THE LOW PRESSURE AERATION OF LANDFILLS: EXPERIENCE, OPERATION AND COSTS

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SUMMARY: The in situ stabilization of old deposits aims for a lasting and controlled reduction of pollutant emissions from the deposited waste in order to diminish expenditure and the duration of landfill aftercare measures. The stabilization operation so far, observed over a period of 1 – 2 years at three landfills in Germany, shows that leachate contamination is permanently reduced, biodegradation processes are significantly accelerated and main settlements take place within a short period of time.

1. IN SITU STABILIZATION FOR THE CLOSING AND AFTERCARE OF LANDFILLS

For operators of landfills, the closing and aftercare will be a central subject over the coming years. Decisions must be made with regard to the technical, economic and personnel organization of the closure and subsequent measures. In this respect, the most different initial conditions and requirements must be taken into consideration:

- Closure and, above all, aftercare will largely be determined by leachate and landfill gas emissions.
- All investigations and experience regarding the emission behavior indicate that aftercare will continue over several decades (Heyer et al., 1997).
- It must be examined, in which way the landfill may be induced into a low-emission state in such a manner that not only the installation of a final surface sealing appears useful, but that release from aftercare also becomes feasible.

The latter considered, the question arises of how to exert positive influence on the emission behavior of municipal solid waste (MSW) deposits in such a way that the duration and extent of aftercare measures may be reduced. For this purpose, two principal in situ stabilization methods may be applied, depending on the boundary conditions of landfills and old deposits (Figure 1):

- Humidification and irrigation methods, e.g. for younger waste deposits equipped with surface sealing, showing a higher proportion of bioavailable organic material for the intensification of

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anaerobic degradation processes (Hupe et al., 2003).
- Aeration methods, e.g. for older waste deposits res. for deposits showing a lower proportion of bioavailable organic substances and decreasing landfill gas production.

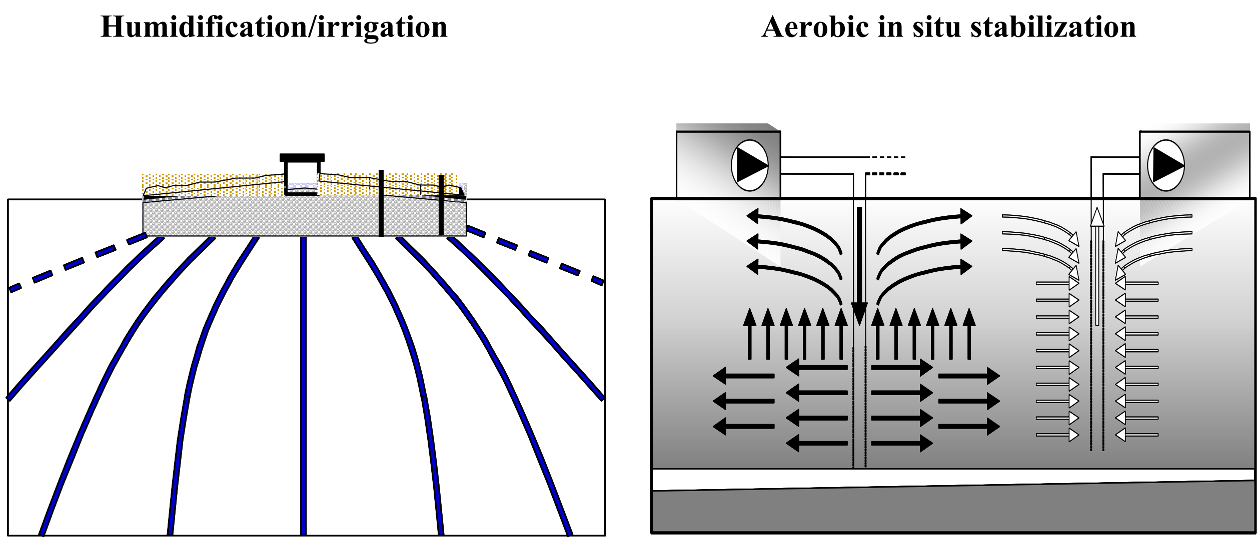

Figure 1. Methods regarding the in situ stabilization for the reduction of the aftercare

