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LANDFILL LEACHATE TREATMENT USING CONSTRUCTED WETLAND WITH SHORT DETENTION TIME

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Abstract: The paper presents results obtained during experiments with constructed wetlands that were built and monitored on the site of a municipal landfill in Southern Poland. The wetland was filled with gravel and rock in which reeds, cattails and willow were planted. A control plot without vegetation was also constructed. Each wetland was loaded with a portion of the leachate generated by the landfill. Measurements of the leachate quality showed very high concentrations of several pollutants. Particularly high concentrations of BOD, COD, nitrogen, and heavy metals were measured. High pollutant levels were probably responsible for the demise of the willows, which were dead within several months of planting. The efficiency of pollution removal with detention time up to 24 h ranged from 0 to 87% based on decreasing concentration of selected parameters. However, the removal efficiency of the control plot was typically only several percent lower than the removal efficiencies of the plots with vegetation.

INTRODUCTION

The leachates are one of the main environmental concerns in the landfills. They can occur as uncontrolled runoff or be collected with engineering facilities [5, 12]. However, when collected, they are difficult and expensive to treat because they are usually high in toxicity and because of wide variations in both quality and quantity [5, 8, 10, 12]. For these reasons, in Poland, more than 50% of landfills send their leachates to municipal wastewater treatment plants using mainly trucks (equipped with containers). Discharge into municipal sewer systems occurs at about 6% of Polish landfills. An alternative and potentially less expensive method of leachate management is available using a constructed wetland.

In this paper, research on this topic undertaken in Southern Poland is described. Main goal was to study the possibility of leachate treatment through application of a constructed wetland in which the water table is maintained under ground level. Experimental plots constructed next to a landfill allowed for the study of several phenomena including the changes of efficiency of the contaminant removal correlated with time of flow through the wetland.

LEACHATE QUALITY AND QUANTITY

Municipal landfill leachate quantity and quality vary substantially depending primarily on meteorological conditions, age of the landfill, and technology of landfilling [1, 8, 12, 16].

Biochemical oxygen demand can vary from 10 ppm to as high as 7 000 ppm, COD from10 ppm to up to 10 000 ppm, phenol from 0.17 ppm to 112 ppm, pH from 1.5 to 9.5, toluene from 280 ppb to 1680 ppb [2, 8, 10, 12, 16]. Also important is considerably high concentration of chloride, which in some cases excides 5000 ppm. A high concentration of heavy metals is another factor that limits options for biological wastewater treatment. Cited in the literature are concentrations of cadmium from 0 to 2 ppm, zinc from 0.2 to 3 ppm, lead from 0 to 6.6 ppm, and cooper from 0.186 to 5.09 ppm.

WETLANDS FOR WASTEWATER TREATMENT

Interest in non-conventional ecologically sound methods of wastewater treatment is not new, but is increasing recently all over the World [2–4, 6–9, 12, 14]. The main advantages of such systems are low cost of construction and low energy and labor for operation. Additionally, there are possibilities of resources recovery in some cases as well as support of wildlife.Wetlands applied to wastewater treatment can be classified in various ways but most commonly can be split into two major categories [3, 4, 7]:

- Free Water Surface Wetlands (FWS),
- Subsurface Flow Wetlands (SFW).

FWS systems can be similar to stabilization ponds, consisting of basins or channels with the vegetation either floating or rooted in the bottom sediments. The treatment processes occur in the water column as well as on parts of the plants submerged in the water [7, 9, 13]. The most common plants used in these systems are duckweed, hyacinth, pennyworth, cattail, bulrush, and reed.

In SFW systems purification processes take place underground where wastewater flows laterally through the medium (soil or artificial substrate such as gravel, for example) and the root zone of vegetation. In Europe these systems are sometimes called Root-Zone Method.

Biochemical processes in the bed of such wetlands are the same as in trickling filters or soil filters with same additional support from vegetation. The roles of the vegetation are considered to be following:

- transportation of oxygen to the root zone to create aerobic conditions that are favorable for biochemical organic matter degradation,
- release of enzymes that participate in biochemical processes in the root zone,
- roots provide additional support for the microbes including symbiotic bacteria,
- direct uptake of the contaminants.

