New experiences with drying effects in covered landfills and technical methods for controlled water addition

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1 Introduction

In the last years more and more completed landfills are provided with surface sealings in Germany. For the completion of a landfill, a surface sealing by means of a plastic sealing foil as central sealing element is often applied. This is mainly carried out to minimize the climatic leachate formation.

With these surface sealing measures a partly significant decrease of the landfill gas production could sometimes be ascertained only a few month after the application of the sealing. Two principle explanation attempts are often given for this unexpectedly strong decrease of the landfill gas production:

- the decreasing gas quantities can be put down to the fast decrease of the biologically convertible substance and have been predicted to be higher beforehand,
- the waste is too dry due to the missing rainwater and a reduced gas production is the consequence. The gas potential in the waste body is still high.

It is supposed that one of the main reasons in the second explanation attempt is the limited water movement in the landfill body and drying effects which lead to a decrease of the biodegradation processes of the organic waste constituents. This can lead to an unintentional conservation (momentary "dry stabilization") of the remaining emission potential of the landfill. On the long-term, redevelopment measures might become necessary when water finds its way into the landfill - because of a damaged surface sealing - and uncontrolled pollutant emissions take place via the leachate- and the landfill gas path.

With this background, the question arises whether the biodegradation processes and thus the gas production can either be kept up or even be optimized by controlled moistening measures below the surface sealing. For an unsealed landfill bottom, such measures would have to be realized taking into consideration the landfill-specific conditions – such as the reduction of the leachate outflow.

2 Objectives of the measures for a controlled moistening

In conventional household waste landfills which are completed with bioavailable organic waste, a degradation (controlled to the largest possible extent) of these organic constituents within short periods shall be achieved. By that, the hazardous potential of these landfills shall be minimized as far as possible. Furthermore, a long-term environmental acceptability shall be attained.

Thus it is tried to reach the following goals by a controlled moistening and irrigation of landfill sections:

- Avoidance of an unintentional delay of the reaction processes in the landfill body due to water famine and desiccation effects.
- Accelerated in situ stabilization of the deposited waste for a lasting reduction of the emission potential and of the resulting hazardous potential of the landfill. This is done via initiation and optimization of biological-chemical conversion processes which are to lead to an accelerated degradation of the organic waste components to landfill gas. The increased landfill gas production should be collected and utilized in a controlled way.
- Reduced costs with regard to the long-term after-care phase by controlled reduction of the emission potential and of the hazardous potential – that means
  - less aftercare measures over a shorter period,
  - significantly reduced risk concerning a cost intensive need for redevelopment on the long-term due to renewed pollutant.

3 Fundamental proceeding regarding controlled moistening and irrigation

The biological stabilization can range from a moistening of the landfill body for the acceleration of the biological conversion processes in the aerobic or in the an

aerobic milieu to an intensive irrigation – that means to an extraction of the pollutants by means of an increased water exchange.

With regard to the absorbing capacity of the non-water-saturated landfill body, water is only added in a way that considerable leachate outflows to the landfill bottom or to the underground do not take place during the moistening.

Especially when a bottom sealing is missing, it should be taken into account that the water quantity does not exceed the capacity of the upper landfill section in order not to produce considerable leachate outflows to deeper parts of the landfill or to the underground. Thus the controlled moistening cannot be compared with leachate recirculation – often practiced in the past.

As an example, Figure 1 shows the moistening of a new landfill section via a horizontal moistening system integrated into the surface sealing to intensify the conversion of bioavailable waste substances.

