Monitoring measures for landfills

Dr.-Ing. Florian Koelsch
Dr. Koelsch Geoenvironmental Technology LLC
Dr. Koelsch Geo- und Umwelttechnik GmbH
Gliesmaroder Strasse 100, 38106 Braunschweig, Germany
office@dr-koelsch.de
www.dr-koelsch.de

Abstract: Monitoring of landfills is still a strongly disregarded issue. Landfill operators used to start monitoring measures not before been faced to heavy problems or failures. Monitoring aims on maintaining landfill constructions (drainage pipes, liner systems) and on continously checking landfill conditions (settlements, leachate amount and distribution). Concerning three major monitoring applications, the article provides on the edge information: State of the art in TV-inspection appliances and procedures at landfills is presented. Furthermore, experiences as well as results of settlement measurings in drainage pipes and in special settlement pipes inside the landfill are described. Long-term measurements over 15 years show that settlement of landfill layers may exceed 50 %. At last, a brand new measuring device is introduced, the leachate discharge measuring system of the Technical University Braunschweig. A first practical result is shown to demonstrate the capability of this method.

Keywords: landfill monitoring, landfill stability, settlements, drainage system, pipe inspection, measuring, leachate

Introduction

Landfills are still a keystone of waste management strategies all over the world. Countries, which are not faced to space problems like the USA, are relying more on landfilling than smaller industrial countries with a high population density do (like Germany and Japan). However, even in these countries, landfilling will not end in a foreseeable time, although the German government set the year 2020 in the political agenda as a target for final landfill closing. During the last 30 years, state authorities have spent a lot of efforts to improve the technical standards of landfills demanding base liners, gas extraction systems, landfill covers and other construction components. Despite all these measures, maintenance of landfills often does not meet the high technical standard of their construction. It literally appears that the use of modern technical methods is suspended as soon as the landfill starts operation. The presentation addresses the state of the art of monitoring technologies for landfills.

Objectives and basics of monitoring

Landfill monitoring aims on two major objectives:

- to prove that landfill constructions are working properly
- to check the landfill condition (leachate and gas flow, settlements) concerning effects on future construction measures (e.g. landfill cover) and landfill stability

The effects of mechanical loads and the water situation in the landfill are the major points of interest, due to their significant relevance on liquid emissions. Vertical loads lead to settlements on the base and in the center of the landfill. Settlements may damage the liner systems and drainage pipes and they may create stability problems as well as diffculties to find the right moment to cover the landfill. It is a basic requirement to monitor these settlements, although landfill operators often find the measurings useless pointing on a leak of rehabilitation methods. Beside settlement measurings, the biggest need on information concerns the leachate situation. In order to support a proper leachate balance inside the landfill, the reliabilty of the dranage system needs to be proved. The dranage pipes are the most important part of the drainage system. They should be visually inspected every year to figure out the need on cleaning or rehabilitation. Measuring on leachate level and distribution may surround these inspections, providing additional information for the landfill operator.

Generally, landfills have two major access ports for monitoring, the surface as the easy one and – more difficult - any kind of pipes (drainage, gas extraction, settlement measuring pipes). Surface control of landfills is not much different from supervising other ground constructions like dams. However, non-surface measurings are more important to receive information on landfill constructions and on landfill condition, because the major parts of landfill construction (liners, dranage system) are covered by waste and the are not accessable. Additionally, most parts of the landfill surface change their shape and condition quickly due to waste placement making it useless for long-term monitoring. Therefore, the following presentation will focus on monitoring methods for pipes.

Methods

TV-inspection and related systems

Generally, TV-inspection is the basic instrument of landfill monitoring. At first, it provides visual information on the condition of the drainage pipes. This information is useful for assessing the overall leachate situation as well as the risk and the occurrence of mechanical damages of the landfill base. Figure 1 shows a severely damaged drainage pipe. The 32 mm thick wall of the PE-HD-pipe has been cracked completely at the crown. The crack runs over a distance of several meters. The type of damage indicates critical mechanical loads for the underlaying liner system. However, the pipe still has its demanded hydraulic capacity, therefore without TV-inspection, the damage probably would not have been detected at all.

