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Aerobic in situ stabilization of Landfill Konstanz Dorfweiher: Leachate quality after 1 year of operation

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ABSTRACT

Modern landfill understanding points out controlled operation of landfills. Emissions from landfills are caused mainly by anaerobic biodegradation processes which continue for very long time periods after landfill closure. In situ landfill stabilization aims controlled reduction of emissions towards reduced expenditures as well as aftercare measures. Since April 2010, a new in situ stabilization technique is being applied at a pilot scale landfill (BAIV) within Landfill Konstanz Dorfweiher. This new method utilizes intermittent aeration and leachate recirculation for waste stabilization. In this study, influence of this technique on leachate quality is investigated. Among many other parameters, leachate analyses were conducted for COD, BOD_5, NH_4–N, NO_2–N, NO_3–N, TKN and chloride besides continuously on site recorded pH, electrical conductivity and oxidation–reduction potential (ORP). Results from leachate quality analyses showed that biological activity in the landfill was accelerated resulting in initial higher leachate strength and reduced emission potential of landfill. During full scale in situ aeration, ambient conditions differ from optimized laboratory scale conditions which mainly concern temperature increase and deficient aeration of some landfill parts (Ritzkowski and Stegmann, 2005). Thus, as a field application results of this study have major importance on further process optimization and application.

1. Introduction

Over the years since the sanitary landfills are used for waste deposition, environmental public awareness is increased and resulted in various environmental regulations (Technical Instructions on Municipal Solid Waste (TASi, 1993), German Waste Storage Ordinance (AbfAblV, 2001) and German Landfill Ordinance (DepV, 2009)). As a direct consequence of these legal developments, many landfill sites are being closed and converted into the aftercare period in Germany. Today, these landfills are still emitting landfill gas and highly polluted leachate to the environment, since many of them are not equipped with sufficient protection barriers and collection systems. Investigations in old landfills as well as laboratory scale research showed that, emissions under anaerobic conditions may continue for very long time periods after landfill closure. This period is in the order of decades for landfill gas and sometimes centuries for leachate emissions, since anaerobic degradation is a very slow process (Christensen and Kjeldsen, 1989; Hudgins and Harper, 1999; Krümpelbeck, 2000; Ritzkowski et al., 2008). To accelerate biodegradation and to reduce emission potential of landfills, aerobic landfill stabilization technology has been developed within the recent years. This method offers rapid stabilization of waste, decreased production of methane gas and reduced organics in the leachate besides minimized odor emissions. Moreover, it could eliminate needs and expenditures for off-site leachate treatment (Heyer et al., 2005a,b; Read et al., 2001; Rich et al., 2007). When combined application of in situ aeration and leachate recirculation is considered, a recognizable reduction in leachate quantity is achieved besides enhancement of leachate quality (Bilgili et al., 2006, 2007; Borglin et al., 2004).

In this study, the influence of intermittent in situ aeration and leachate recirculation on leachate quality is investigated at field scale. The results obtained after 1 year of operation are presented.

2. Materials and methods

2.1. Project description

To overcome problems which arise from both leachate and gas emissions and to further develop technology of landfill stabilization, a pilot project was planned and named as "TANIA", (Totale Aerobisierung zur Nachsorgeverkürzung durch Intervallbelüftung von Abfalldeponien, Aerobic stabilization of landfills by interval aeration to reduce aftercare period). The stabilization strategy enabled in this project combines already known methods (i.e. leachate recirculation and aeration). This new approach is named as EISBER (Extensive Intervallbelüftung mit Sickerwasserrückführung und

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Biologischer Emissionsreduzierung, Extensive interval aeration with leachate recirculation and biological emission reduction). In comparison to the already applied methods, EISBER differentiates itself with three new innovative characteristics which are intermittent aeration with different pressure levels, implementation of biological emission reduction by a surface biofilter and recirculation of leachate (Kranert et al., 2009). In Fig. 1, a basic scheme of the process is summarized.

2.2. Site description: Landfill Konstanz Dorfweiher, section BAIV

Landfill Dorfweiher is in the district of Constance (Landkreis Konstanz) which is located south of the State of Baden Württemberg, Germany. Between 1966 and 2009, municipal waste, commercial waste and sewage sludge were deposited in Landfill Dorfweiher. It has an area of 220,000 m^2 and a volume of 5,500,000 m^3. As base liner, there exists 1 m mineral sealing above 10–30 m boulder clay. Above base sealing, a leachate collection system was installed. For this research project, a pilot area of ca. 1.0 ha was selected and named as BAIV within Landfill Dorfweiher (Fig. 2a and b). BAIV was used as final deposit for household waste and household-waste-like commercial waste between 1996 and 2003. The project on BAIV was started in 2007 with preliminary investigations. Site construction and installation of equipments continued until end of 2009. During site construction, portions of deposited waste in section BAIV were excavated and analyzed for waste properties. The average composition of deposited waste was determined as 24% organic waste, 15% recyclables, 8% light packaging fraction and 53% residual waste. The average water content was 40% referred to wet mass. Defined volume of waste samples were taken from the excavated material and weighed. By this means, average bulk density was found as 1115.75 kg/m^3. With air and water pycnometry methods, average free pore space was determined as 9%. In addition, respiration index for 4 days (RI_4) was measured as 10 mg O_2/g TS.

The project area BAIV possesses 1 m thick mineral sealing above boulder clay layer as well as leachate collection system. No gas extraction system has been installed; however, a compost biofilter layer was applied over the project area. Residual gaseous emissions during aeration are passively treated by the compost biofilter layer. Above biofilter, methane emissions from BAIV are being measured by TDLAS – Gasfinder®2.0 system. Measuring landfill methane concentrations by flame ionization detector (FID) is considered to be a standard method (Rettenberger, 2004, after Zhu et al., 2010). However, FID is not completely appropriate for landfill methane monitoring while in most cases methane is emitted from area sources (or multiple points) rather than point sources (Reiser et al., 2009; Zhu et al., 2010). Methane measurements by FID may result disturbed emission rates due to hot spots. However, TDLAS – Gasfinder®2.0 system overcomes the drawbacks by measuring average methane concentrations continuously over an optical path up to 1000 m without further interference, which is suggested to be a more precise method to define areal methane emissions (Zhu et al., 2010).