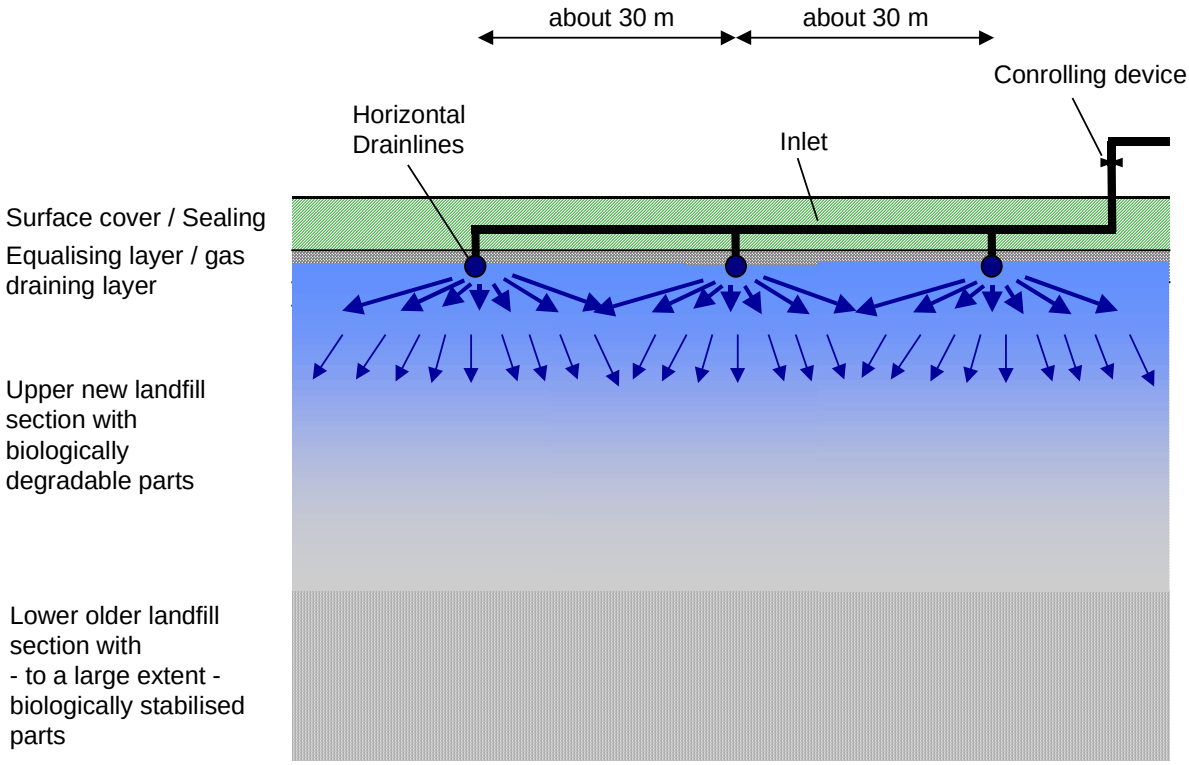

Figure 1 Spreading behavior of the applied water for the moistening of a landfill section, schematic representation

In contrast to that, the leachate formation rate is strongly increased in an artificial way in the "flushing bioreactor" (Walker et al., 1997; Blakey et al., 1997) by adding purified waste water or process water so that a very good leachate collection system is absolutely necessary. A leachate collection system is also necessary if the acceleration of the anaerobic biological conversion processes shall be achieved by reinfiltration or recycling of leachate.

4 Technical processes for the infiltration of water into landfill sections

Basically, horizontal irrigation systems under the surface sealing or vertical irrigation systems such as irrigation by soil injection can be taken for infiltration. All measures are carried out taking into account the water balance of the whole landfill.

The following infiltration processes can be applied (see also Bayerisches Staatsministerium für Landesentwicklung und Umweltfragen, 1996):

- Use of available vertical gas collectors
- Installation of vertical wells to add water
- Installation of horizontal irrigation lines under the surface sealing
- Moistening via soil injection in shorter gaps
- Partially controlled moistening via climatic leachate formation due to slightly permeable surface sealing

As an example, Figure 2 shows the irrigation via vertical irrigation lances.

