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Reduction of seepage water in landfills using capillary barriers – results of large scale lysimeters at a sanitary landfill

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ABSTRACT: The city of Bayreuth is interested in covering its sanitary landfill with a capillary barrier system. The preliminary investigations, done by using a specially developed assurance programme, indicated that the selected materials will satisfy the demands. Two experimental fields with large scale lysimeters have been built on the landfill. Now they are monitored under natural weather conditions. Data for more than one year have been collected so far. The measurements show a performance of the surface sealing system of more than 95 %. The fields will be observed for some more years. Specific investigations of the effects of penetrations, settlements and gas are currently made in the laboratory and in the field.

1 INTRODUCTION

Long term investigations on capillary barriers for landfills and waste dumps have shown that such barrier systems are an economical alternative to conventional surface sealing for landfills and waste dumps (Breh & Hötzl 1999, von der Hude & Möckel 1997, Jelinek 1993, Jelinek & von der Hude 1994, Melchior 1993, Zischak 1997). So far there are only a few experiences in the practical construction of a capillary barrier cover system which refer particularly to specially adapted solutions under various site conditions. Subject of the present research is the sealing effect of the total system under the influence of penetrations (drainage and gas wells), waste deformations (hydraulic weak points in local settlement basins) and bioturbations (macro pore discharges in root and animal caves) on the drainage capacity, as well as the gas lock effect.

The landfill of the city of Bayreuth (Germany), Heinersgrund, is situated near the village of Ramsenthal north of the city (Fig. 1). It has been used to deposit sanitary waste since 1965. Now it has a waste volume of 1,000,000 m^3 and covers an area of 130,000 m^2. As most of the waste of the city is now incinerated in Schwandorf, the landfill of Heinersgrund is used only for a small amount of waste. It will be closed in a few years and has to be covered by a surface sealing. Because of potential savings the city is interested in doing this by using a capillary barrier system.

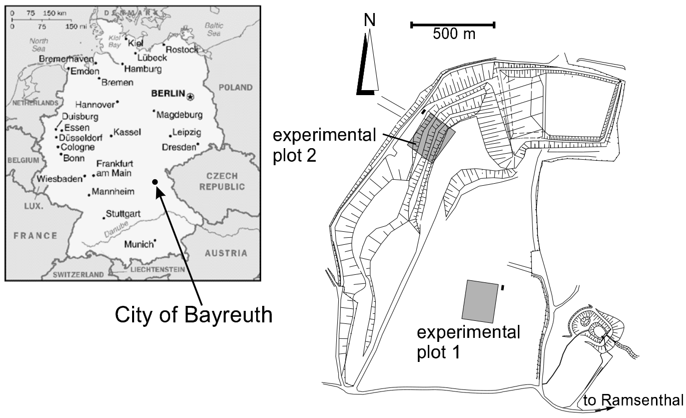

Figure 1. Location of Bayreuth and sketch map of the landfill with the positions of the two experimental fields at the hill of the landfill.

2 CONSTRUCTION OF ON SITE EXPERIMENTAL FIELDS

To proof the function of the capillary barrier system, two large scale lysimeters have been built on site at the landfill (Fig. 1). The concept of the project has been done by close co-operation between the building authorities of the city, the BEN consulting engineers (Bayreuth) and the authors.

Each of the two experimental plots covers an area of 2000 m^2. The integrated large scale lysimeters have a width of 20 m and a slope length of 30 m. They are completely sealed against the rest of the experimental field by a HDPE geomembrane.

The profile of the surface sealing is shown in Figure 2. It lies on the top of the present temporary cov-

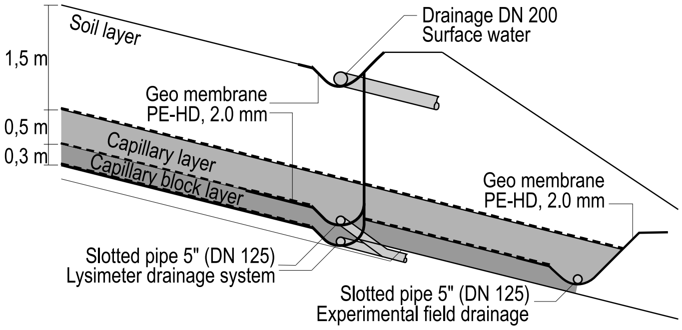

Figure 2. Vertical section through the field lysimeter showing the installations to capture the discharge from different layers.

erage. The capillary layer and capillary block layer consist of 0.50 m sand and 0.30 m crushed rock. They are separated by a geotextile. This has no negative influence on the capillary block effect but it simplifies the construction of the essential sharp border between the materials (Balz et al. 1999). The selected Materials have been examined according to a quality assurance programme specially developed by Wohnlich & Bauer (1999). The capillary barrier characteristic of the material combination have been determined in an experimental tank (Barth & Wohnlich 2001).

