

# 9 TREATMENT WETLANDS FOR LANDFILL LEACHATES — CASE STUDIES FROM NORWAY

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## SUMMARY

The paper describes operational experiences of landfill leachate treatment systems at three Norwegian landfill sites, with emphasis on the reduction of COD, nitrogen and Fe concentrations. The leachate systems described consist of aerated lagoons with aspirator propeller aerators/mixers, and horizontal subsurface flow treatment wetlands. Results of leachate monitoring and treatment efficiencies are presented. Operational data show that leachate treatment with aerated lagoons has problems with removal of organic matter and nitrogen, but remove Fe. Failure seems to depend on high loads (especially in winter times), sludge erosion and toxicity. The hydraulic retention time should to be >20 days to keep the nitrifiers in the lagoon during periods with low temperatures. Simple filtration techniques with e.g. bark, shell or coral sand, crushed concrete and others can improve leachate quality both during and after other treatment stages and remove nitrogen, colour, heavy metals, organic pollutants and pesticides, and buffer pH and add other nutrients. A combination of aeration, dams and filtering techniques probably gives the best treatment options.

## 1. INTRODUCTION

Activated sludge systems are extensively used for leachate treatment in Europe. The leachate treatment method that used to be most common in the UK, extended aeration activated sludge, has relatively long retention time (3-10 days) with good results for removal of C and N. This is a common treatment method also in the rest of Europe (Ashbee and Fletcher 1993). Traditional activated sludge systems are generally not optimal due to high variation in leachate quality. Typical problems are foaming, precipitation and excessive sludge production. Aerated lagoon systems are the most frequent treatment option also in Scandinavia. It is a simple concept without recirculation of sludge and a high removal of C (Maris et al., 1994). Additional P is often recommended to enhance the biological processes (Robinson, 1997; Britz 1995; Mæhlum et al., 1998). Minimal maintenance with retention time usually in the order of 3-20 days.

On-site treatment of landfill leachate is not widespread in Norway. Fewer than 20 of the 350 municipal sanitary waste (MSW) landfills use on-site biological treatment systems. About 35 landfills discharge raw leachate to sewers without on-site pretreatment. New regulations require that most landfills must be built with a liner to control leachate; and leachate treatment is compulsory. On-site "high-tech" leachate treatment systems are avoided due to high construction and operation costs. Low-cost treatment methods operating in cold climate need to be implemented. Several studies conclude that aerating lagoons removes COD and  $\text{NH}_4\text{-N}$

(e.g. Maris and Harrington, 1984, Robinson and Maris, 1985, Robinson and Grantham, 1988, Robinson, 1990). Constructed wetlands (CWs) have been used successfully as secondary and tertiary treatment of effluent from aerated lagoons in UK (Robinson, 1993) and USA (Martin and Moshiri, 1995). CW properties that make them suitable for wastewater treatment include extensive adsorptive surfaces (sediments, plants and roots), aerobic-anaerobic interfaces, and diverse, active microbial populations, which will translocate, metabolise, or use the various contaminants. According to Robinson et al. (1997) there are no technical barriers to the treatment of landfill leachates to whatever standards are appropriate.



Figure 1. Trends in landfilled waste in Norway (SSB, 2001).

There are more than 3000 landfills in Norway, of which more than 500 are industrial, more than 1000 are municipal, and about 200 are in operation today. The public record of landfills has files for 1150 locations, of which 94 are registered closed. Total annual production of MSW is about 1.2 million tons (SSB, 1997). The volume of landfilled waste cannot be expected to decrease rapidly, in spite the effort to do so, see Figure 1. Both the public and government advocate more waste sorting, recycling and incineration to reduce landfilling. 20-30 % of MSW landfills treat leachate at waste water treatment systems. Less than 10 % receive some kind of local pre-treatment. Non-treated leachate is basically emitted from small landfills. The main recipients are fjord/coastal waters (36 %), rivers and streams (26 %) and soil (25%) (SSB 1997). The specific leachate production measured at Norwegian landfills is 50-200 m<sup>3</sup>/day, or 300-600 mm/year, about 30-60% of the precipitation, a relatively large production compared to other European countries. For on-site leachate treatment it is better to isolate the waste body from surface and groundwater from non-polluted areas. The hydrological properties of the landfill can be analysed with time series of leachate production and precipitation. Norwegian experiences show removals of COD 50-90%, Fe >70%, Tot-N 30-50% and NH4-N 0-99%. Seasonal effects have been observed (Mæhlum et al. 1998). High removal can be observed even during low temperatures or even floods due to the high buffering volume of the lagoon.