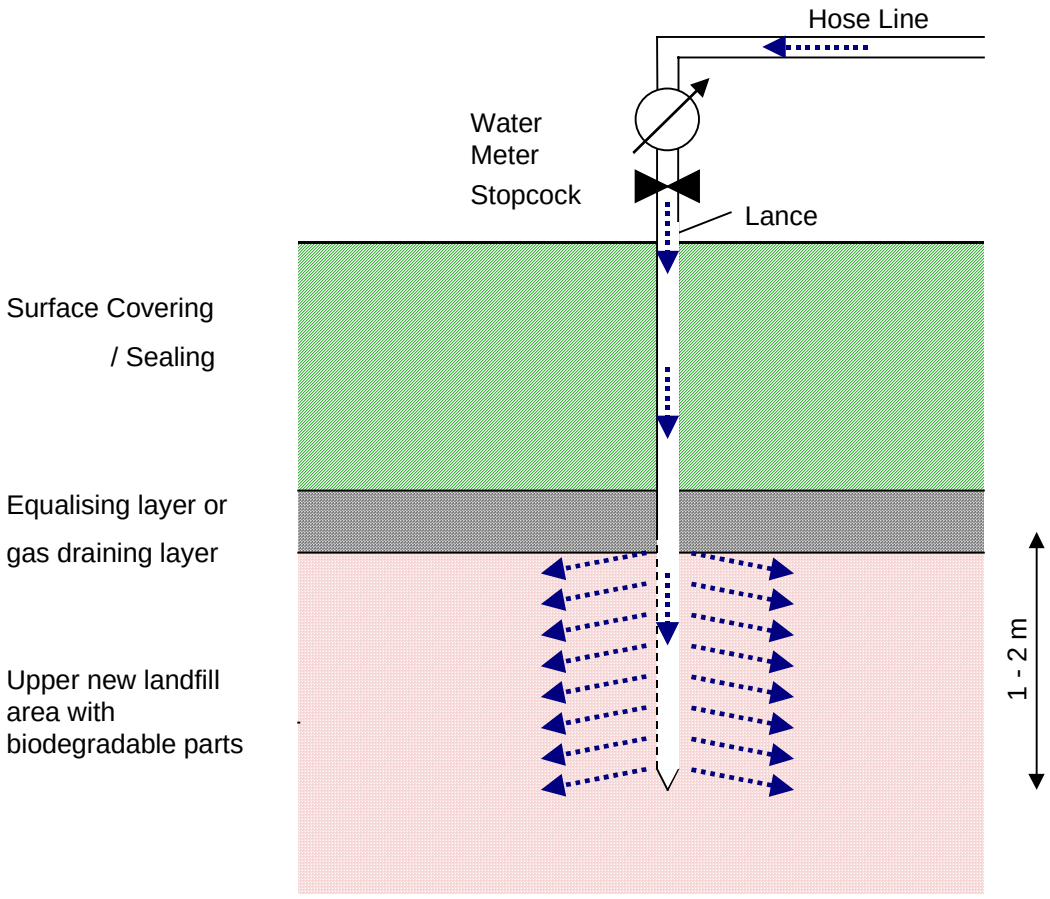

Figure 2 Irrigation by means of vertical lances; schematic representation (not to scale)

5 Experiences and investigation results concerning the controlled moistening

Many experiences regarding the influence of moistening- and irrigation measures on the water balance and on the emission behavior of landfills could be gained due to investigations on lab-scale, lysimeter tests and partly due to practical experiences. In Germany, the investigations were carried out i.a. by Cord-Landwehr, Doedens, Ehrig, Rettenberger, Spillmann and Stegmann (see bibliography). Mostly, it was not the reactivation of the biodegradation processes by means of a moistening of the waste body which was to the fore but the pretreatment of the highly polluted leachate obtained during the "acid" phase of a landfill in which the waste body was used as a fixed-bed-reactor.

