.6)
COD_t	mgO_2 L^{-1}	5,016-20,837 (11,572)	19,840-27,120 (23,210)
BOD_5	mgO_2 L^{-1}	32-7,555 (1,641)	1,450-2,150 (1,853)
NO_3-N	mg L^{-1}	116-2,473 (887)	66.9-251.9 (190.7)
H_2S	mg L^{-1}	15.3-33.2 (21.1)	8.4-17.0 (10.9)

SBR – biological treatment

Parameter	Value
Reactor active volume, m^3	1.33
Treated volume, m^3/d	0.4
HRT, d	3.33
Cycles per day	4
Fill time per cycle, h	0.25
Aeration time per cycle, h	1.75
Settling time per cycle, h	0.75
Decant time per cycle, h	0.25

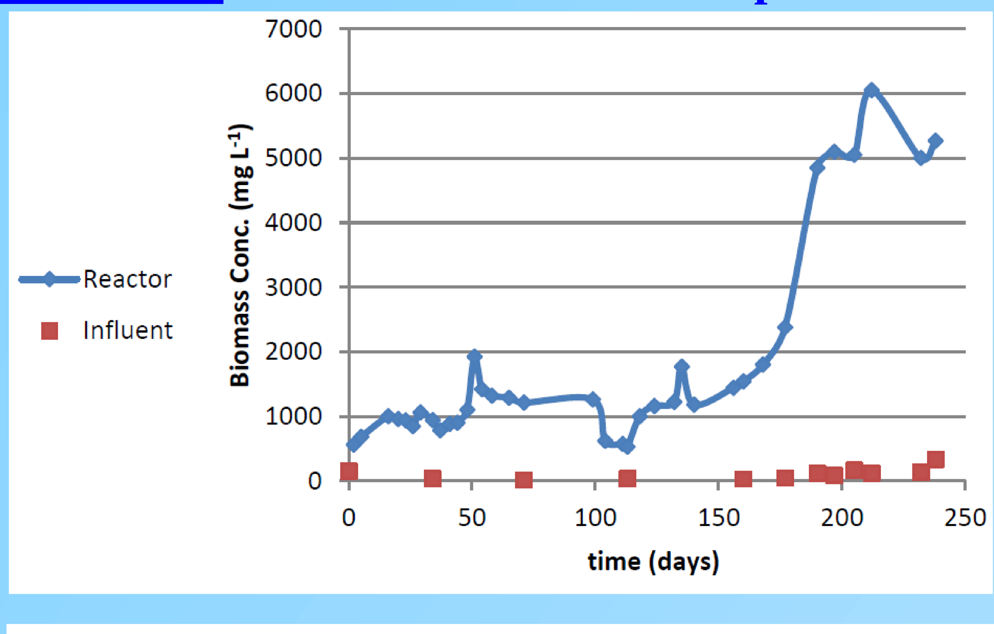
Chemical precipitation of ammonium

Removal of ammonia by MAP precipitation (as Struvite) was performed with 2 different sources of magnesium and phosphate in molar ratio of 1:1:1 in order to find the most efficient and economical chemicals to remove high concentrations of ammonia.

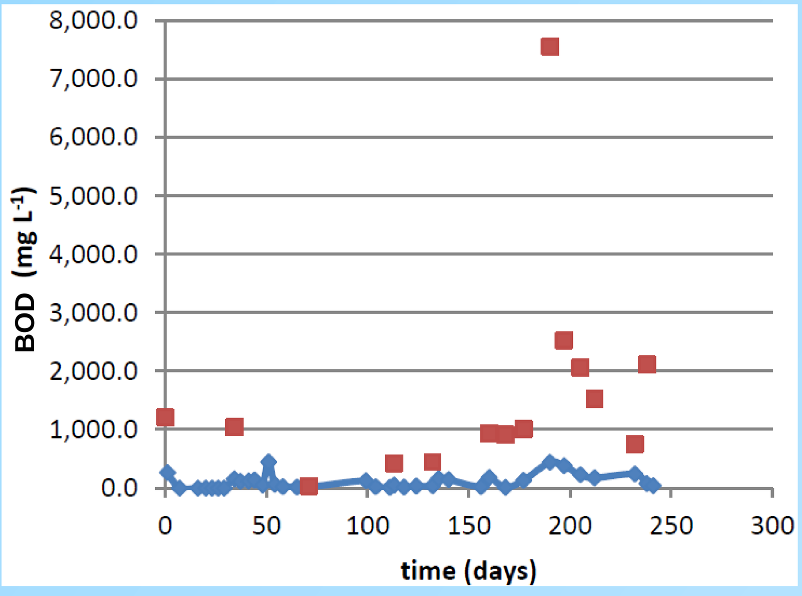
Results

Performance of SBR:

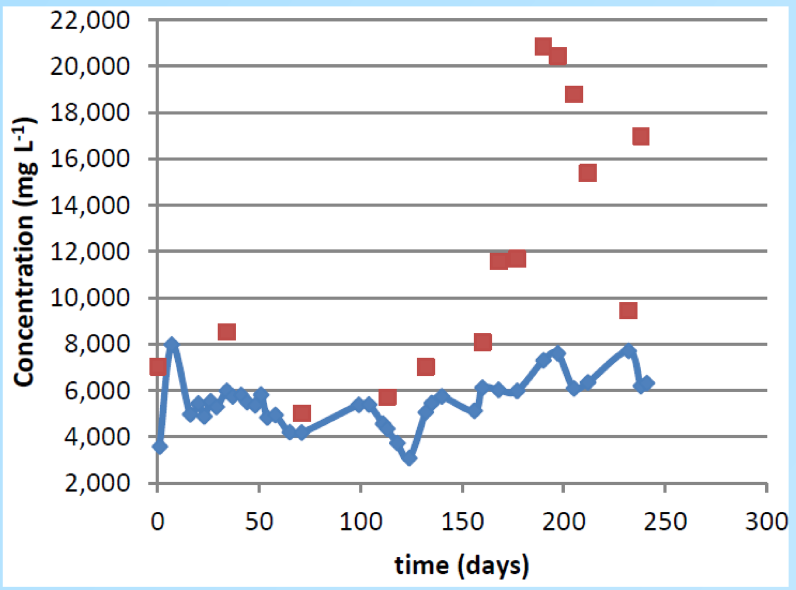
Biomass buildup



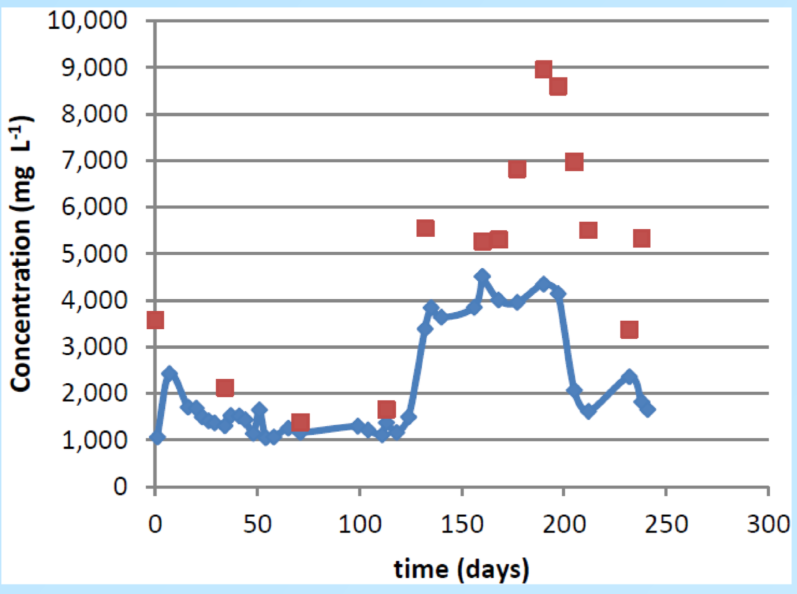
BOD removal

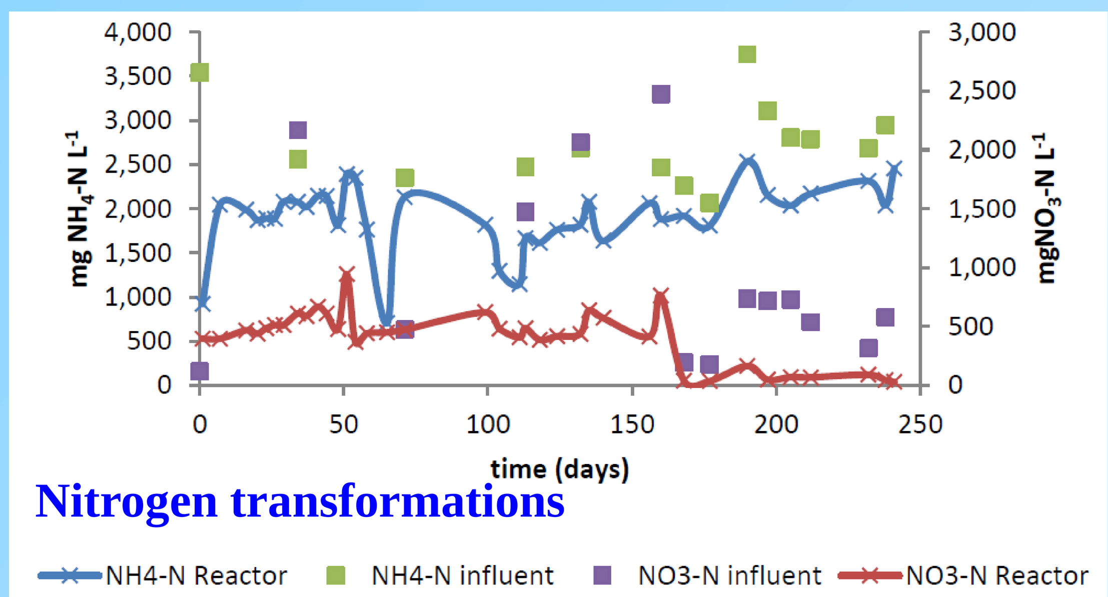


COD removal



TOC removal





Nitrogen transformations

Chemical precipitation of magnesium-ammonium-phosphate (MAP)

Chemicals added	NaOH 10M (ml 100 ml^{-1})	%NH_4 Removal	Residue (mg ml^{-1} leachates)
MgO / H_3PO_4	3.36±0.47	76.8±6.4	42.65±6.56
$MgCl_2 \cdot 6H_2O$ / $Na_2HPO_4 \cdot 7H_2O$	1.76±0.09	80.7±4.5	42.35±1.27

Conclusions

- The leachates of Dudaim are considered difficult for treatment because of low amount of biodegradable organic matter and high amount of ammonia.
- Biological treatment of Dudaim leachates was found to be a feasible solution for the removal of biodegradable organic matter. However, aiding processes should be incorporated to improve organics removal.
- The removal of the high ammonia concentrations cannot be achieved by biological nitrification. A chemical precipitation (Struvite) with $MgO+H_3PO_4$ or with $MgCl_2 \cdot 6H_2O+Na_2HPO_4 \cdot 7H_2O$ in molar ratio of 1:1:1 demonstrated high removal of ammonia (76.8±6.4% and 80.7±4.5%, respectively). In addition, Struvite precipitation with $MgO+H_3PO$ resulted in a decrease of organic matter in the pre-treated leachates.
- Incorporation of anoxic periods in SBR operation (during Fill and Settling stages) enables to achieve efficient denitrification to remove nitrates present in the raw leachates.
- High diversities of bacteria were found, especially in the raw leachates. *γ-proteobacteria* was the most abundant class in the reactor and in the raw leachates, whereas in the evaporation lagoon, it was *Thermotogae*. In addition, a large portion of Sulfate Reducing Bacteria (SRB) was found in the evaporation lagoon.
- Analysis of the gas phase revealed a problematic compound Dimethylacetamide (DMA), which should be further quantified and treated if necessary.
- Inhibition of H_2S production can be achieved by use of chemical agents such as nitrite, molybdate or copper. Significantly lower concentrations of inhibitors are needed at pH 6.6 in comparison to pH 7.8 to inhibit H_2S production. Synergism of the metabolic inhibitors nitrite and molybdate was found to be most suitable.