This study is based on detailed investigations of leachate from 3 landfills (Esval-referred to as e, Bølstad-referred to as b and Spillhaug as s), from the southeastern part of Norway, from 1992-to date. In addition leachate data from 10 other landfills representing a variety in size (5-50 ha), age and hydrology, have been compiled and are presented here. The specific landfills have been described earlier (Mæhlum et al., 1995).

## 2. METHODS

All analyses are made at Jordforsk according to accredited methods and Norwegian standards. At Esväl the leachate is sampled as weekly grab samples and analysed 6 to 8 times per year. The leachate volume is manually measured weekly. The electrical conductivity of the raw leachate is also sampled manually each week to monitor the weekly variability of the concentrations in the leachate. At Bølstad the leachate is sampled 6 to 8 times per year. The leachate volume is sampled continuously. At Spillhaug the leachate is analysed 5 to 10 times per year, and leachate volume is measured continuously. Leachate removal is calculated on a concentration basis without correction of Cl removal. Control calculations with removal on a weight basis showed little bias between the two methods.

### 3. RESULTS

The landfills and leachate systems are described in Table 1. The sites have a cool temperate continental climate, with 800 mm annual precipitation and a January mean air temperature around -6°C. Although leachate temperature and production rates are similar, one landfill (Esval) is about twice as large as the other two, see Table 1.

*Table 1. Description of Esval, Bolstad and Spillhaug MSW landfills and treatment plants in Norway.*

General information	Esval Landfill	Bolstad Landfill	Spillhaug Landfill
Start operation	1962	1972 (closed 1999)	1973
Landfill area (1996)	100 da	50 da	60 da
Landfill catchment area	150 da	80 da	150
Annual waste flow (1995)	50 000 t	7 000 t	10 000 t
Total waste received	500 000 t	190 000 t	200 000 t
Landfill depth	25-30 m	20 m	30 m
Waste type	MSW, septic sludge	MSW	MSW
Annual mean precipitation	825 mm	785 mm	800
Mean air temp	7°C	8°C	7°C
Mean air temp Jan.	-7°C	-5°C	-7°C
Landfill sealing	clay	clay	no
Drainage system	gravel ditches	pipe	Sand/gravel aquifer
Leachate production mean, Q <sub>dim</sub> (range)	120 (30-800) m <sup>3</sup> /d	80 (30-300) m <sup>3</sup> /d	130 m <sup>3</sup> /d
Leachate temp Jan./June	1°/20°C	1°/20°C	5°/10°C
<b>Leachate treatment systems</b>			
Established	1993	1994	1998
1. Stage - pretreatment	anaerobic pond	none	Sandy aquifer, 300 m
Area	450 m <sup>2</sup>	-	HRT 40-50 d
Volume	650 m <sup>3</sup>	-	
2. Stage - oxidation	aerated lagoon	aerated lagoon	aerated lagoon
Area	2700 m <sup>2</sup>	1000 m <sup>2</sup>	1000 m <sup>2</sup>
Volume	4100 m <sup>3</sup>	2200 m <sup>3</sup>	1800 m <sup>2</sup>
Aeration equipment	3 floating aspirator propeller/mixers, each 5 - 10 kW	1 floating aspirator propeller/mixer, 10 kW	1 floating aspirator propeller/mixers 10 kW
3. Stage - filter/wetland	2 parallel SHF-CW <sup>a</sup>	4 parallel SHF-CW, mesoscale <sup>c</sup> system	3 free water CW in series HRT 7 - 10 d
Area	2 x 350 m <sup>2</sup>	4 x (1 x 10) m <sup>2</sup>	3000 m <sup>2</sup>
4. Stage	FWS-CW <sup>b</sup>	none	
Area	2000 m <sup>2</sup>	-	
Volume	1000 m <sup>2</sup>	-	
Total costs	200 000 USD	150 000 USD	