On the whole, the positive effects of an optimally regulated moisture content on the degradation processes and on the landfill gas production become clear in the specialist literature. Only a few definite results could be achieved concerning the specific question of the influence of the surface sealing on the water balance in the landfill body and on the reactivation of dry landfill sections by means of irrigation measures. In the following, experiences and results of moistening- and irrigation measures are shown for different landfills.

5.1 Reinfiltration measures on landfill "B"

In many cases, a direct comparison between the landfill gas situation before and after the installation of a sealing cannot be drawn as a gas extraction system was only set up in the course of the surface measure. This makes a direct proof of the causes for the declining gas quantities more difficult.

Krümpelbeck and Ehrig (1998) reported examination results about a further reinfiltration measure on a MSW landfill "B". It has been carried out after the installation of a surface sealing since the gas production there was also significantly declining.

The area of landfill B temporarily covered with PE-foil was divided into single fields which have been watered one after the other with 15 – 30 mm each. The periods between the repeated water additions were between 4 and 6 month on average.

The investigation period of the reinfiltration measure was very short on the whole. The tests are carried on actually and long-term statements concerning function, technical practicability and prospects of success of these measures can only be made in a few years. After a repeated infiltration of 15 – 30 mm water into different fields, some of them showed considerable increases of the gas quantities (Figure 3). However, these were subject to significant variations. In contrast to that other fields did not show any enhancement of the gas quantities.

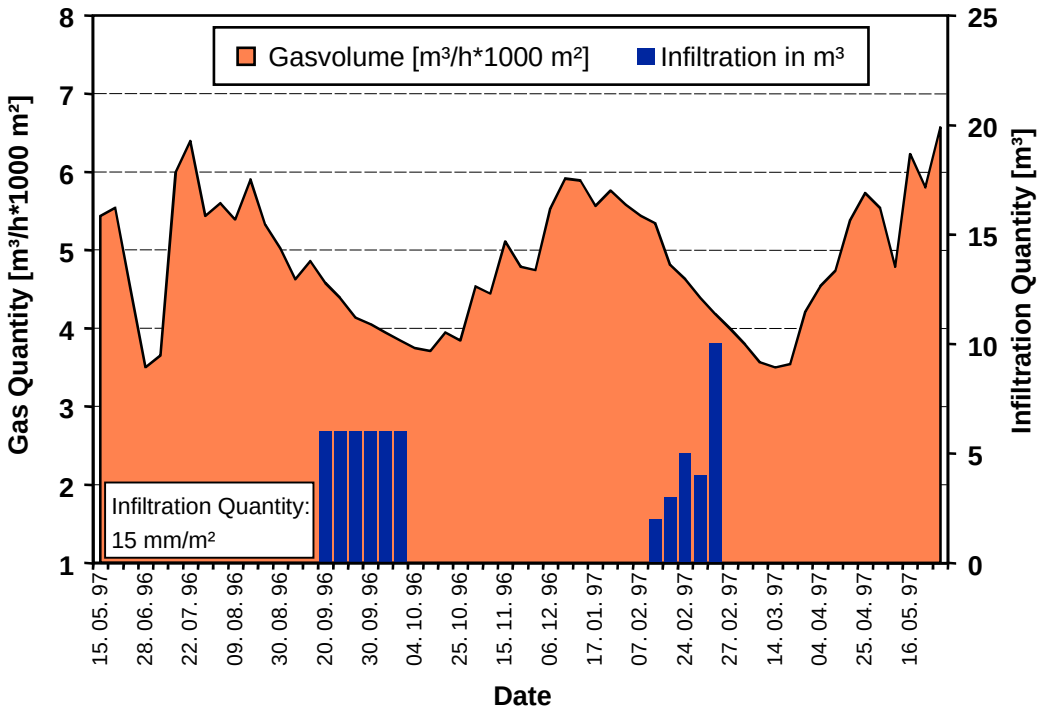

Figure 3 Landfill "B": Gas quantity development after infiltration, field 5 (Krümpelbeck and Ehrig, 1998)

Probably, the water quantity is not yet sufficient or an increase of the gas production can no more be realized for these fields due to their age or due to their waste composition. In all probability, the returned water did not enter into the lower layers of the waste body during the investigations. For this, the reinfiltrated water quantities were not sufficient.

