Long term leachate management based on anaerobic/aerobic landfill simulator studies

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Background and research questions

Leachate management and treatment costs form the most remarkable part of the landfill operation costs during the aftercare period. As the aftercare period can be very long before leachate emission limits to surface waters can be achieved, it is of question of considerable total costs during the life cycle of the landfill. Therefore it is of importance to find out alternatives based on appropriate engineering solutions to achieve the leachate emission limits (Wang et al. 2011). Related to this the research questions in this paper are as follows:

- how does the L/S-ratio (liquid to solid) affect the aftercare period length at different temperatures to achieve the leachate emission limits?
- what is the impact of initialization of aerobic conditions at different stabilization stages on the aftercare?
- based on the above, what are the impacts on the costs and how the costs can be minimized during the whole aftercare period?

Materials and methods

Waste samples were taken from a big landfill near Helsinki, Finland at different depths (2 – 30 m) and combined to obtain an average composition of the waste in the landfill. Estimated age of the samples was approximately 1 – 9 years, average around 3 years. Around 85 kg of waste was filled to each simulator, of which 2 were run at 20 °C, 3 at 33 °C and 2 at 46 °C. Deoxygenated tap water was added 0.2 – 1.5 l/week (depending on the simulator) preceding equal leachate volume removal. Leachate was recirculated 2.2 l/d during working days, to keep the waste wet enough for near optimal degradation conditions. Organic fraction (VS) of the dry solids (TS) was 45 %. Leachate and gas quality was analysed frequently and gas production was determined.

Air pumping was started in one thermophilic simulator at L/S=4.6, in two mesophilic simulators at L/S 1.8 and 4.6 and in one psychrophilic simulator at L/S 3.6, other 3 simulators were operated in anaerobic conditions the whole period, total of 4.5 years.

Results and discussion

In this study direct leachate discharge emission limits for COD 200 mg/l, Ntot 70 mg N/l and chlorides 100 mg/l were applied. The highest L/S ratios needed were for nitrogen and are shown in Table 1. Anaerobic reactors were run until L/S 5.3, and higher L/S values given are extrapolated from the estimated slopes of the decreasing curves. Liquid to solid ratio around 5.9 was needed in the psychrophilic and mesophilic ranges to achieve the limit value in anaerobic conditions, and in the thermophilic range it was considerable higher. Next highest L/S ratios were needed for chlorides and lowest ones for COD. After the initialization of aerobic conditions nitrogen and COD limit values were achieved within 0.4 - 0.6 L/S units, which showed a clearly faster stabilization and a shorter aftercare period, but chlorides may still remain as a problem.

Table 1. Liquid to solid ratios (L/S) needed to achieve direct discharge limit for nitrogen
Abstract proceedings for the 7th ICLRS, Sunderbyn, Sweden, June 25-27.

| Psychrophilic | anaerobic/aerobic from L/S 3.6 | 4.0 |
|              | anaerobic                     | 5.9 |
| Mesophilic   | anaerobic/aerobic from L/S 1.8 | 2.3 |
|              | anaerobic/aerobic from L/S 4.6 | 5.0 |
|              | anaerobic                     | 5.9 |
| Thermophilic | anaerobic/aerobic from L/S 4.6 | 5.2 |
|              | anaerobic                     | 6.7 |

The simulator results were applied to calculate the length of aftercare period for a big landfill (50 ha, average waste height 25 m) and a medium size landfill (25 ha, height 10 m) in Nordic conditions. In the scenarios infiltrations of 200 mm/a (base case), 600 mm/a or 1200 mm/a were assumed, including fresh water and pretreated leachate (with nitrification). To find out most economic management alternatives, cost calculation was made for the scenarios and different level of local treatment was included: a) on-site biological treatment with activated carbon filtration, b) pumping to municipal wastewater treatment plant (WWTP) or c-d) two alternatives with lower/higher nitrogen removal efficiency before pumping to WWTP. Results show that aftercare period length is 75 – 145 years for the big landfill even with elevated infiltration in anaerobic conditions, but by introducing aerobic conditions at L/S 1.8 the period length is 30 – 60 years. For the medium size landfill aftercare period length would decrease from 25 – 50 years (elevated infiltration, anaerobic) to 10 – 20 years (aerobic respectively). Lowest total costs were estimated for scenarios with highest infiltration in both landfills sizes with efficient nitrogen removal before pumping to WWTP, next lowest costs with similar infiltration and on-site treatment with direct discharge. Direct pumping to sewer (WWTP) showed highest costs in all scenarios. Initialization of aerobic conditions (from L/S 1.8) would decrease the total costs clearly, but a later start did not bring economic advantages. In conclusion, aftercare period length was shortest in scenarios with highest water infiltration with initialization of aerobic conditions at L/S around 1.8. The total costs of leachate management during aftercare period were lowest in scenarios with shortest aftercare period together with high nitrogen removal before pumping leachate to WWTP. Hence both economic and environmental benefits can be combined.

References