Meanwhile, aeration processes for the aerobic in situ stabilization are applied with success in Germany on the old Kuhstedt landfill in the Rotenburg (Wümme) district, the Milmersdorf landfill in the Uckermark district as well as on the old Neumühle deposit in Amberg (Bavaria). Common to all sites is the ultimate target: the controlled reduction of emissions and the resultant risk potential within a relatively short period of time in order to be able to undertake an economic site closure, aftercare or securing measures. In this respect, e.g. the final installation of a surface sealing adjusted to the low-emission landfill body is of great importance. It should be functional in the long term but still cost-effective. Surface sealings require high investment costs and maintenance and, just for this reason, offers enormous cost-saving potentials (Hupe et al., 2002).

In the following, experiences regarding low pressure aeration are presented, taking into consideration technical and economic aspects and contemplating the effects on the emission behavior.

2. BOUNDARY CONDITIONS CONCERNING THE EMPLOYMENT OF AEROBIC IN SITU STABILIZATION

The aerobic in situ stabilization may be employed where the following boundary conditions are met:

- low landfill gas production only (collection and treatment is still required but economic utilization of methane as an energy source is no longer possible), avoidance of a long-term and cost-intensive poor gas treatment
- prior to the installation of a surface sealing, in order to enable the anticipation of the main settlements and at low landfill gas production in order to avoid concentration and gas migration
- prior to any development measures to be taken, or at any existing development where the

subsoil and any intensely used surrounding fields should be kept free of landfill gas

- as regards landfills with bottom sealing: decreasing leachate contamination which, in the long term, still exceeds the requirements of the 51^{st} appendix of the German Waste Water Ordinance (AbwV, 1997)
- as for landfills without bottom sealing: increased risk potential exists due to the subjects of protection thereby concerned (e.g. ground water, surface water)
- as regards old deposits: missing technical barriers where subsequent securing measures (surface sealing, vertical slurry walls etc.) would be too cost-intensive or technically impracticable

3. TECHNICAL REALIZATION OF THE AEROBIC IN SITU STABILIZATION USING LOW PRESSURE AERATION

3.1 Technical concept of low pressure aeration

The *basic technical concept* of the aeration of the landfill body consists of a system of gas wells, through which atmospheric oxygen is led into the landfill body via active aeration in such a way that an accelerated aerobic stabilization of deposited waste is realized. Simultaneously, the low-contaminated waste gas is collected and treated in a controlled manner by means of further gas wells. Aeration is effected using low pressures and is continuously adjusted to meet the oxygen demand so that energy consumption is low and constantly optimized.

Figure 2 shows the arrangement of the technical installations for aeration and waste gas collection at the old Kuhstedt landfill.

Each of the 25 *gas wells* is connected to a distribution station by means of separate mains. There, the mains may be connected to the distribution system for aeration or to the system for the collection of waste gas.

Aeration via the gas wells: Aerobization of the area of influence of each gas well is guaranteed by the adjusted excess pressure, respectively by the added air volume.

Waste gas collection via the gas wells: By means of adjusted negative pressure, waste gas is continuously sucked within the area of influence of the gas well so that uncontrolled waste gas emissions via the landfill surface respectively gas migration via soil vapor path into the neighboring subsoil are kept at a low and acceptable level.

Separate mains connect the gas wells to the distribution station for the distribution of added air respectively for gas collection. The installation of the separate mains took place on the existing provisional surface covering. Uneven spots were adjusted when required and a planum was produced to serve as location route. They were installed with a continuous slope and covered with 30 cm of soil material.