TV-inspection technology has developed quickly over the past 10-15 years. Meanwhile, several manufactures offer TV-vehicles adapted for specific landfill requirements. Basically, a TV-vehicle need to have a working range of at least 300 m, it must fit into pipe diameters down to 200 mm (8’’) and it has to be explosion proofed. In Germany, at least 4 manufactures meet these requirements with their products. Usually, the TV-inspection is recorded on video tape, however digital recording is currently growing and will likely replace conventional taping soon.

Figure 1: Damaged drainage pipe – axial crack

A typical TV-vehicle is loaded with additional monitoring systems. Temperature sensors provide information on the temperature in the pipe, laser based measuring systems are useful for measuring the shape of the pipe offering data on mechanical loads. Only concering the task of measuring the slope and the elevation of the pipe respectively, the engineers failed. Although many manufacturers offer vehicles with ready installed inclinometers, for physical reasons, the measuring systems do not work properly– and they never will.The measuring concept bases on monitoring and recording the angle of dip within a small intervall of distance, typically every 10 cm (4''). The measuring resolution (0,01 % slope, equal to 1/100 mm elevation difference per distance intervall) and accuracy (0,1 % slope, 1/10 mm per intervall) of the inclination angle is excellent. However, a small measuring error remains in every intervall and accumulates with increasing measuring distance. The minimum measuring error of 1 mm per 1 m distance adds up to 30 cm elevation error in a pipe 300 m long. This calculation does not include non systematic errors and describes just the optimal measuring situation. Even elevation errors of 1 m has been detected in control measurings. Therefore, a camera based inclinometer measuring is needless for assessing settlements. At least, it may help to evaluate the current slope of the drainage pipe within a accuracy range of +- 0,2 %. However, since a TV-vehicle is able to carry stuff, external sensors like hydrostatic elevation measuring devices can be used for elevation and settlement measuring.

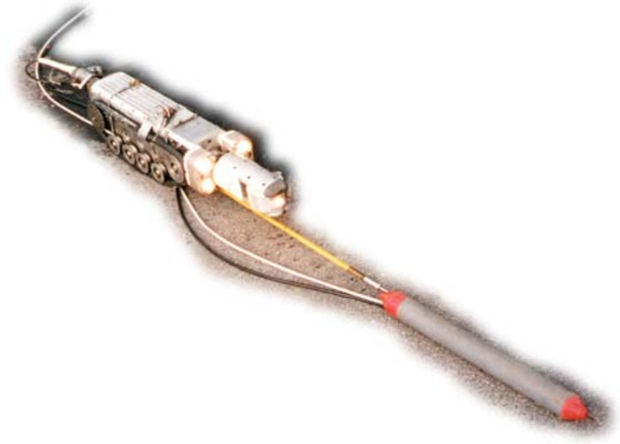

Fig. 2: TV-vehicle with elevation sensor

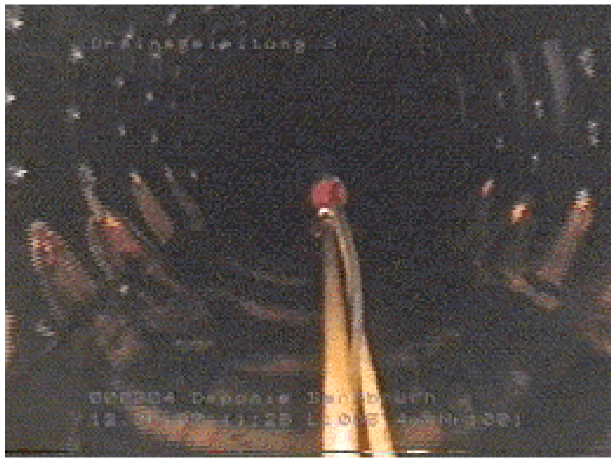

Fig. 3: View inside the pipe while driving

Pipe elevation measuring

Figure 2 shows a TV-vehicle with a hydrostatic measuring device amounted, figure 3 shows an image taken by the camera inside the drainage pipe. The most appropriate way to determine settlements of the landfill base is by means of repeatedly measuring the elevation of drainage pipes or a special settlement pipes. Hydrostatic elevation measuring is the only system able to measure pipe elevation exactly. Developed in the beginning of the 20th century and adapted for pipe measuring in the early eighties, it has become a well experienced and reliable technology. Hydrostatic elevation measuring bases on the physical principle that hydrostatic pressure increases linear with the geodetic depht as shown in figure 4.