In summary, Krümpelbeck and Ehrig (1998) stated that the reinfiltration measures on the landfill B led to an enhancement of the collected gas quantities but that only on some fields the return of 60 – 90 mm in total led to an increase of the gas extraction rate close to the surface. Furthermore, the gas quantities were subject to considerable variations. The reinfiltrated water quantity was not sufficient so that probably with a higher water return rate a lasting gas quantity enhancement can be achieved.

5.2 Influence of irrigation measures on the gas balance of landfill "D"

On landfill "D" the last landfill section was completed in 1993 and a surface sealing was installed shortly after. Basically, this is a mineral sealing layer with drain- and recultivation layer. Since 1996, the recorded landfill gas production significantly

decreased although over a period of years (since 1987) parts of the obtained leachate were recirculated via 11 horizontal drain lines. The question was if drying up effects resulted from the surface sealing which were responsible for the decrease of the gas production. Furthermore, the effect of the leachate recirculation on the biodegradation processes should be evaluated.

Figure 4 shows the development of the water balance since 1995 (Heyer and Stegmann, 1998).

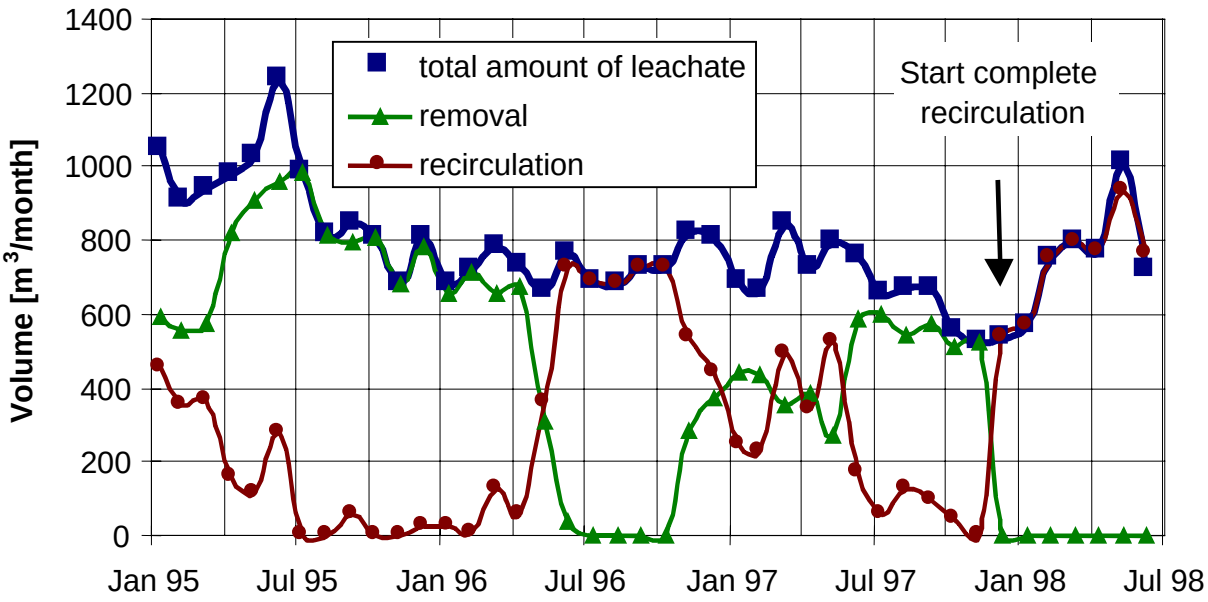

Figure 4 Water balance of landfill D from January 1995 to July 1998

The gas balance is shown in Figure 5. The collection rate decreased from about 600 m^3/h at 60 vol.-% methane before 1996 to under 300 m^3/h at ca. 50 vol. -% methane till July 1998. According to that, the energy output of the gas motors for the generation of electricity was reduced by more than 50% within 3 years. This is why only one to two gas motors are operated of the four gas motors in the beginning.