Three *distribution stations* allow the connection of the separate mains to the main aeration ducts (air supply) and with the main gas extraction line (waste gas collection for a waste gas treatment). Furthermore, they include armatures (valves, ball stop-cocks etc.) for each separate main and for the trunk mains for supervision and control.

The *distribution network for aeration* is connected with the compressing unit for aeration by the main supply duct. The *gas collection system for the collection of waste gas* is provided with a condensate separator and connected to the compacting unit for the collection of waste gas by the main suction duct.

Compressing unit for aeration and collection of waste gas: Design and operation of the aeration- and waste gas collection devices are chosen in such a way that, under normal automated operation,

- no explosive atmospheres are to be expected on the waste gas side,
- a high level of utilization of the added oxygen is achieved – meaning that oxygen concentration is low in the waste gas.

Waste gas cleaning: As a matter of principle, the contaminated waste gas may be purified by means of biowashers and biofilters or by adsorption on activated carbon and by noncatalytic, autothermic methods.

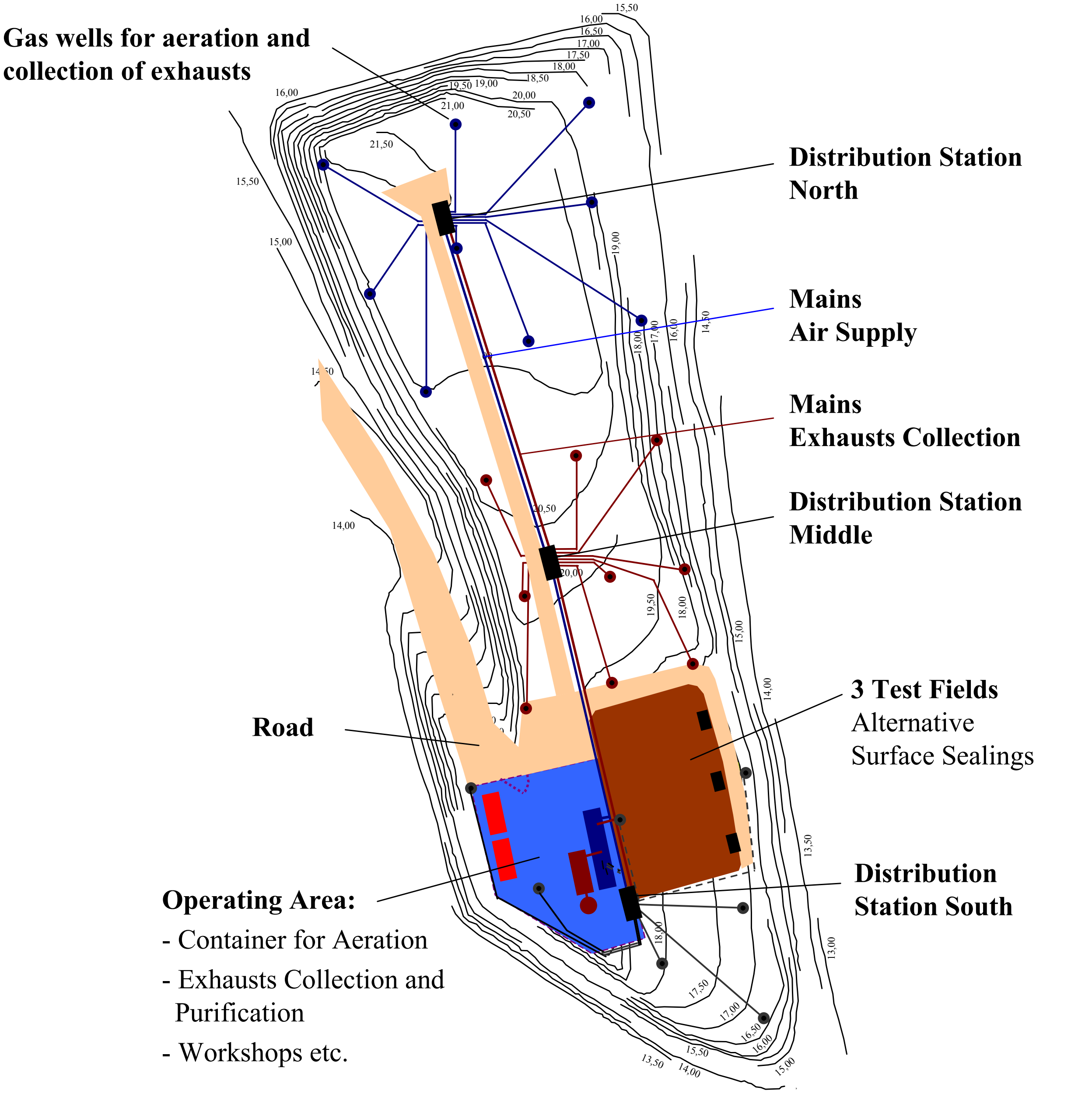

Figure 2. Master plan of the installations for in situ stabilization of the old landfill in Kuhstedt (Heyer et al., 2000)

3.2 Processes and effects during aerobic in situ stabilization

In principle, the following processes proceed during aeration in the landfill body (Heyer et al., 2000 and 2002; Ritzkowski et al., 2000):

- A change from anaerobic to aerobic milieu conditions takes place, resulting in an accelerated and, in part, further-reaching degradation of the bioavailable waste components. The increased carbon conversion during in situ aeration therefore leads to a faster stabilization of organic substances.
- At the end of the stabilization process, organic compounds only consist of hardly or non-degradable compounds with a very low residual gas potential.
- As a result of the accelerated biodegradation processes, the anticipation of the main settlements is also accelerated.

Effects on the water path:

- In the leachate path, accelerated decrease of the parameters of COD and, above all, BOD_5 as well as nitrogen (TKN res. NH_4-N) occurs with the aerobic degradation of organic compounds and their release into gas phase (mainly as carbon dioxide) as a result of aeration.