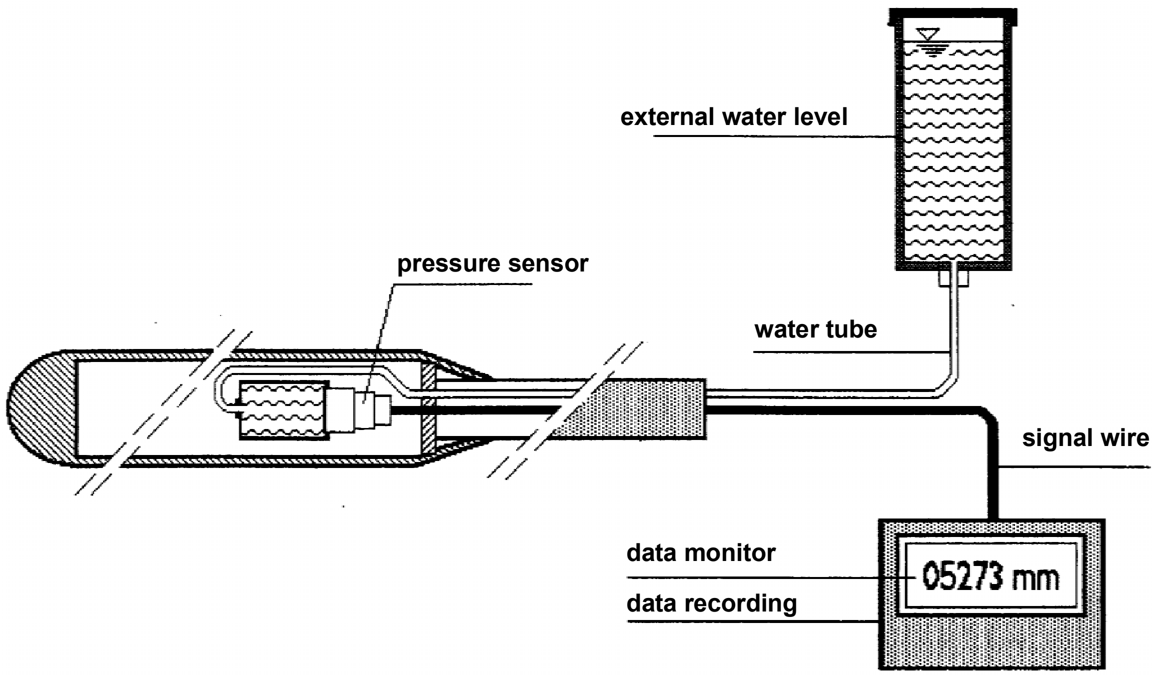

Figure 4: Pysical principle of hydrostatic elevation measuring

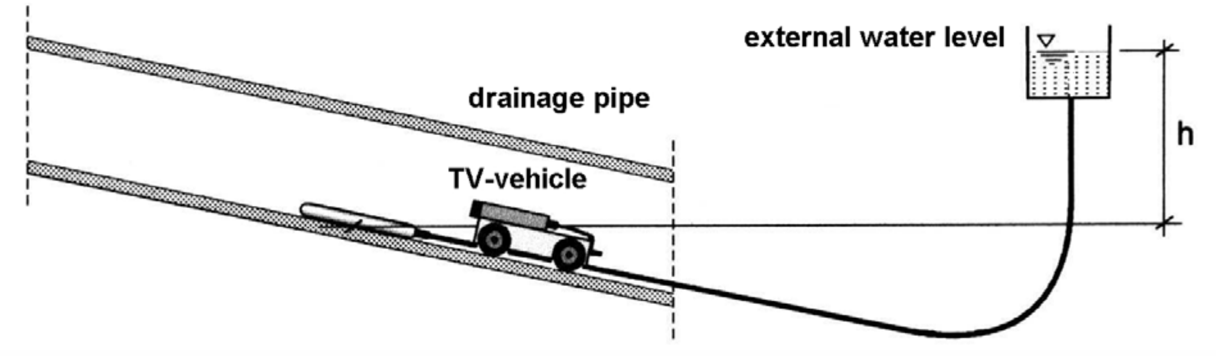

Figure 5: Measuring procedure

To enable measuring the pipe elevation, the hydrostatic sensor needs to be transported into the drainage pipe. This procedure can be realized using the TV-vehicle as shown in Fig. 2,3 and 5. Alternative transportation systems are pulling ropes (provided both sides of the pipe are accesable) or direct pushing methods by rods. Once the sensor has been placed at the first measuring point in the pipe, the elevation measuring can start immediately. The water pressure applied by the constant external water level via the water tube, is proportional to the elevation difference between the water level and the altitude of the measuring point. In free fixable intervalls (usually between 0,5-2 m) more data are collected. Provided the msl altidtude of the water level or of one measuring point is given, the entire data can be referred on msl.