Separated by a geotextile there is a soil layer above the capillary layer with an extent of 1.45 m. The quality for this material has not been defined exactly to enable the use of cheap excavated material accruing at other constructions.

On top of the system there are 5 cm of compost to ease the growth of vegetation which is necessary for the water balance.

To get the entire amount of weak points of the intended surface sealing the two experimental fields are constructed in two extreme locations. Experimental field 1 has a gentle slope of 10 % which represent the lower end of the range of possible inclinations preferable for capillary barriers (Schnatmeyer & Wagner 1996).

Field 2 has a very steep slope with an inclination of 26 % which is advantageous for the efficiency of the capillary barrier but may be problematic for its slope stability. Additionally each field contains a gas well for studying the effects of penetrations through the capillary interface.

3 PERFORMANCE OF THE SEALING

One of the major aims of this research project is to examine the performance of the constructed capillary barrier system.

3.1 *Discharge measurement*

Since the construction of the test sites had finished in autumn 1999 they are observed under natural weather conditions. The investigations are done by monitoring the test sites with the integrated large scale lysimeters.

The discharges of the surface, the capillary layer (CL) and the capillary block layer (CBL) are grabbed in drainage ditches in each lysimeter. To prevent seepage of the collected water down to deeper layers, the ditches are lined by HDPE geomembrane (Fig. 2). Fluid tippers are metering these discharges continously. The weather is observed by an automatic weather station fitted up on the site. All the measured data are automatically recorded online by a data logger installed together with the drainage meter in a container near each field. The data logger can be remotely controlled from the office via modem.

3.2 *Measurement results*

The daily values of the precipitation and the discharge measurements are plotted in Figures 3, 4. For better readability the plot for the capillary block layer has a stretched x-scale.

The data of the first winter have to be interpreted carefully. Two basic facts affected the system adversely. There was an increased water content because of rain during the construction works. The outflow of this water had been measured in addition to the regular seepage water. There was nearly no vegetation at the surface. A dense vegetation which is important for the water balance could not grow before summer 2000. Considering this effects the data can give just a tendency of the performance of this capillary barrier system.

The data show that the surface runoff is nearly negligible. Lysimeter 1 had a little bit more surface runoff in winter 2000. This can be interpreted as an effect of the compaction by vehicles during the construction. In the meantime the soil has been loosened by roots. So there is only surface runoff during heavy rainfall continuing on for some days.

Because of evaporation and vegetation activity in summer high capillary layer drainage can only be measured during autumn, winter and early spring. It shows small peaks after rainfall or snow melting periods with a following tail of discharge.

A small amount of the peaks of the capillary layer drainage can also be measured in the capillary block layer. Only a couple of days of the data show a capillary block runoff of more than half a millimetre per day.

In general lysimeter 1 shows slower reactions compared to lysimeter 2 because of its lower inclination.

4 CONCLUSION

The summary of discharges of one year (01/03/00 – 28/02/01) is shown in Table 1. Both lysimeters show a low surface runoff of about 2 % of the precipitation. The summary of capillary layer and capillary block layer is equal to the groundwater recharge. It differs between 30.6 % and 44.1 %. This is a usual range for the humid climate of the location. The recharge of