- Compared with strictly anaerobic conditions, the aftercare periods for the leachate emission path are reduced by at least several decades under in situ aeration. The after-care phase is not considered complete after aeration has been terminated but the after-care expenditure is significantly reduced as costly leachate purification measures may be terminated earlier. If leachate percolated directly into the underground as is sometimes the case in old deposits without sealing and drainage systems for the collection of leachate, the polluting effects would be considerably lower.

Effects on the gas path:

- Particularly the carbon dioxide formation rate is enhanced by accelerated carbon degradation.
- Avoidance res. reduction of the methane content in the exhaust air (reduced gas production in old deposits at the end of the stable methane phase), thereby reduced risk of explosion, for example, and lower expenditure with regard to long-term waste air treatment.
- In solid waste samples of “landfill simulation reactors”, the carbon discharge res. the degradation of organic substances during aeration were 1.5 to 5 times higher than during the reference period under anaerobic conditions (Heyer, 2003).

4. RESULTS AND EXPERIENCE REGARDING STABILIZATION OPERATION

In situ aeration operation is planned for a period of 2 to 4 years at average landfill conditions. Meanwhile, results and experience concerning the operation of stabilization are available on the sites for a period of 1 to 2 years. The latter are presented exemplarily for the following fields:

- effects on the leachate/ground water contamination
- effects on the gas balance
- effects on the settlements
- effects on temperatures

4.1 Effects of in situ stabilization on the leachate contamination

Experience has been gained with aeration operation over a period of 24 months at the old Kuhstedt landfill (Ritzkowski et al., 2002):

- The results of the monitoring of the old Kuhstedt deposit confirm the aforementioned development of the processes and effects in principle.
- Changes in the consistency of the aquifer may be detected, e.g. enhancement of the redox potential, oxygen content and pH value as a first step towards the reduction of the contamination with organic compounds and nitrogen.

- Figure 3 shows the development of the nitrogen contamination in the ground water off-flow using a test level installed at the edge of the landfill. From the outset of aeration in April 2001, a considerable decrease in the nitrogen contamination may be ascertained after one year of stabilization in spite of several deviations.