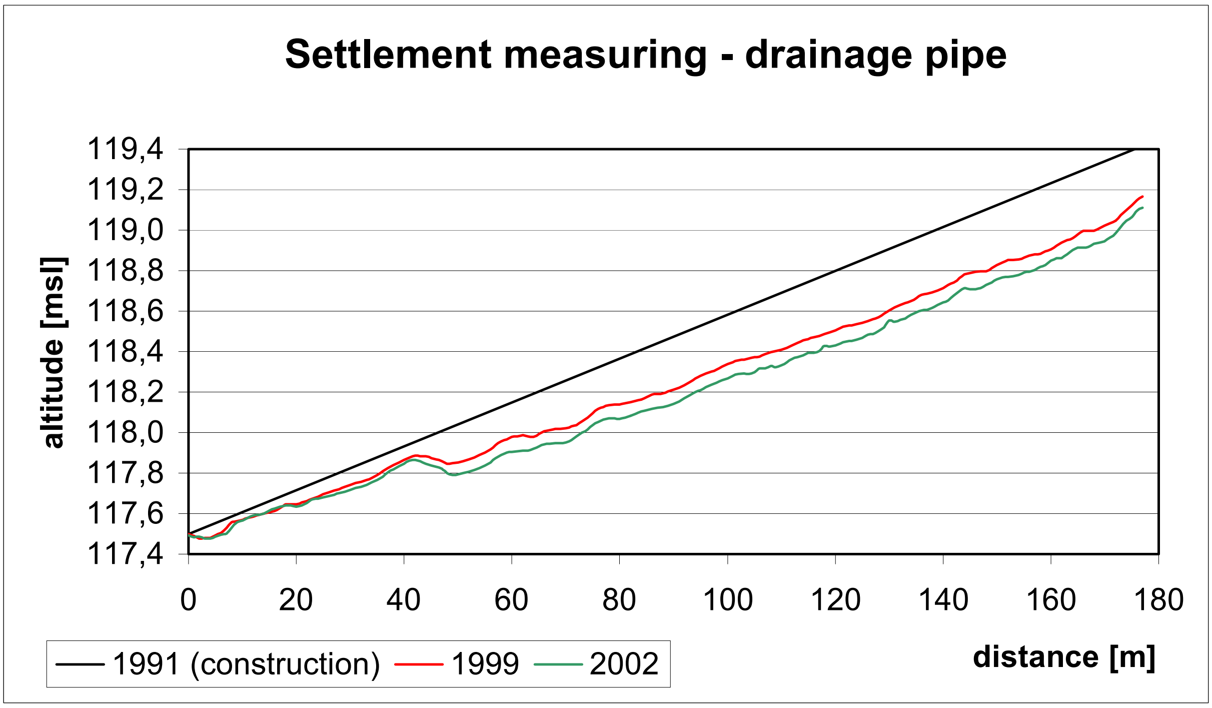

Figure 6: Results of settlement measurings in drainage pipe

Figure 6 shows the result of settlement measurings in a drainage pipe. The pipe elevation has been measured twice in 1999 and 2002. To evaluate the overall settlement, the results were compared to the elevation after construction. As it can be seen, total settlement ranges between 10 cm and 30 cm. Between 1999 and 2002, only the inner part of the landfill base (distance to end of pipe: 40-160 m) shows settlements related to higher normal loads. The differences in settlement causes a critical mechanical situation around the point located at 40 m distance.

Settlement measurings are also possible inside the landfill, as long as an access is available, e.g. via a settlement measuring pipe. Figure 7 shows the result of a 15 year monitoring of a settlement