The most common plants used in subsurface systems are reed, cattail, rush, bulrush, and sedge [4, 7]. SFW are found to be very resistant to changes in quality and quantity of wastewater and even to the presence of toxic substances such as heavy metals, does not decrease efficiency of treatment substantially [4, 9]. However, the price we usually have to pay for these benefits is in the form of a significant requirement for land on which the wetland is to be constructed.

EXPERIMENTAL SITE DESCRIPTION

The studied landfill is located in Southern Poland, about 20 km South of Cracow. Ground elevation is about 215 m above sea level. The site is in a valley of the Vistula River with an interesting microclimate characterized by large differences in ambient temperature between night and day. Also high variations of the humidity are monitored. Average rainfall is 665 mm, 60–70% of which occurs during the vegetation (growing) season.

About 300 000 Mg of municipal wastes were stored during the 20 years of the landfill operation. The wastes were not segregated before disposal, and some toxic wastes were present, such as batteries, pesticides or their containers, containers of automobile oil, light bulbs, home appliances and many other household wastes. There is a possibility that some industrial wastes from small businesses were also damped illegally from time to time. The area of the landfill is 6 ha at the bottom and about 4 ha at the top. No special compactor was used except for a caterpillar tractor for moving and burying waste. The landfill had no leachate management facilities.

The experimental plots are located on the north side of the landfill, just between the landfill and a pond created by uncontrolled outflow of leachates from the landfill. They consist of three channels made of wooden board lined by the two-geomembrane layers (Fig. 1).

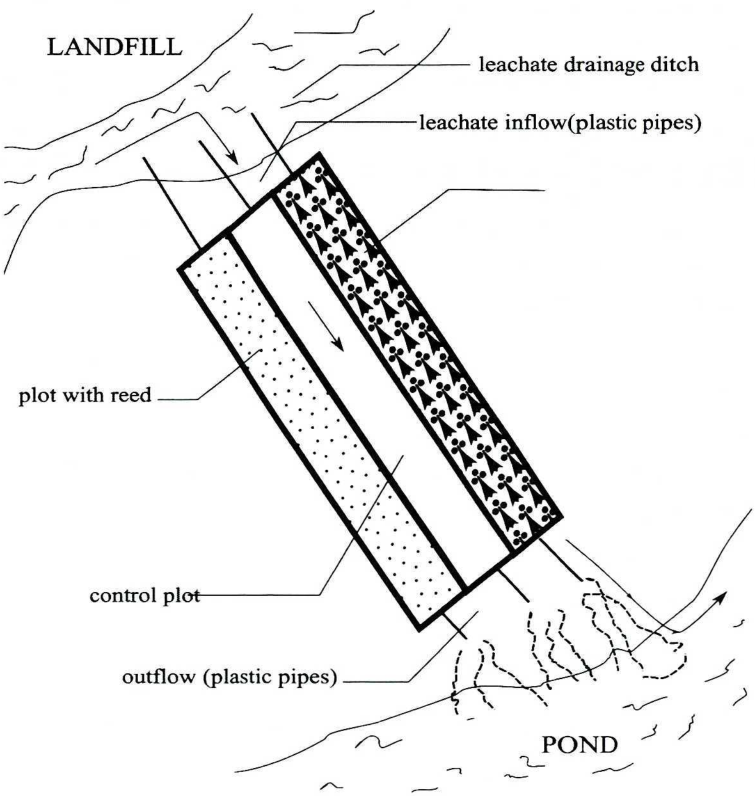


Fig. 1. Experimental plots at Skawina

Each channel was 20 m long, 0.53 m width, and 0.5 m deep. The slope was 1.5%. The plastic pipe at the inflow allows for directing the leachates to the experimental plots.

The experimental plots were filled up with porous media dominated by rocks and gravel of about 25 mm (see the sieve curve of this material in the Figure 2).