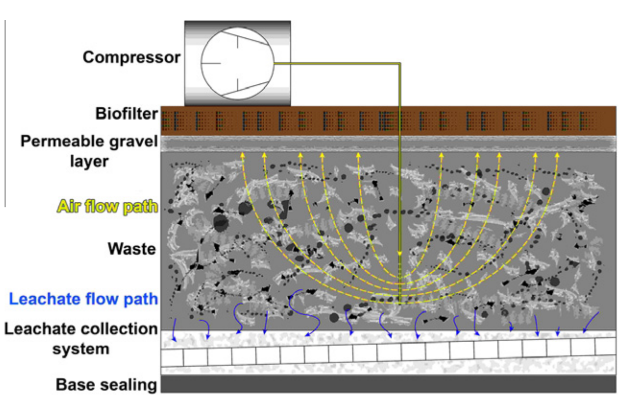

Fig. 1. Basic scheme of the process in Landfill Konstanz Dorfweiher (Kranert et al., 2009).

The landfill section BAIV is equipped with 64 temperature and 24 gas sensors that are located at different depths within the landfill and biofilter. By this means, the aeration process can be controlled continuously.

2.3. Aeration strategy and leachate recirculation

During preliminary investigation period, it has been determined that some areas of the landfill are densely packed in comparison to the other areas within a short distance. On the other hand, large areas with leachate accumulation were detected. Such formations in the landfill are expected to inhibit gas and leachate distribution during in situ aeration. It has been concluded that, to achieve better distribution of air and to displace accumulated leachate, an intensive pressurized aeration regime is beneficial for BAIV. For this purpose, 80 lances were constructed in a 10 m grid over the pilot area BAIV to achieve air distribution (Fig. 2c). Based on waste material analyses (RI_4 = 10 mg O_2/g TS) and landfill properties (low free air space, leachate accumulation, very dense areas), the initial air demand was estimated between 900 and 1200 m^3N/h. To release methane and leachate which is located in the pore spaces of waste, a higher initial aeration rate was preferred. Due to the aforementioned landfill properties it is more likely that problems in air distribution thus oxygen utilization might occur. Therefore, approximately three times of the air demand calculated based on RI_4 was initially used. For air supply, three compressors with differential pressures of 0.4 bar, 1 bar and 4 bar are being used. At the areas where leachate is accumulated, connection to the high pressure compressor (1 bar) was preferred. 36 lances out of 80 lances were connected to the high pressure compressor. All lances are also connected to the very high pressure compressor which is operated at 4 bars with intervals up to a couple of pressure pulses in an hour. By 24 gas sensors gas composition as well as the utilized oxygen in the landfill can be continuously monitored. In Fig. 3, the average gas composition over the landfill is illustrated. Likewise, by 64 temperature sensors located at different depths, the intensity of aerobic degradation at different parts of the landfill can be evaluated by monitoring the temperature profile (Fig. 4). Referring to the temperature and gas concentration readings, aeration rate for the next stage of the process is adjusted. For instance, when temperature sensors at a part of the landfill show a steep increase, the following actions could be taken; the nearby aeration lances are closed, the overall aeration rate is reduced (depending on the size of the area affected by temperature rise) or the duration of aeration is reduced.

Since April 2010, BAIV is being intermittently aerated with different pressure levels. Applying different pressures, varying from continuous low pressure flow to short high pressure pulses, enables better distribution of air also in the deeper parts of the landfill. In addition, high pressure pulses change the favored flow paths both for air and leachate helping to disturb leachate ponds within the landfill. Therefore, portions of waste subject to aerobic degradation are increased. Moreover, installation of aeration lances allows adjustment of air supply to different regions, considering the necessity due to degree of biological activity.

The aeration of pilot section BAIV was started with an air flow rate of ca. 1350 Nm^3/h (ca. 0.028 Nm^3/Mg TS $*$ h). Initially, continuous aeration strategy was applied. However, as a result of exothermic processes, temperature profile at some areas in the landfill was increased up to 70 °C (Laux et al., 2010). To avoid

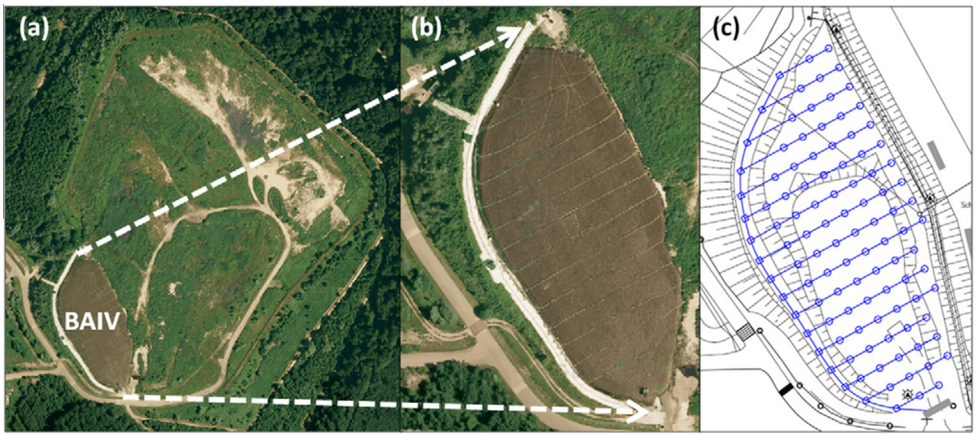

Fig. 2. (a) A general view of Landfill Dorfweiher and section BAIV (Orthophoto from LGL-BW, 2011). (b) A detailed view of BAIV (Orthophoto from LGL-BW, 2011). (c) Distribution of aeration lances over pilot section BAIV and leachate bypass line (Kranert et al., 2008).