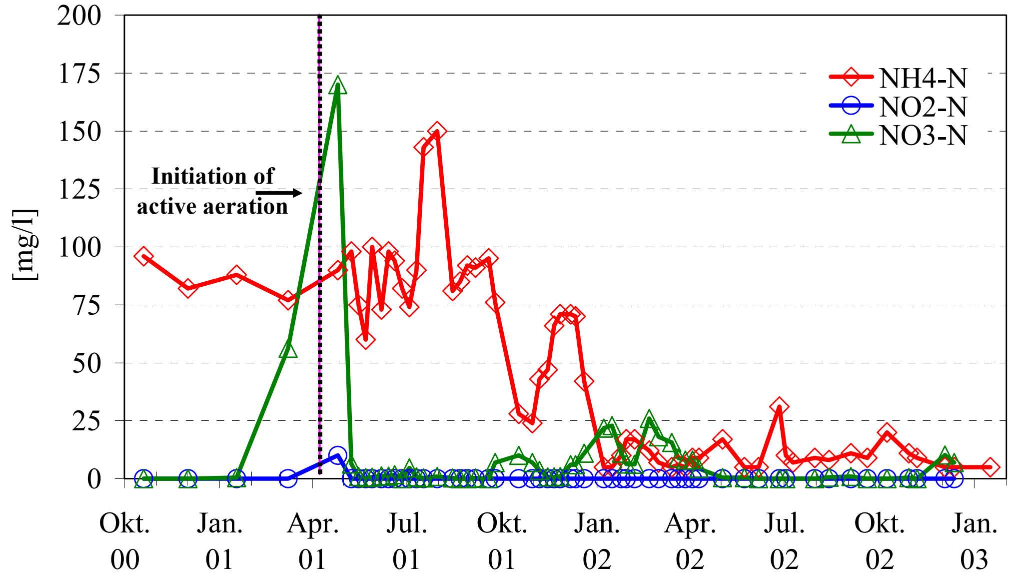

Figure 3. Development of the leachate contamination within the off-flow area at a ground water measuring point during in situ stabilization at the old Kuhstedt deposit

4.2 Effects of in situ stabilization on the gas balance

The effects of in situ stabilization on the gas balance may be detected when examining the total waste air flow in the gas compressing station as well as individual gas wells.

Figure 4 represents the landfill gas composition for the Milmersdorf landfill before the starting up of in situ stabilization and for the first 10 months of stabilization to follow.

Before the initiation of the stabilization, the methane contents at the gas wells were found to be between 50 and 80 vol.-%. The carbon dioxide contents ranged around approx. 20 vol.-% at all gas wells where no oxygen was available. During a relatively short suction operation period, decreasing tendency with regard to the methane content could be observed in all gas wells. Aeration which was started in June 2002 is now clearly recognizable. The rapid decrease in the methane concentration at almost constant carbon dioxide content levels clearly shows the influence of the aeration measures. Carbon discharge is now accelerated.