Presumably, this significant decrease of the landfill gas production did not occur in spite of the enhanced moistening of the landfill body – which was already carried out since 1987 - but because of it. In the years preceding the year 1996 favorable degradation conditions could probably be found in the landfill body so that a fast conversion of the bioavailable substance took place.

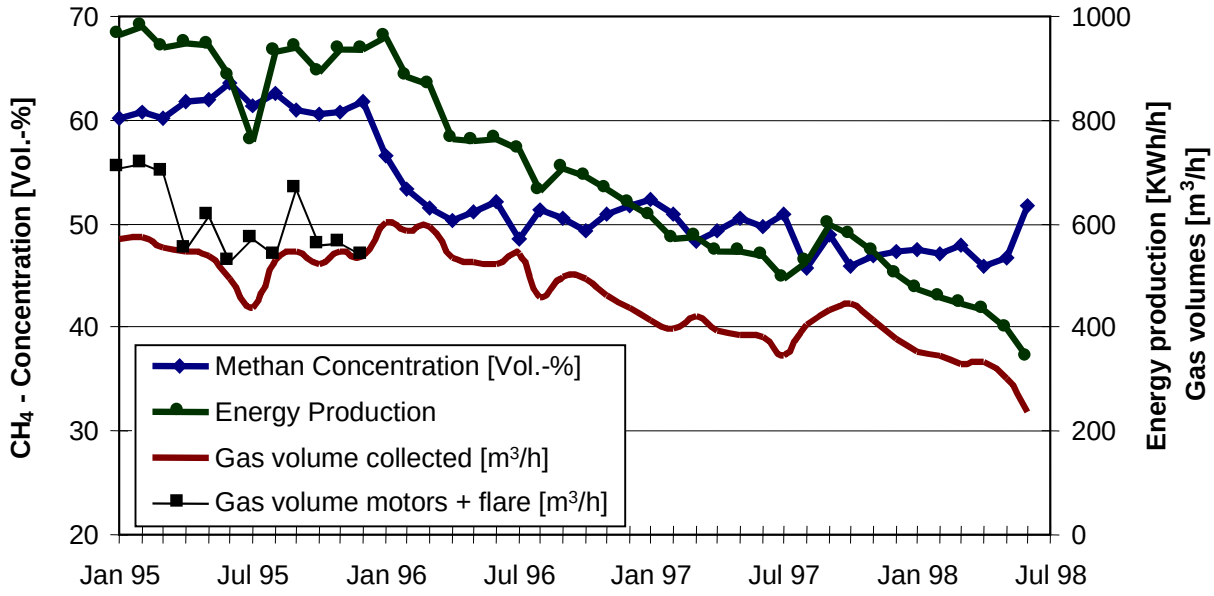

Figure 5 Landfill gas balance of landfill D from January 1995 to July 1998

Especially before 1996, the irrigation of landfill "D" had a significant influence on the gas balance and on the course of stabilization of the landfill body. Presumably, the biological conversion of the deposited organic waste substances could be enhanced in a way that the degradation processes already extensively progressed and that there was almost no available substrate left. Therefore, the irrigation over a longer period which was already carried out during the whole operation time of the landfill led to a faster decrease of the landfill gas production from 1996 on. From this moment on, the leachate recirculation did no more have an important influence on the landfill gas production.