pipe. The pipe has been installed in 1988, when the landfill was filled with waste not more than 5 m thick. Meanwhile, the landfill has grown 20 m high, the load on the settlement pipe has reached 15 m waste (equal to 120-150 kN/m^2). The maximum total settlement exceeds 2,50 m or 50%. Although under heavy load and large vertical deformations, the pipe, an 80 mm (3'') PE-HD pipe, pressure level PN10, is still in function. A camera inspection in 2002 obtained that the shape has changed from round to oval, but still an effective diameter of at least 50 mm is available. The result demonstrated impressively, that the waste settlement can not be monitored from the surface, where the huge settlements had not been recognized at all..

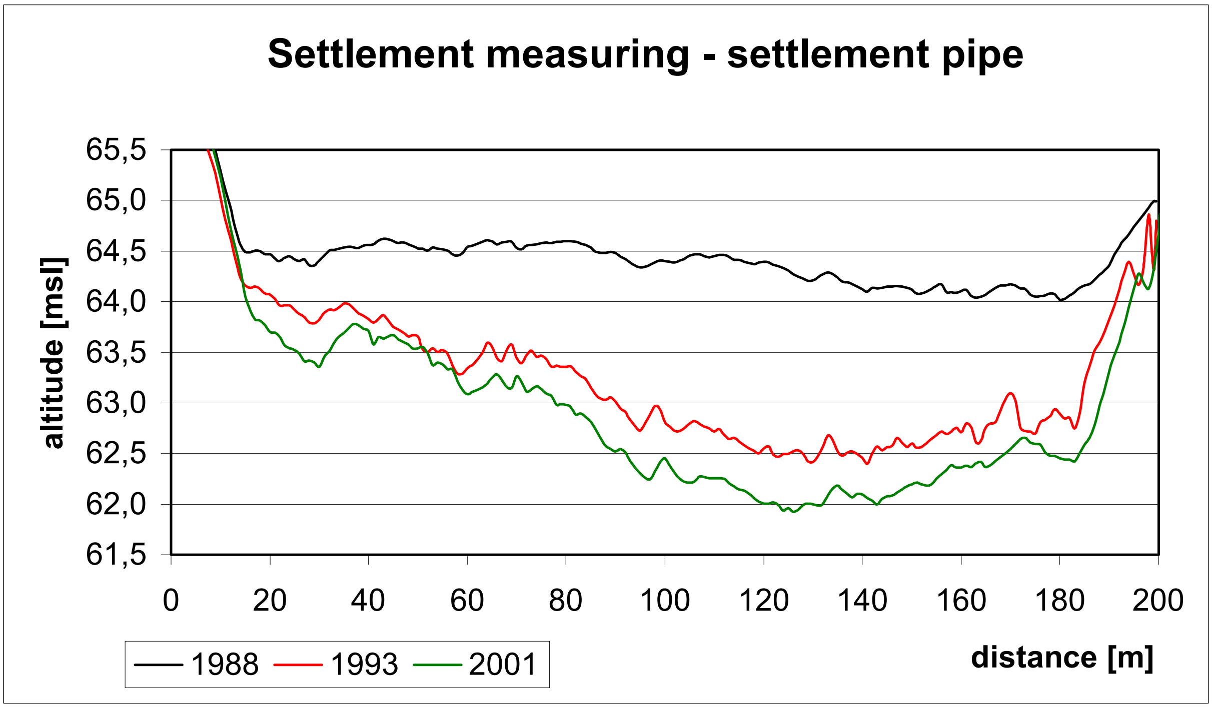

Figure 7: Results of settlement measurings in a special settlement measuring pipe