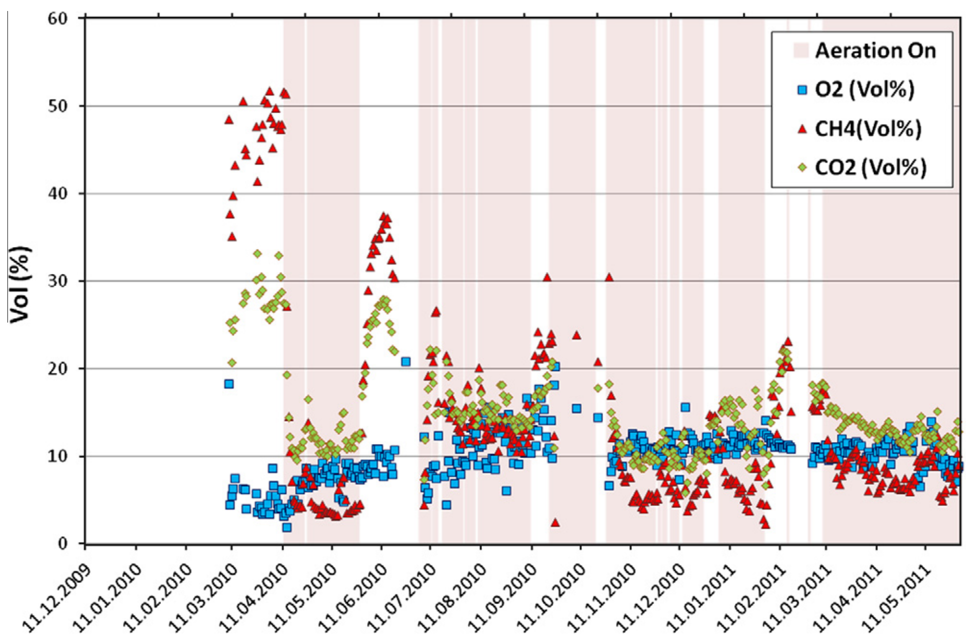

Fig. 3. Gas composition measured below the biofilter throughout the first year of operation.

any combustion risk, continuous aeration was shifted to discontinuous aeration with 150–250 Nm^3/h (ca. 0.004 Nm^3/Mg TS ∗ h) after an interim shut down. From July 2010 to October 2010, discontinuous aeration was applied. After high temperatures at some areas of the landfill are reduced, the intensity of aeration was increased to 150–250 Nm^3/h (ca. 0.004 Nm^3/Mg TS ∗ h). Because of some technical problems and arrangements, aeration plant had to be temporarily shut down in February 2011. From March 2011, aeration was rearranged by alternating operation times of high and low pressure aeration aggregates. The aeration periods and average air flow rates are summarized in Table 1.

During aeration, a significant amount of water is expected to be released via exhaust gas. This kind of moisture loss is strongly linked with the temperature increase during aerobic processes. Since biological degradation processes develop only in a narrow moisture range, it is necessary to equalize the moisture deficits. In BAIV, each aeration lance is equipped with a leachate distributor below the biofilter to enable leachate recirculation when necessary (Fig. 5b). By means of leachate distributors, targeted irrigation to the zones with increased temperature can be achieved. In the first year of aeration, there was no need for leachate recirculation because of the high level of accumulated leachate in the landfill. However, during the operation a pond, leachate mixed with precipitation, was formed at the bank of the landfill (Fig. 5a) after the heavy rainfall events. Concurrently, temperature increase was very intense at some deeper parts of the landfill ($T \geqslant 70$ °C).

To reduce temperatures and to avoid accumulated water at the landfill bank, ponded water was recirculated to the landfill with the volume flow rate of between 0.5 m^3/h and 0.8 m^3/h. By this means approximately 3500 m^3 of ponded water was recirculated to the landfill.

In case leachate recirculation is required in the further phases of operation, outflow leachate can be pumped to a secondary station from where it is forwarded to the selected distributors. Thereafter, leachate is introduced through a 1 m radius distributor below the biofilter to avoid possible odor emissions.

2.4. Leachate quality investigations

The effectiveness of aeration on leachate quality can be distinguished by analyzing leachate for several parameters. To obtain meaningful data about how aeration affects leachate quality, pilot

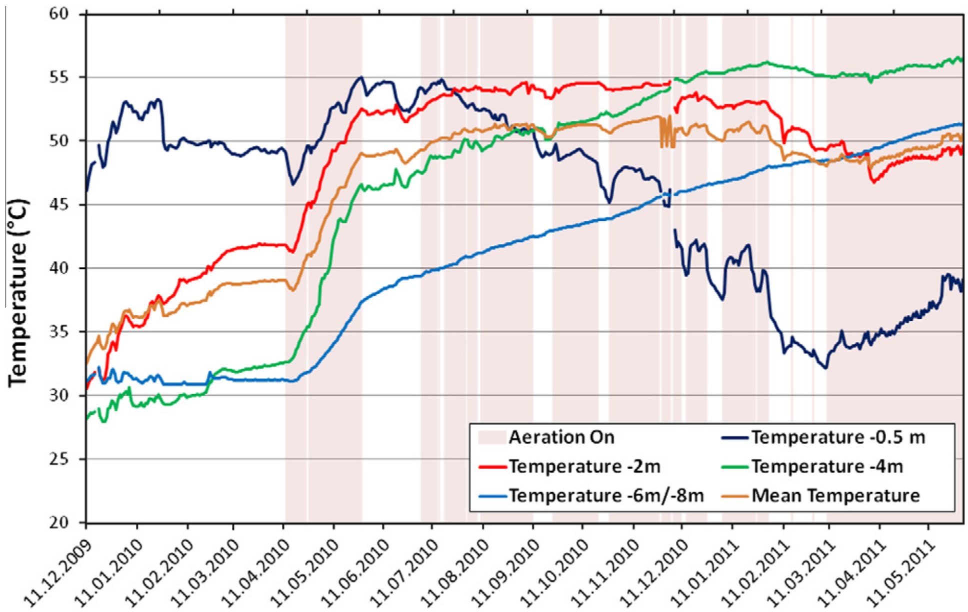

Fig. 4. Temperature profile of BAIV during the first year of aeration.