a) SHF-CW - horizontal subsurface flow constructed wetland

### 3.1. Esval

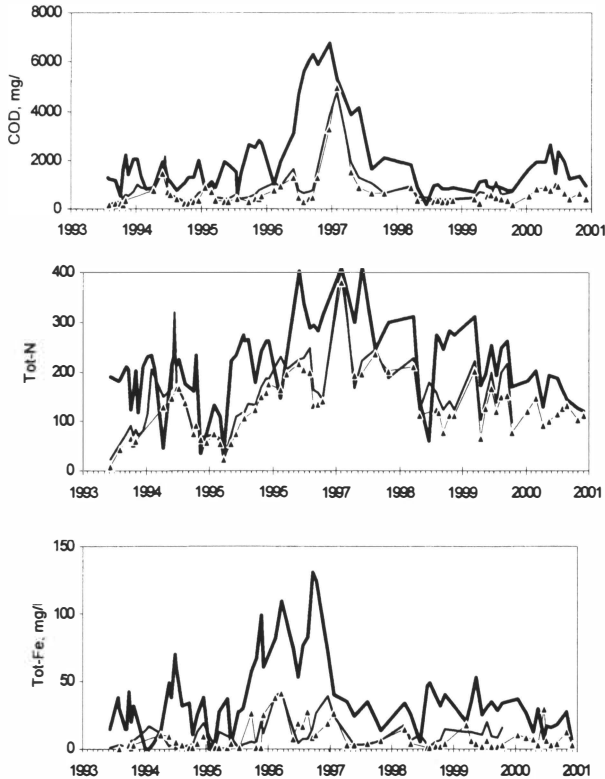


Figure 2. Time series in mg/L of organic matter (COD), nitrogen (Tot-N) and iron (Tot-Fe) from Esval Landfill (raw leachate=heavy line, lagoon=thin line, wetland=triangles)

The leachate at Esval has changed considerably during the operation of the treatment system. For COD and Fe there is a peak concentration from 1996-1997. The system has not been able to remove the prescribed 75% COD and 45% Tot-N. It is also clear that the wetland has low removal, mainly due to hydraulic and chemical overloading.

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3.2. Bølstad

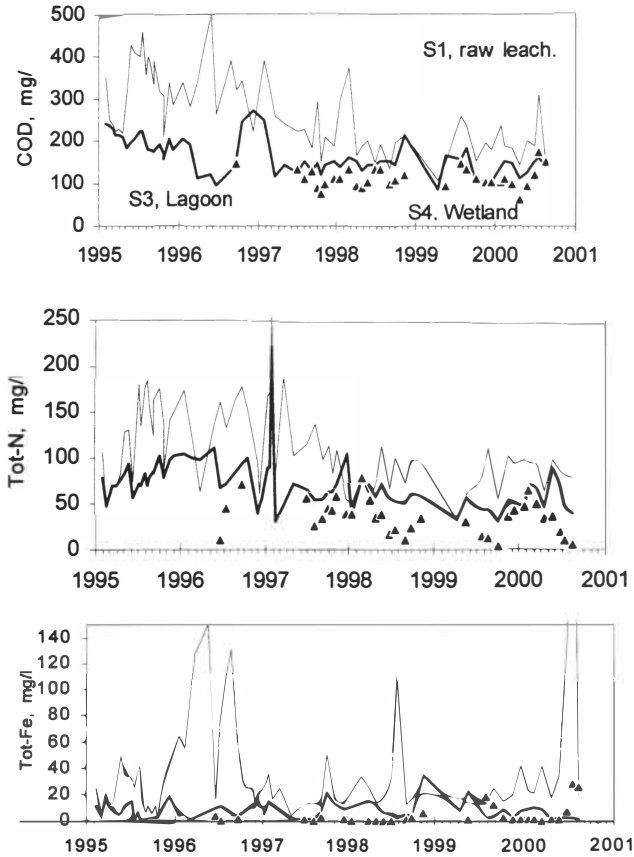


Figure 3. Time series in mg/L of organic matter (COD), nitrogen (Tot-N) and iron (Tot-Fe) from Bølstad Landfill (raw leachate=line, lagoon=heavy line, wetland=triangles).

At Bølstad the wetland has higher removal. Also here the removal of COD is not up to the target value of 75% removal.