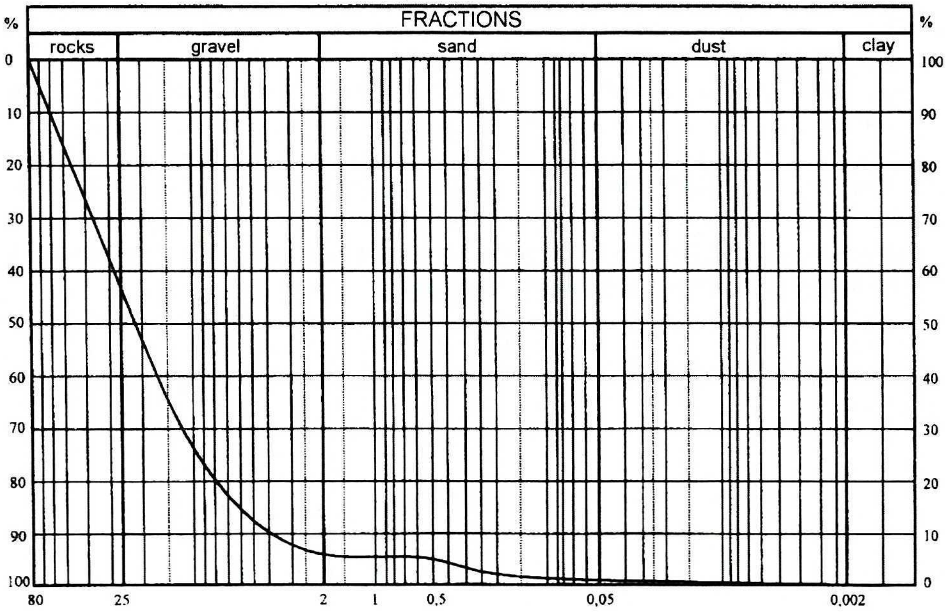


Fig. 2. Sieve curve of the media in experimental plots (size of the grains in mm)

Experimentation began with planting of about 500 seedlings of willow (*Salix viminalis*) on one plot and about 600 seedlings of reed (*Phragmites communis*) on another plot. One control plot was left without vegetation. After a year all of the willows and about 50% of the reeds died. An additional 450 seedlings of reed were planted to reach 75 plants/m^2. Also it was decided to replace the willows with cattails, about 400 seedlings of which were planted. Unfortunately, after a year many of the cattail plants died as well, and during the testing and monitoring phases described in this paper, the density of cattail was only about 3 plants/m^2.

Reeds and other vegetation grow near the plots, so a lot of effort was required to keep the plots free of other vegetation, which came to the plot as a natural migration process.

TESTING AND MONITORING METHODS

Three different flow rates through the experimental plots were obtained by adjusting the inflow manipulations to obtain detention times of 8 h, 12 h, and 24 h. For each detention time the samples were taken from the influent and effluent in accordance with this time so as to capture the same volume of leachate on inflow and on outflow. The samples were analyzed in a certified laboratory according to the Polish Standards. Since cattail density during the experiments was very low, also this plot could be considered as control plot.

RESULTS

The pH during the experiments did not change significantly (Fig. 3a), with the exception for a decrease in the cattail plot for the 24 h detention time (which was most probably due to experimental error).

The COD of the influent during the experiments was high and varied from 599 ppm to 897 ppm. Increase of detention time caused increase efficiency of COD of the effluent (Fig. 3b). For the detention times of 8 h, 12 h, 24 h, the COD reduction was 20%, 23%, and 41%, respectively. It is important to notice that for 8 h and 12 h there is a difference in efficiency of treatment between reeds and the control plot as well as the plot with some cattails. However for 24 h detention time this deference was much smaller.

Similar effects were obtained for reduction of BOD (Fig. 3c). For 24 h detention time, the reduction in BOD was very good for all plots. BOD of influent varied from 80 ppm to 186 ppm.

Increases in detention time resulted in improved total nitrogen removal for all plots (Fig. 3d). For this parameter there were significant differences of efficiencies between the plot with reed and control plot for all detention times. The plot with reeds experienced significantly more nitrogen removal which reached 35% for the 24 h detention time. Total nitrogen of the influent varied from 80 ppm to 180 ppm.