Table 1
Aeration strategy applied in Landfill Dorfweiher, section BAIV.

Time period	Aeration strategy
13.04.2010–28.05.2010	Continuous (1350 Nm^3/h, ca. 0.028 $Nm^3/Mg\ TS * h$)
29.05.2010–04.07.2010	Interim shutdown
05.07.2010–10.09.2010	Discontinuous (150–250 Nm^3/h, ca. 0.004 $Nm^3/Mg\ TS * h$)
11.09.2010–22.09.2010	Interim shutdown
23.09.2010–20.10.2010	Discontinuous (150–250 Nm^3/h, ca. 0.004 $Nm^3/Mg\ TS * h$)
21.10.2010–27.10.2010	Interim shutdown
28.10.2010–04.01.2011	Discontinuous (250–350 Nm^3/h, ca. 0.006 $Nm^3/Mg\ TS * h$)
05.01.2011–01.02.2011	Discontinuous (350–500 Nm^3/h, ca. 0.008 $Nm^3/Mg\ TS * h$)
02.02.2011–09.03.2011	Interim shutdown
10.03.2011–15.05.2011	Discontinuous (150–250 Nm^3/h, ca. 0.004 $Nm^3/Mg\ TS * h$)
16.05.2011–31.05.2011	Discontinuous (350–500 Nm^3/h, ca. 0.008 $Nm^3/Mg\ TS * h$)

area BAIV was hydraulically separated from the rest of Landfill Dorfweiher by forwarding the leachate to waste water treatment plant through a leachate by-pass line (Öncü et al., 2010).

In this paper, results for chemical oxygen demand (COD), biological oxygen demand (BOD_5), ammonium–nitrogen (NH_4–N), nitrite–nitrogen (NO_2–N), nitrate–nitrogen (NO_3–N), total Kjeldahl nitrogen (TKN), chloride (Cl^-), pH, electrical conductivity, oxidation reduction potential (ORP) are presented. Composite 2-h leachate samples were analyzed according to the standardized methods listed in Table 2.

Electrical conductivity, pH and oxidation reduction potential (ORP) were recorded continuously on site throughout the aeration period. A portion of outflow leachate is pumped out from the leachate collection well (Fig. 6a and b) by means of a pump equipped with liquid sampler. Leachate outflow rate is measured continuously in the collection well (Fig. 6b). Probes for electrical conductivity, pH and ORP are inserted in an analyzing container where the leachate volume is replaced continuously (Fig. 6c). Electrical conductivity, pH and ORP of leachate are recorded every 5 min throughout the operation.

During preliminary investigations and aeration period, water level measurements were conducted from aeration lances. Leachate level in the landfill is measured at each lance by an electric contact gauge. Results showed that a significant leachate accumulation is present in the landfill. The average leachate head at the beginning of the aeration period (April 2010) was 3 m. After 6 months of operation, water level measurements were repeated and the average leachate head was found as 3.8 m. It has been concluded that both influence of aeration and seasonal climatic conditions (Fig. 7) caused such an increase. Moreover, the pressure change inside the landfill promoted higher leachate levels.

3. Results and discussion

Pilot area BAIV is covered with a compost biofilter that allows infiltration of precipitation, which has an influence on leachate outflow. Leachate outflow, precipitation and outflow during leachate sampling are illustrated in Fig. 7 to have a better sight on how climatic conditions and aeration influence leachate quality. Results of leachate analyses are presented as concentrations (mg/l) and mass loads per unit time (kg/h) to give more specific information about leachate quality and emission potential of the landfill. Aeration periods are integrated into the graphs where vertical bars indicate active aeration periods. Since section BAIV was under construction between 2007 and 2009, outflow leachate sampling was started after the installation of aeration lances. Results of leachate analyses prior to aeration are also presented in the graphs. Thus, results from December 2009 until April 2010 represent the leachate quality of BAIV before aeration.

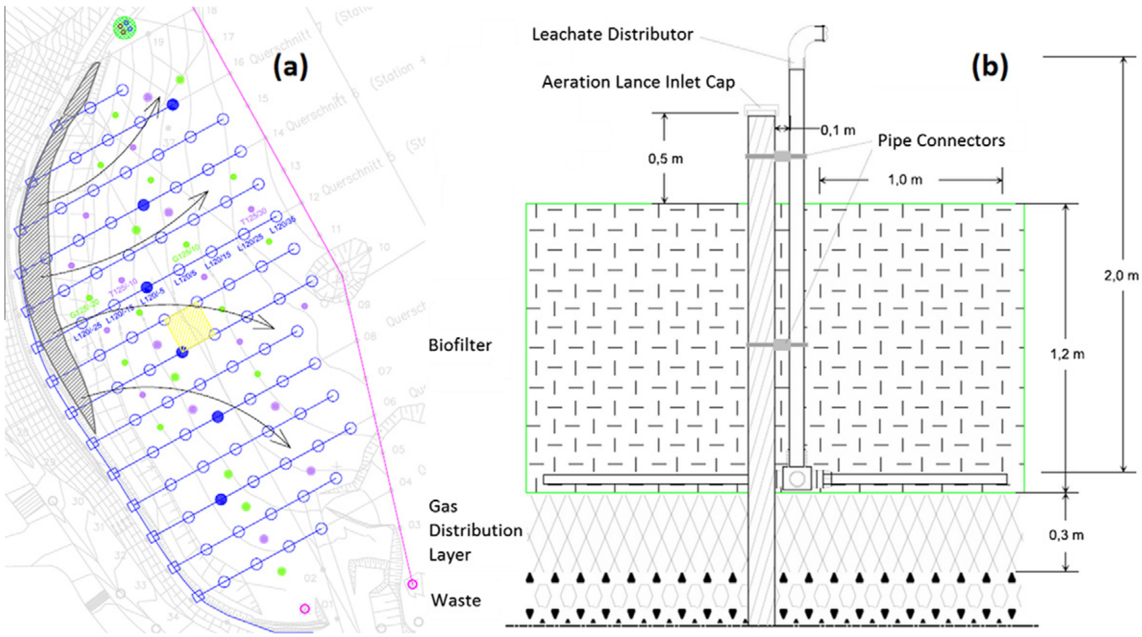

Fig. 5. (a) Ponded water distribution over the landfill and (b) Sketch of leachate distributor, (Kranert et al., 2009).