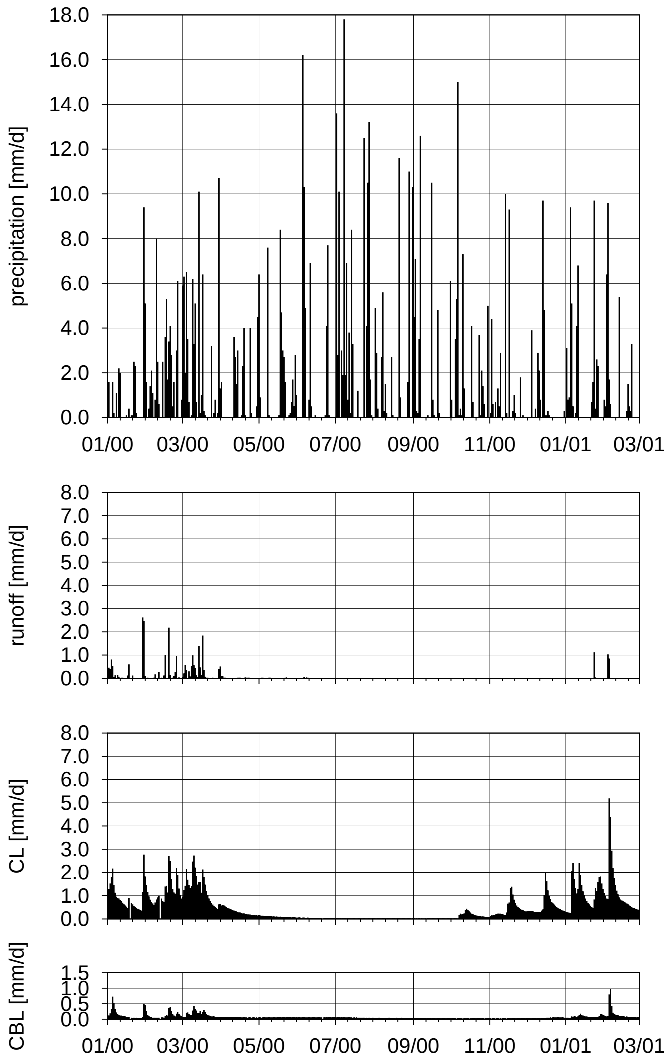

Figure 3. Daily values of precipitation and discharge measurements for lysimeter 1 (10 % slope).

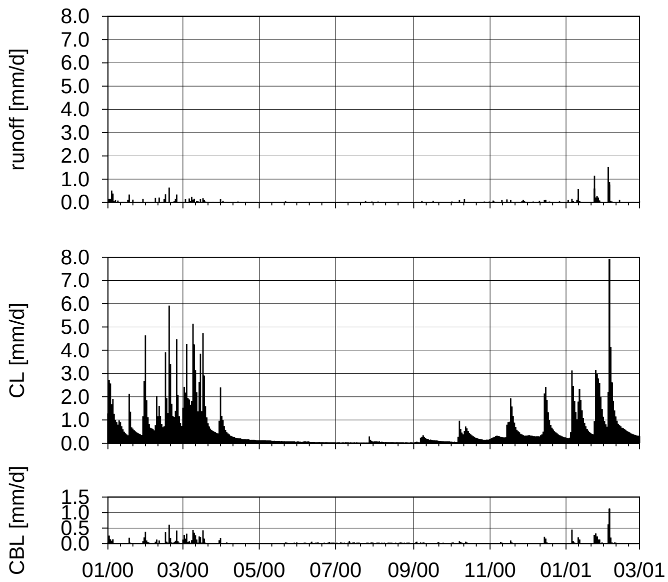

Figure 4. Daily values of discharge measurements for lysimeter 2 (26 % slope).

Table 1. Summary of recent precipitation and discharges for one year (01/03/00 – 28/02/01) as discharge height in mm and percentages of precipitation.

	Lysimeter 1		Lysimeter 2	
Precipitation	612.0 mm			
Surface runoff	13.6 mm	2.2 %	14.4 mm	2.3 %
CL	162.4 mm	26.5 %	254.1 mm	41.5 %
CBL	25.3 mm	4.1 %	15.7 mm	2.6 %
CL + CBL	187.7 mm	30.6 %	269.8 mm	44.1 %

lysimeter 2 is much higher because of its northwestern exposition (Fig. 1).

The amount capillary block runoff would penetrate into the landfill in a single capillary barrier. So it can be used as a value for the barrier performance. Lysimeter 2 performs better because of its higher inclination. 95.9 % and 97.4 % of the precipitation would have been prevented from penetrating into the landfill in this exemplary year. However the author expects a better efficiency of the system if the hydraulic conditions and the vegetation will have become more stabilised because of the facts given in 3.2. This is also supported by the preliminary investigations with the same materials where even with an inclination of 10 % more than 99 % of the seepage water could be drained by the capillary layer under normal conditions (Barth & Wohnlich 2001).

5 FURTHER INVESTIGATIONS

Additional measurements of the soil hydraulic conditions in the lysimeter are done by tensiometers, TDR probes and thermometers.

After the compilation of the obtained data it is intended to use the acquired knowledge to develop a model for the unsaturated flow within the capillary barrier system for the test sites and in the next step for the whole landfill. The ability of modelling the drainage capacities can be used in the future to reduce the costs of expensive experimental capability tests.

In addition to the field investigations detailed experiments for special problems are currently made in the laboratory. They examine the gas lock effect of capillary barriers and the effect of penetrations on the performance of the sealing.

6 ACKNOWLEDGEMENTS

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