new developments: in-pipe leachate discharge measurement

Although landfill operators used to be reluctant on spending money for monitoring, however, when they got in trouble, they are asking for new monitoring devices providing more information on what is going on inside their "black box" landfill. Leachate amount and water balance are big issues. A disorder of leachate flow inside the landfill and towards the drainage system may rise huge problems: A rising water level inside the landfill can block gas generation, can reduce landfill stability dramatically and can create problems, if a leachate circulation process is operated. Within the DFG collaborative research center SFB 477 "Life cycle assessment of structures via innovative monitoring" (herein the subproject D: "monitoring and evaluation of landfills"), scientists from the Technical University Braunschweig developed a new device for measuring the leachate discharge inside a drainage pipe (**Ziehmann et al., 2002**). The brand new device allows measuring the leachate discharge at any free selectable point inside the pipe. Checking several points in a certain pipe, the discharge versus the location can be determined. That offers the opportunity to collect informations on the distribution of leachate inside the landfill.

Although the physical principle of the measuring method is simple, the technical application was difficult to achieve. The leachate discharge is measured by a spillway weir, which is amounted on a TV-vehicle. The TV-vehicle carries the weir into the pipe to the anticipated measuring point. Using the capability of the vehicle to lift its front part up and down as shown in figure 8, the weir is placed at the measuring point in a matter that the leachate flow is retained completely behind the weir and is directed over the spillway. If the correlation between the water level behind the weir and the fluid discharge is known from laboratory tests, the discharge at the measuring point can be measured by monitoring the water level. The water level behind the spillway is visible in an corresponding water tube (storage tube) in front of the weir.

Figure 9 provides an view from the camera on the operating device. The leachate flows over the spillway, on the right hand of the spillway the storage tube and the measuring meter can be seen. The current water level behind the spillway is about 35 mm. The current outflow, obtained from the laboratory calibration curve, amounts about 7 l/min. The devices allows measurings in a range from 100 ml/min to 10 l/min, depending on the shape and the size of the spillway. The accuracy is limited by the visual ability to read the meter scale. Since the unit weight of the leachate effects the hydraulic energy, parameters effecting the unit weight need to be monitored, too. Therefore, the electric conductivity and the temperature of the leachate is conducted (figure 9: display on the left side of the spillway). The results can be used to select the appropriate spillway calibration function.

Figure 10 gives an idea about the potential of leachate discharge measuring. At a landfill in Lower Saxony (Germany), the landfill operator recognized a reduced leachate amount. Only one data was available, the total amount of leachate for the entire landfill, measured as intake at the waste water treatment plant. The operator was wondering, whether the leak of leachate was indicating an rising water level inside the landfill, especially in the non-covered, operated areas, a situation, which probably could create stability problems. These areas had an extension of about 2 ha (20.000 m^2 or 5 acres) and they were supposed to deliver between 10 and 20 m^3 leachate per day, collected in 3 drainage pipes. In one of the three pipes, leachate discharge measurings were conducted, the results are given in figure 10.