Table 2
Standardized methods used during leachate analyzes.

Parameter	Standard method
COD (mg/l)	DIN 38409(H41)
BOD_5 (mg/l)	DIN EN 1899(1) 07/1980
TOC (mg/l)	DIN EN 1484 08/1997
Ammonium-N (mg/l)	DIN 38406(E5/2)
Nitrite–N, Nitrate–N, Chloride (mg/l)	DIN EN ISO 10304
TKN (mg/l)	DIN EN 25663 11/1993

3.1. COD and BOD_5

Throughout the aeration period, COD and BOD_5 loads of leachate were increased from 0.43 kg/h to 1.66 kg/h and 0.03 kg/h to 0.07 kg/h, respectively (Fig. 8). The concentrations of COD and BOD_5 were increased from 2000 mg/l to 6000 mg/l and 70 mg/l to 150 mg/l, respectively (Fig. 9). BOD_5 concentrations showed a fluctuating increase up to 400 mg/l in the first 10 months of aeration.

Initially, a steep increase was observed which was possibly due to release of leachate located in the pore spaces of the waste joining the leachate flow. During aerobic degradation, more microbial products are produced causing higher COD concentrations (Fig. 9). Cossu and Rossetti (2003) linked presence of high COD but low BOD_5 concentrations in leachate to high humic substance concentrations which are considered as hardly degradable to biological degradation. The influence of precipitation on both COD and BOD_5 loads can be detected comparing the trends in curves in Figs. 7–9. It can be concluded that infiltration of precipitation has a diluting effect on leachate. Heavy precipitation events cause increased leachate outflow but temporarily decreased concentrations resulting in increased loads.

3.2. Organic indicator ratios

BOD/COD ratio is assigned as an indicator of stability whereby it represents ratio of biologically degradable organic matter to total organic matter. BOD/COD ratio closer to zero indicates poor biodegradability (Bilgili et al., 2006; Ehrig, 1988; Erses et al., 2008; Reinhart and Grosh, 1998). This ratio decreases with landfill age. Meaning that, the amount of biodegradable organics, which are leached from the landfill, is reduced with landfill age. Although low BOD/COD ratio is considered as a condition for leachate stability, it could be insufficient to insure landfill stability due to refuse inhomogenity, which is more likely in field scale. Draining leachate from active methane production areas may percolate through more stabilized waste and BOD/COD ratio may be considerably

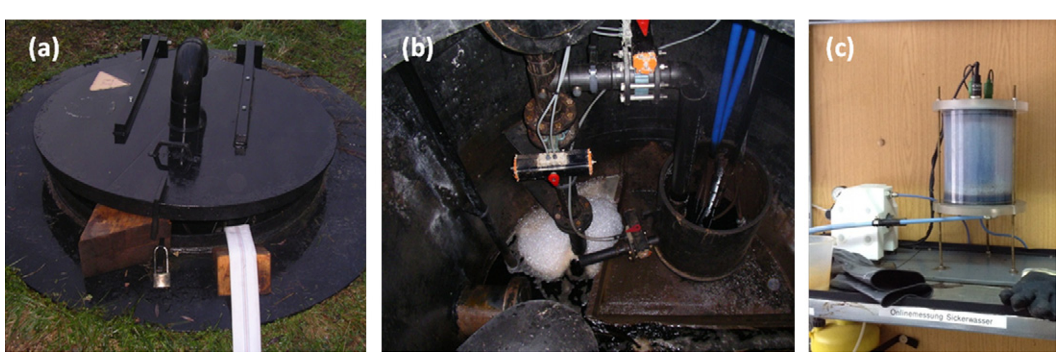

Fig. 6. (a) Leachate well (outside). (b) Leachate well (inside), outflow measurement and sampling station. (c) Onsite leachate measurement for electrical conductivity, pH and oxidation reduction potential (ORP).

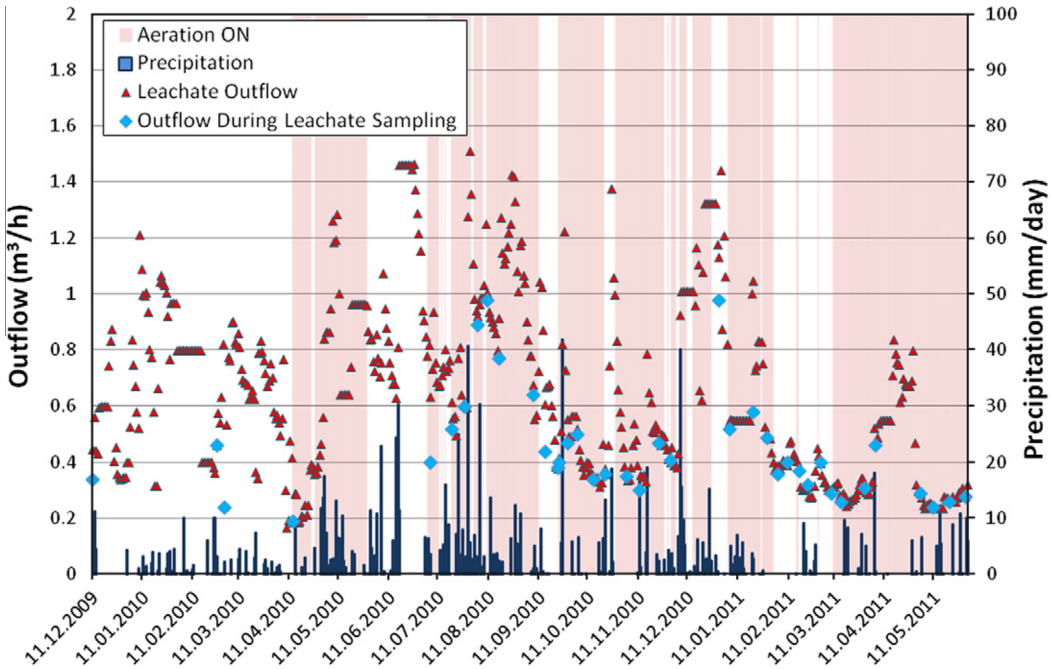

Fig. 7. Leachate outflow and precipitation throughout the first year of operation.