### 3.3. Spillhaug

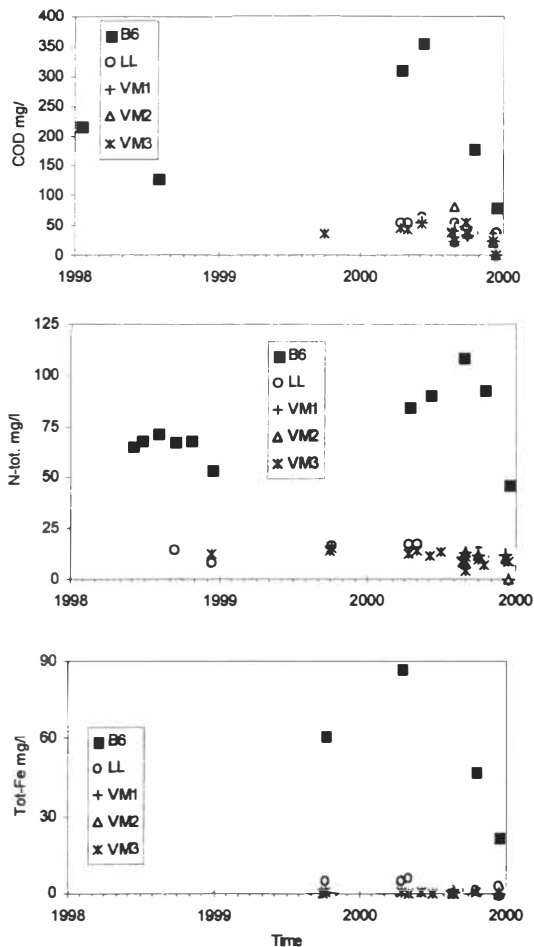


Figure 4. Trends in COD, Tot-N and Fe at Spillhaug landfill (B6=upstream groundwater well close to the landfill, LL=aerated lagoon, VM1-3=wetlands)

At Spillhaug the removal is above the target values. Here the concentrations are much lower due to infiltration to groundwater before treatment in the lagoon and wetlands.

#### 4. SUMMARY

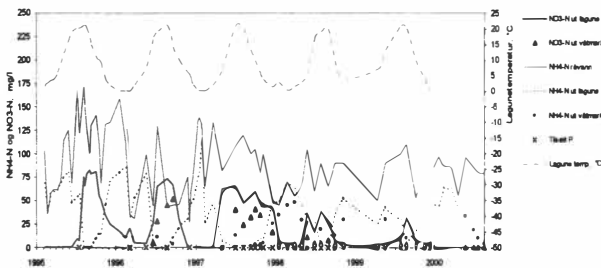
Figures 2-4 shows that the leachate at Esväl is moderately strong, and at Bølstað and Spillhaug the leachates are weak. Esväl experienced an increase in concentrations during 1996-1998, probably due to high input of waste producing leachate in the acetogenic phase. 2000 was an exceptionally wet year and can be seen as an increase in COD and N concentrations at Esväl and Bølstað. A summary of the annual mean removal of organic matter, nitrogen and iron is shown in Table 2.

*Table 2. Time series of annual mean removal, systems including all treatment stages (%)*

Year	Esväl			Bølstað			Spillhaug		
	COD	N	Fe	COD	N	Fe	COD	N	Fe
1993	86	83	89						
1997	65	45	80	38	43	61			
1998	56	47	87	27	26	64			97
1999	53	40	84	36	68	70	75	80	99
2000	59	28	55	41	60	90	81	87	99

Table 2 shows that for the two landfills Esväl and Bølstað, the removal of organic matter and nitrogen is occasionally below target values, usually 75 % removal for COD and 45 % for total nitrogen. The systems are better in removing iron (and other metals). The reasons for malfunctioning of the systems can be several: the hydraulic loading or the loading of organic matter and nutrients is higher than the system design, the hydraulic detention time is not according to specifications (shortcuts), flooding and erosion of the lagoons, or the leachate is too toxic for the given treatment option.

The hydraulic retention time should to be >20 days to keep the nitrifiers in the lagoon during periods with low temperatures. Liquid temperature will be an important factor especially at high latitudes.



*Figure 5. Lagoon temperature and concentrations of NO<sub>3</sub>-N and NH<sub>4</sub>-N in raw leachate and effluent aerated lagoon and CW (mesoscale) of landfill b, as response to changing temperatures and addition of supplemental phosphorus.*



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