Figure 8: TV-vehicle with amounted weir and spillway - lifted (above) and lowered (below)

Figure 9: camera view on the operating weir and spillway inside the pipe

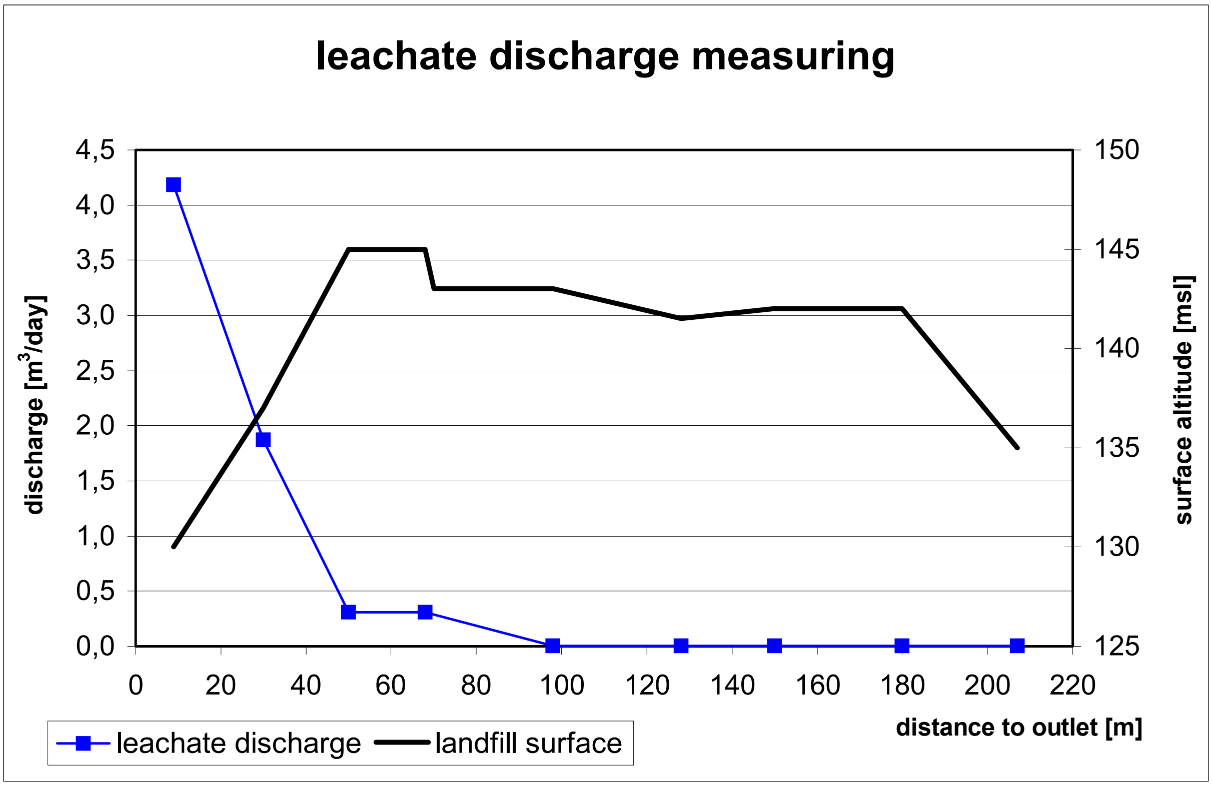

Figure 10: Results of leachate discharge measuring

The total leachate discharge of the pipe (discharge measurement at the outlet of the pipe) was determined to about 4 m^3/day. An value of 3,5 to 7 m^3/day was expected, corresponding to 1/3 of the expected total leachate amount of 10 to 20 m^3/day for the entire operated field. Therefore, the result was in the lower range but still acceptable. On the other hand, the leachate discharge profile (leachate versus distance from outlet) as shown in figure 10 (blue line and markers) was surprising. Half of the operated field (from 100 to 200 m distance from outlet) did not contribute any leachate by vertical water flow. More than 90 % of the leachate entered the drainage pipe at the last 50 m before outlet. Two conclusions could be drawn from the results: Extended parts of the operation field do either not deliver any water or the leachate runs laterally forced by any kind of barrier effects (e.g. capillary or impermeable layers, blocked by gas) inside the waste. Monitoring efforts at this side are not finished, yet, to clear all questions on the water situation.

Acknowledgement

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References

Ziehmann, Münnich, Fricke (2002): Leachate discharge measurement via spillway weir and TV-camera. 12th European Water, Sewage and Solid Waste Symposium, IFAT. GFA (eds), Hennef.