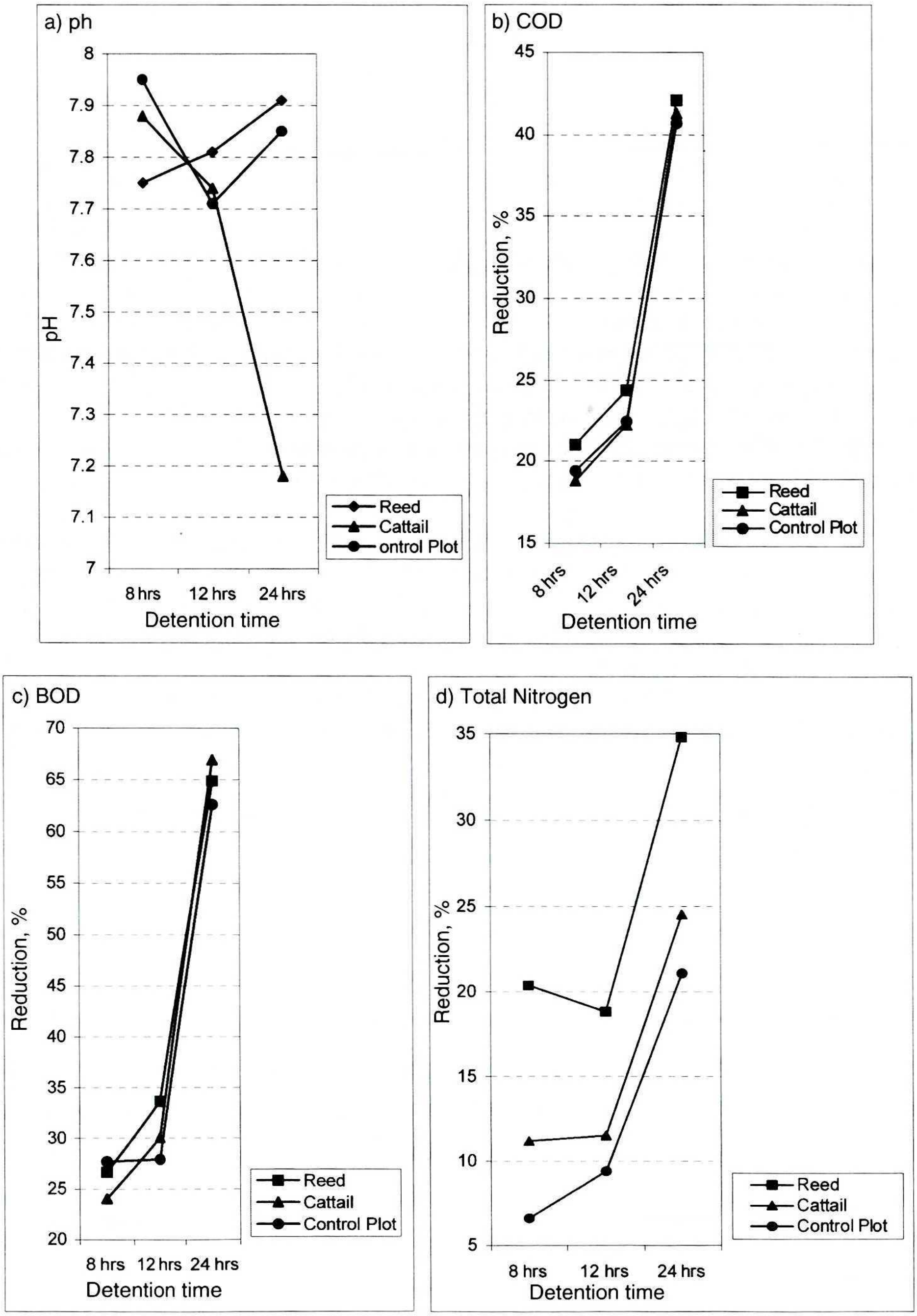
Very high removal efficiency of zinc, lead and other heavy metals was observed (Figs 3e and 3f). However, there were variations with detention time that cannot be explained, and more data are required to find relationships between the vegetated and control plots for various detention times. Concentrations of zinc and lead at the influent were up to 0.5 ppm and 0.12 ppm, respectively.

The influent had a very high salinity resulting in high conductivity which reached 17 mS/cm during the course of research.