6 Calculation and monitoring program for the irrigation

6.1 Solid investigations for the determination of the water balance and of the water volume to be injected

For the determination of the water volume to be added and of the addition intervals, solid samples can be taken from the landfill section to be moistened which are analyzed with regard to the following parameters:

- Determination of the **carbon content** of the solid samples: *Via the determination of the carbon content the quantity of existing bioavailable organic material can be assessed that can be converted into landfill gas.*

- Determination of the **water content** of the solid samples: *The water contents indicate dryer or more humid landfill sections and allow conclusions regarding the actual biological degradation and the landfill gas production*. *Thus a first assessment of the moistening effects to be expected is possible.*
- Determination of the **water holding capacity** of the solid samples: *The determination of the water holding capacity in connection with the comparison of the actual water content allows an assessment of the water volume to be added in the respective landfill section to achieve an optimal moistening.*

When carrying out the irrigation measure it has to be taken into consideration that an even water distribution as shown in the idealized form in Figure 1 and as implicitly included in the assumptions does not seem to be realizable to that extent. Especially the heterogeneity of the deposited waste can lead to an uneven water distribution in the landfill body and to water movements on preferential flow paths.

6.2 Monitoring program for the observation of the water- and of the gas balance

6.2.1 Control of the landfill gas balance

The biological activity of a landfill section can be determined by the landfill gas production and –composition. At the gas wells which are situated in the area of influence of the moistening measures and in not moistened reference areas, the following parameters should be determined:

- main landfill gas components [vol.-%]
- exhausted gas volume [m^3/h]
- gas trace components and physical properties of the landfill gas

6.2.2 Control of the water balance

The monitoring program for the control of the water balance can include several measures complementing one another:

- solid sampling before, during and – if need be – after the controlled moistening
- regular leachate sampling in selected gas wells as well as at level measuring points

- if need be monitoring program with regard to the ground water quality
- tracer tests during the water addition

7 Conclusions and recommendations

7.1 Conclusions regarding drying up processes and irrigation measures on sealed landfills

Although there is no trend indicating that a setback of the biodegradation processes and of the landfill gas production was ascertained on all landfills provided with an impermeable surface sealing – negative effects of the limited water supply on the processes in the landfill body could be proved.

First experiences were gained in the field of the controlled irrigation of landfill sections and of big landfill pilot fields. Even though the results differ from each other in detail it could be ascertained for all measures that an acceleration of the biodegradation processes and especially an intensification of the landfill gas production could be achieved.

7.2 Cost-saving possibilities by means of moistening- and irrigation measures

As a considerable reduction of the hazardous potential due to the significant emission reduction is the result of moistening- and irrigation of waste deposits the following cost-saving potentials turn out regarding landfill aftercare or redevelopment measures:

- On old disposal sites with a bottom sealing the costs and the duration of the leachate treatment – and thus the treatment costs – can be significantly reduced due to the reduction of the leachate impact as a consequence of the biological stabilization or of the extraction of readily soluble leachate portions ("flushing"-concept).
- As far as old deposits are concerned costs can be saved especially by the biological stabilization as a result of a moistening measure with regard to the ground water redevelopment and to additional securing measures.
- This can lead to a shortening of the whole aftercare period by several decades.
- An earlier recultivation and new utilisation is possible.

These cost-saving potentials are compared with the costs for moistening- and irrigation measures and it can be stated that on the medium-term and on the long-term costs can be saved with a lasting improvement of the environmental acceptability of waste deposition.

7.3 Recommendations

All examinations and evaluations have shown that each landfill has to be considered as an individual case to a certain extent so that it is difficult to compare the experiences gained with one landfill with those gained in another location. Therefore, before carrying out irrigation measures several preliminary tests have to be effected in landfill areas supposed to be dry (actual data regarding water content, water storage capacity and bioavailable organic waste material).

On the whole, the implementation of the controlled moistening is a demanding task for engineering technology. This is why a scientific assistance should be guaranteed for planning, implementation and documentation of the measures for a controlled moistening and irrigation.

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