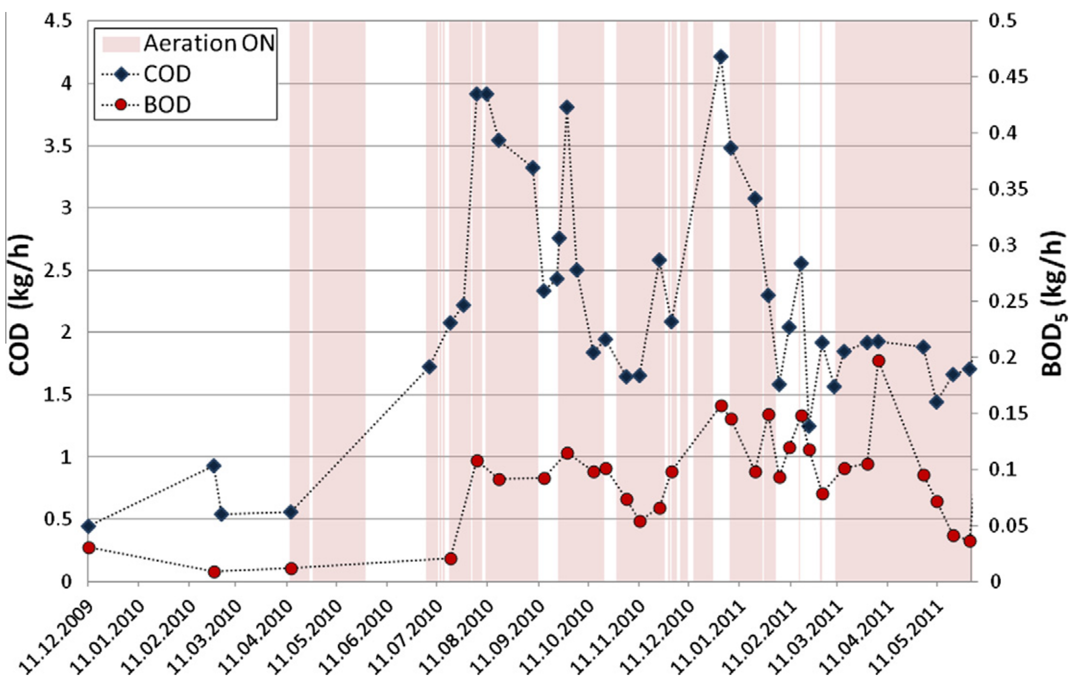

Fig. 8. COD and BOD_5 loads in leachate during aeration.

low, even though the whole landfill is not stabilized yet (Rooker, 2000). In Fig. 10, BOD/COD ratio of leachate from section BAIV is illustrated. During aeration, BOD/COD ratio of leachate was increased from 0.02 to 0.05 which indicates an increased biological degradability. According to the BOD/COD ratios mentioned by Labanowski et al. (2010), (biodegradability of stabilized leachate BOD/COD < 0.1), leachate from BAIV is in the stable state. However, inhomogenities, accumulated leachate and dilution via precipitation could result such a low ratio although the landfill is not stabilized.

Similar to BOD/COD ratio, COD/TOC ratio tends to decrease with increasing stability. High ratio indicates high proportion of easily oxidizable organic compounds in the process (i.e. alcohols, proteins, etc.). For old landfills this ratio is around 1.16 (Reinhart and Grosh, 1998). The COD/TOC ratio of leachate from BAIV prior to aeration was 2.74 (April 2010) which was then increased to 2.88 (May 2011) after 1 year (Fig. 10). During aeration COD/TOC ratio of BAIV leachate showed various fluctuations between 2.5 and >4, which is most probably due to change of type and availability of organic compounds as well as microbiological activity. In comparison to

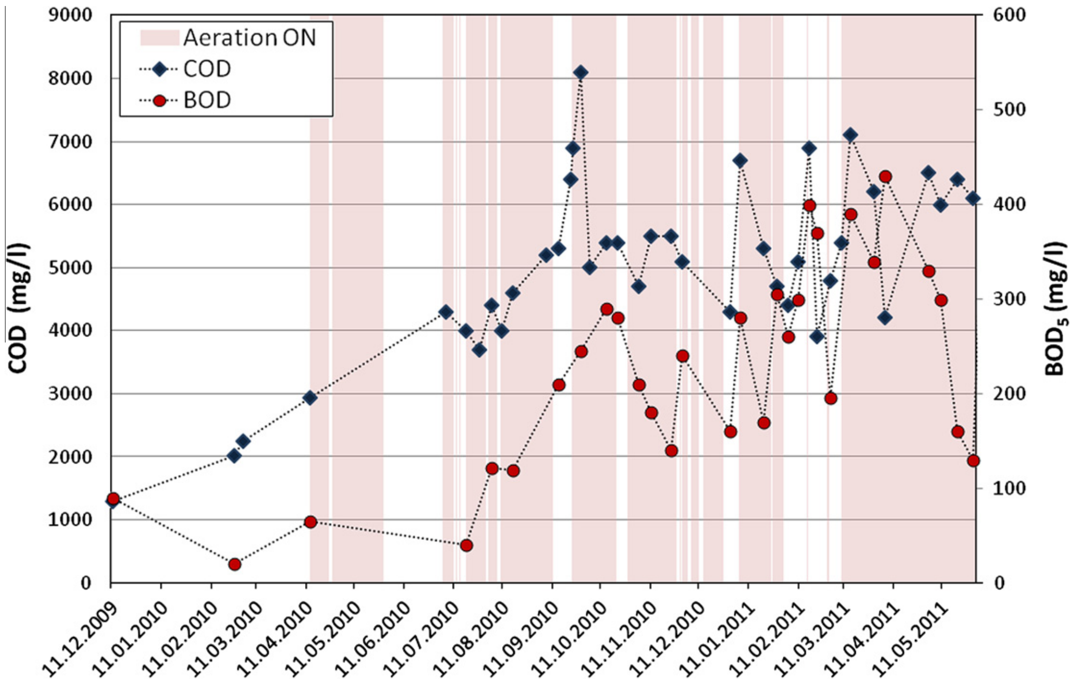

Fig. 9. COD and BOD_5 concentrations in leachate during aeration.

the given ratio for old landfills by Reinhart and Grosh (1998), COD/TOC ratio of BAIV leachate is rather high indicating high portion of readily oxidizable organics in the system, in other words capacity to be stabilized.