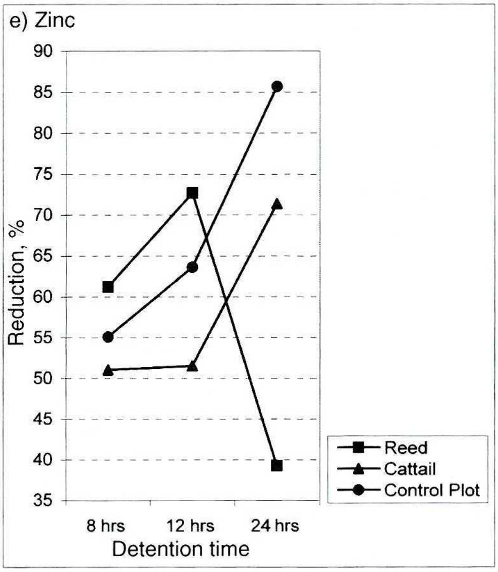
CONCLUSIONS

Constructed wetlands are shown to have a good ability to remove contaminants from landfill leachates, even with a short detention time not exceeding 24 h. Efficiency of removal of nitrogen and metals was significantly higher on the plot with reeds than on control plots with little or no vegetation. However, removal of BOD and COD was just as effective in the control plots as it was in the vegetated plots, probably due to microbial growth in the control plots.

As it was expected, increasing the detention time strongly increases the treatment effect.



a) ph
pH
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7
8 hrs
12 hrs
24 hrs
Detention time
Reed
Cattail
ontrol Plot
b) COD
Reduction, %
45
40
35
30
25
20
15
8 hrs
12 hrs
24 hrs
Detention time
Reed
Cattail
Control Plot
c) BOD
Reduction, %
70
65
60
55
50
45
40
35
30
25
20
8 hrs
12 hrs
24 hrs
Detention time
Reed
Cattail
Control Plot
d) Total Nitrogen
Reduction, %
35
30
25
20
15
10
5
8 hrs
12 hrs
24 hrs
Detention time
Reed
Cattail
Control Plot



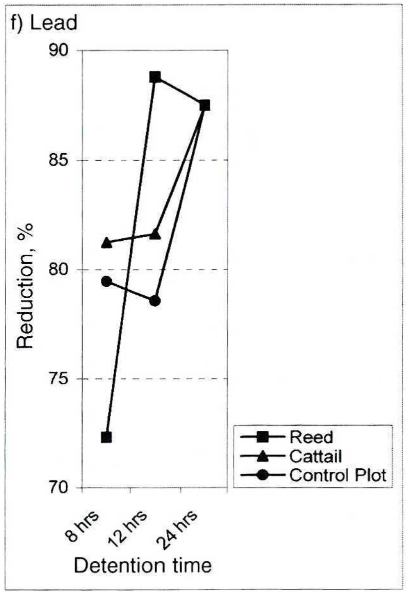


Fig. 3. Efficiency or removal of selected leachate contaminants by constructed wetland

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OCZYSZCZANIE ODCIEKÓW ZE SKŁADOWISK ODPADÓW KOMUNALNYCH Z WYKORZYSTANIEM SZTUCZNYCH MOKRADEŁ Z KRÓTKIM CZASEM PRZETRZYMANIA

Artykuł przedstawia wyniki otrzymane podczas eksperymentów na sztucznych mokradłach, które były wybudowane oraz monitorowane na obrzeżu składowiska odpadów komunalnych na południu Polski. Mokradło miało złoże składające się ze żwiru oraz kamienia, na którym posadzono trzcinę, pałkę oraz wierzbę. Wykonano też poletko kontrolne bez roślinności. Każde poletko było zasilane kontrolowaną ilością odcieków ze składowiska odpadów. Pomiary jakości odcieków wykazywały bardzo wysokie stężenia szeregu wskaźników. W szczególności stwierdzano wysokie stężenia: BZT, ChZT, azotu oraz metali ciężkich. Ten wysoki poziom zanieczyszczeń był prawdopodobnie odpowiedzialny za wypadnie wierzby, której rośliny obumarły po upływie kilku miesięcy od posadzenia. Efektywność usuwania zanieczyszczeń mierzona jako obniżenie stężeń wybranych parametrów, dla czasów zatrzymania do 24 h wynosiła od 0 do 87%. Zauważono jednak, że efektywność usuwania zanieczyszczeń na poletku kontrolnym była tylko o kilka procent niższa niż na poletkach z roślinnością.