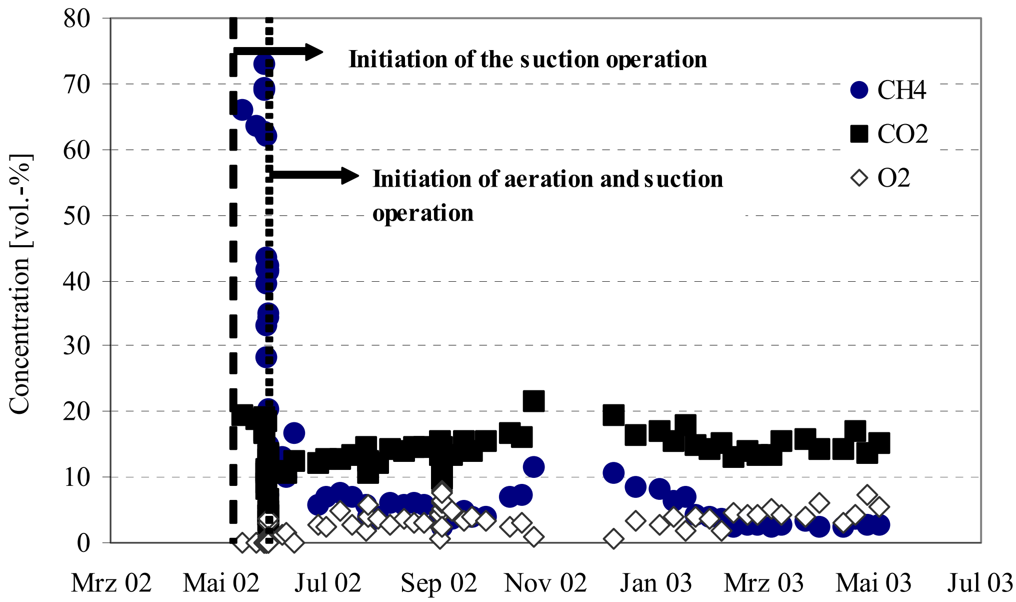

Figure 4. Gas composition at the waste air collection at the outset and during the stabilization process in the Milmersdorf landfill

4.3 Effects on settlements and temperatures

Until present, considerable settlements were found to be within the decimeter range at all three landfill locations. This may be attributed to the accelerated mass degradation and the weakening of the structure produced by the remaining waste matrix. After an aeration period of just under 2 years at the old Kuhstedt landfill, settlements or subsidence between 15 and 70 cm res. 1.7 and 8% regarding the landfill height took place as is shown at several settlement levels in Figure 5.

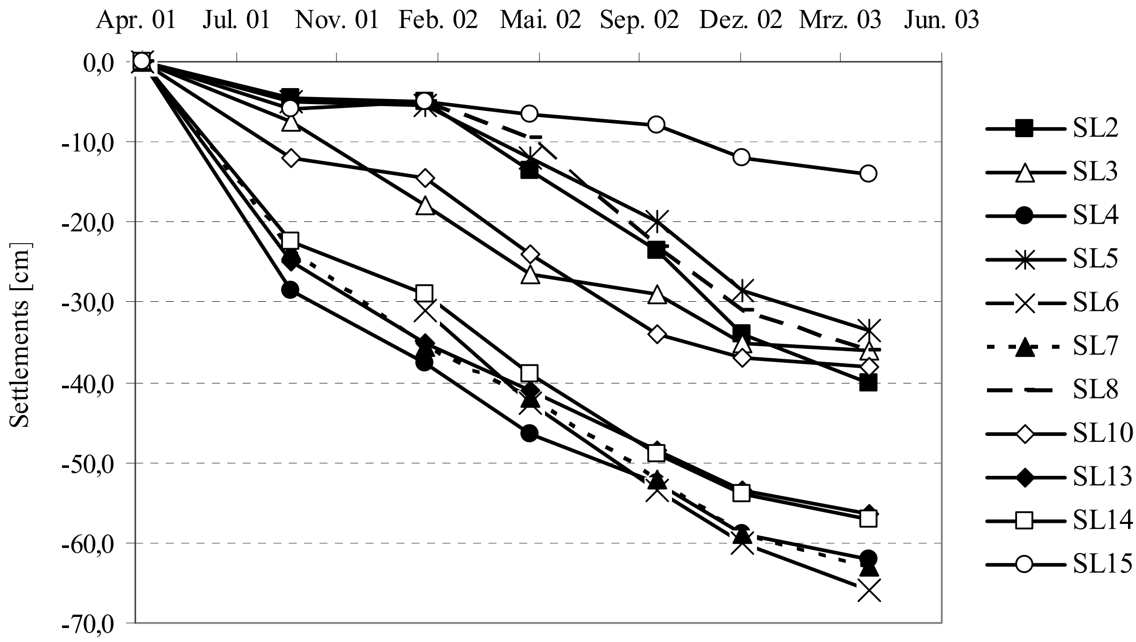

Figure 5. Course of the settlements subsequent to the commencement of in situ stabilization at the old Kuhstedt landfill in April 2001