3.3. Electrical conductivity, pH, oxidation–reduction potential and chloride

With start of aeration, leaching of chloride already present in the waste mass may promote an increase of electrical conductivity (Rowe, 1995). During aerobic stabilization processes, acid production is reduced by complete oxidation of biodegradable substances to CO_2, which causes an increase of pH (Stessel and Murphy, 1992). According to Bilgili et al. (2009), pH increase promotes solubility of chloride which results high chloride concentrations in leachate. Consequently, increased chloride concentrations lead to an increase in electrical conductivity of leachate. pH values of leachate from BAIV increased from 7.4–7.5 to 7.9–8.0 whereas electrical conductivity increased from 10 mS/cm to 17 mS/cm throughout the aeration period (Fig. 11). The processes described by Rowe (1995) and Bilgili et al. (2009) took place in BAIV. With aeration, chloride as well as electrical conductivity was increased due to

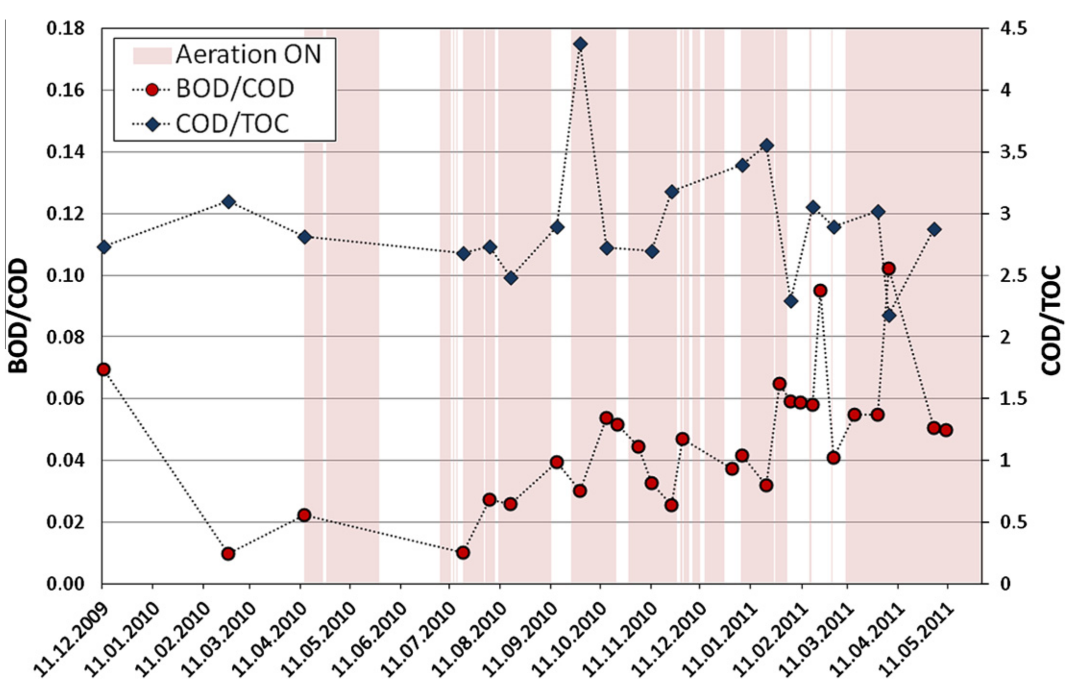

Fig. 10. BOD/COD and COD/TOC ratios of leachate during aeration.

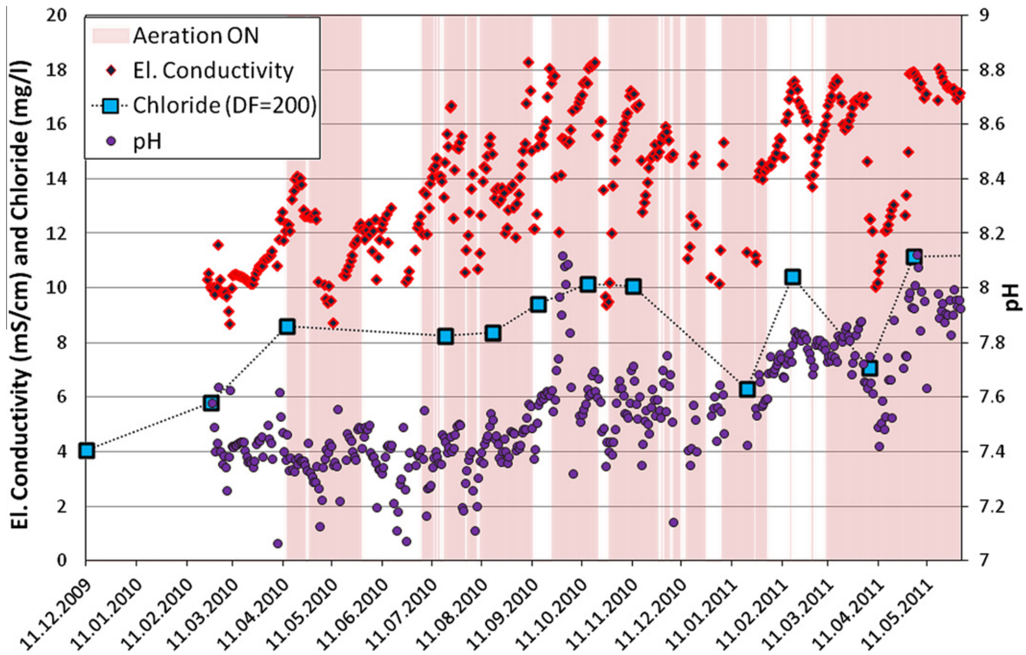

Fig. 11. Electrical conductivity, pH and chloride concentration (DF = 200) of leachate during aeration.

displacement of the leachate in the waste mass containing higher chloride and electrical conductivity. Concurrently, the trend of pH values was stable. After a period of aeration, pH values started to increase and the correspondence between pH, chloride and electrical conductivity described by Bilgili et al. (2009) was distinguished for leachate from BAIV.