Further experience with regard to in situ stabilization: Aerobic in situ stabilization leads to temperatures in the landfill body which lie mainly between 35 and 50°C. Figure 6 shows an exemplary temperature distribution in the middle landfill zone of the old Kuhstedt deposit, indicating the temperature stratification over the depth of the landfill body as well as the little influence of the outside air temperature. Appreciable rises in temperature up to the thermophilic range (50 – 70°C), as known from composting, occurred in a few landfill sections of the Kuhstedt and Milmersdorf deposits over a period of several months. Temperature developments in their entirety are unequivocal indications for thermal energy being released as a result of intensive aerobic conversion processes.

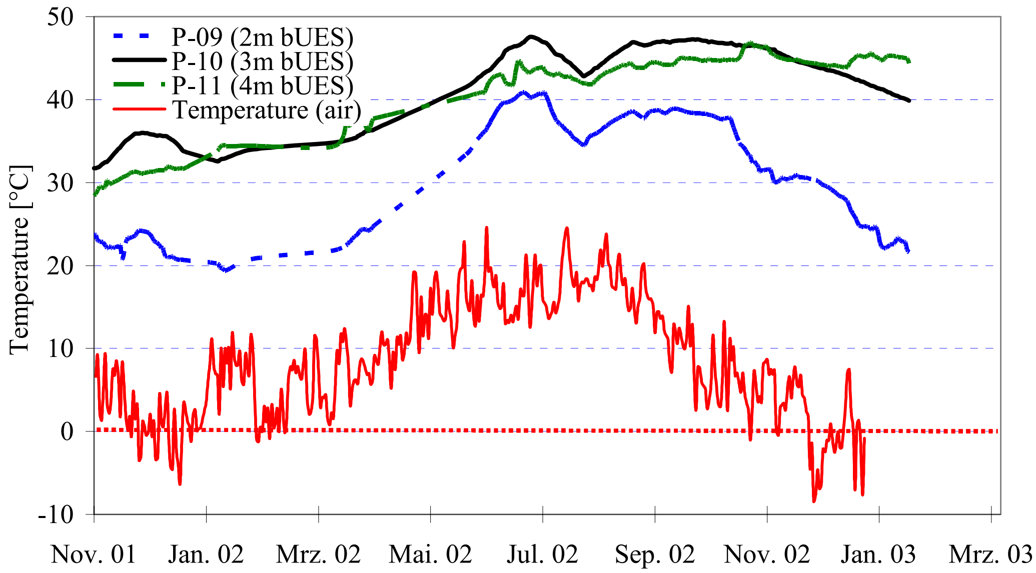

Figure 6. Course of the temperature development in the middle landfill zone subsequent to the outset of in situ stabilization in April 2001, at the Kuhstedt landfill (bUES = below upper edge of surface)

5. COSTS AND COST SAVINGS BY MEANS OF AEROBIC IN SITU STABILIZATION USING LOW PRESSURE AERATION

5.1 Costs of low pressure aeration

In dependence on the technical expenditure regarding aeration devices to be determined site-specifically, on the duration planned for stabilization, aeration capacity and other general set-ups, the costs for landfill stabilization may vary considerably.

Table 1 indicates the basic costs of the three projects operating at present as regards aerobic in situ stabilization using low pressure aeration.

The projects operated at present with regard to landfill aeration and accelerated stabilization will lead to estimated basic costs of € 650,000 for investment and operation, this lying within the order of magnitude of 1 – 3 €/m^3 (Table 1), in relation to the total landfill body volume to be stabilized. Flat allowances and generalized indications are impossible as landfills, apart from the volume, show very different boundary conditions and requirements (oxygen demand, thickness of the deposition, lengths of the ductworks, number of gas distributing stations, development situation, infrastructure etc.).

Table 1. Basic investment and operating costs for three sites regarding aerobic in situ stabilization using low pressure aeration

Component / Capacity	Kuhstedt	Amberg	Milmersdorf
Investment and operating costs (net)*)	€ 650,000.00	€ 650,000.00	€ 640,000.00
Landfill volume (in total)	220,000 m^3	420,000 m^3	580,000 m^3
Specific costs (related to m^3 landfill volume)	3.0 €/m^3	1.5 €/m^3	1.1 €/m^3
Aeration capacity max.	2400 m^3/h	900 m^3/h	2400 m^3/h

*) Net costs for infrastructure, construction site equipment, gas wells, ductworks, gas distributing station, compressing station, waste air treatment, operating costs for 2 – 3 years, not including monitoring measures, planning, approval certificates, reporting, documentation

Stabilization using low pressure aeration will take 2 – 4 years in all probability. The structural and technical expenditure of the three projects is slightly higher. As sponsored pilot projects, they were provided with more equipment for scientific attendance and with technical add-on devices for a more extensive monitoring program. Costs of approx. 0.5 - 1 €/m^3 landfill content are estimated at optimized and standardized stabilization operation, provided that the local conditions are favorable to average. Costs may only increase to up to 2 – 3 €/m^3 landfill content in cases where the general conditions are unfavorable to middling (e.g. very small old deposits without existing infrastructure).

The costs for the aerobic in situ stabilization using low pressure aeration must be opposed to considerable cost-saving possibilities as regards landfill closing and aftercare which affect the determination of the required provision of capital:

- Replacement of a cost-intensive surface sealing by an alternative long-life surface sealing which is adjusted to the low-emission landfill body and, therefore, lower expenses, particularly for the maintenance of the latter.
- Lower expenditure with regard to the ground water decontamination of old deposits and to technical securing measures.
- Lower operating costs as regards leachate purification and earlier termination of the latter in landfills with bottom sealing.
- Avoidance of lasting diffuse gas emissions which may require poor gas treatment, possibly evoke danger of explosion and pollute the atmosphere.
- Reduction of the aftercare period by at least several decades.
- Earlier recultivation and after-use, this being of increasing importance, particularly in congested urban areas.

Therefore, considerable cost-saving potentials must be set off against the costs for aeration measures so that cost reduction may be expected in the medium and long term. Calculations show that by means of stabilization, total cost reductions of 10 to 25% are possible as regards closure and aftercare measures.

5.2 Aerobic in situ stabilization as service

The technology and operation of low pressure aeration are continuously optimized, based on the experience gained. There are additional cost reduction possibilities in cases where technical equipment, such as the compressing systems for aeration and collection of waste air or waste air purification aggregates, is rented or leased for the duration of the stabilization measures. Furthermore, the stabilization operation of the plants including monitoring and documentation may be realized using external services.

Leasing of the technical equipment over a limited period of time or in situ stabilization as full service offers the following advantages to landfill operators (Hupe et al., 2003):

- Integration of the comprehensive know-how of the service provider.
- Very low or even no investment costs at all: no financial risks.
- Financial demands are eked out, financing may possibly be covered by parallel after-use or by subsequent higher-order after-use.
- Operation, maintenance and repair is carried out by qualified personnel.
- Cost reduction due to the adjustment of the aggregates for aeration, waste air collection and treatment to the particular course of the stabilization.
- Company-owned personnel is not involved in the production of reports and documentations for authorizing bodies or surveillance authorities.
- Reduced technical and economic business risk.
- Coordination and integration into further measures regarding closure and aftercare within the scope of a “master package”.
- Other aftercare measures may thus be cost-effectively integrated in external services, e.g. the collection and treatment of contaminated ground water or leachate, control and maintenance measures, annual reports with regard to the landfill behavior, as a basis for the release from landfill after-care.

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