In Fig. 11, continuously recorded pH and electrical conductivity are plotted with chloride concentrations. To illustrate chloride concentrations in a comparable range with pH and electrical conductivity, a dilution factor of 200 (DF = 200) was used for chloride concentrations. Chloride is also assigned as an indicator of dilution in leachate due to its resistance to biological degradation (Bilgili et al., 2009). Regarding the latter, the declines in electrical conductivity and chloride concentration in Fig. 11, can be linked with dilution via infiltration of precipitation.

ORP is regarded as one of the parameters used to define decomposition mechanism of waste. In general, aerobic environments have high ORP which promotes accelerated decomposition. If ORP range for optimum methane production is considered, from −100 mV to −300 mV (Christensen and Kjeldsen, 1989; Farquhar and Rovers, 1973), leachate from BAIV is slightly aerobic with ORP values around −35 mV by May 2011 (Fig. 12). Continuously recorded ORP values tend to decrease during the aeration. On the other hand, fluctuations could be explained by the influence of pressurized air on leachate flow paths. As air is introduced, new paths are generated and anoxic ponded leachate in some areas is

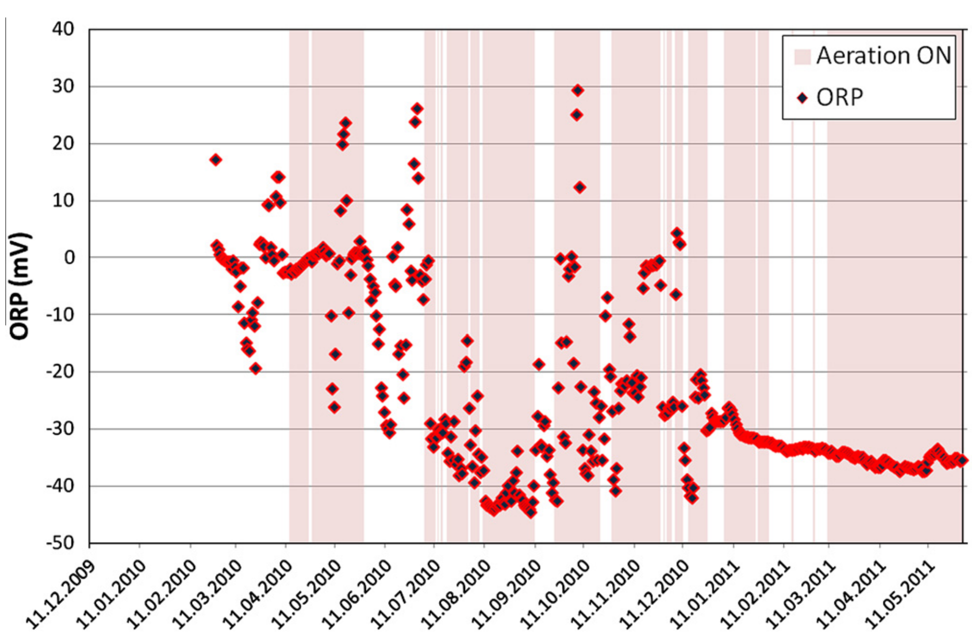

Fig. 12. Oxidation–reduction potential (ORP) of leachate during aeration.

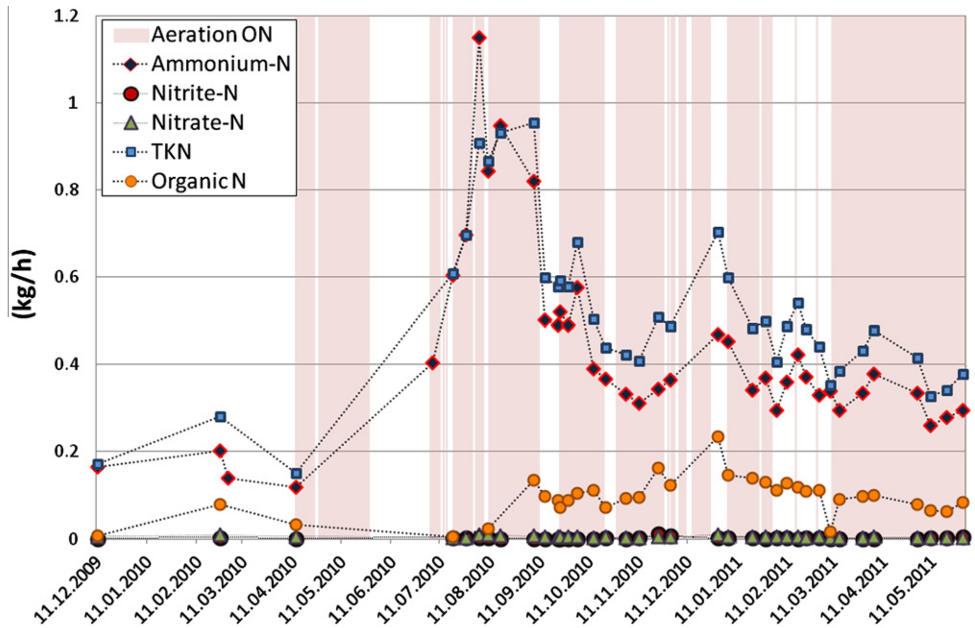

Fig. 13. Nitrogen loads (NH_4–N, NO_3–N, NO_2–N, TKN and organic N) in leachate during aeration, (Öncü et al., 2011).

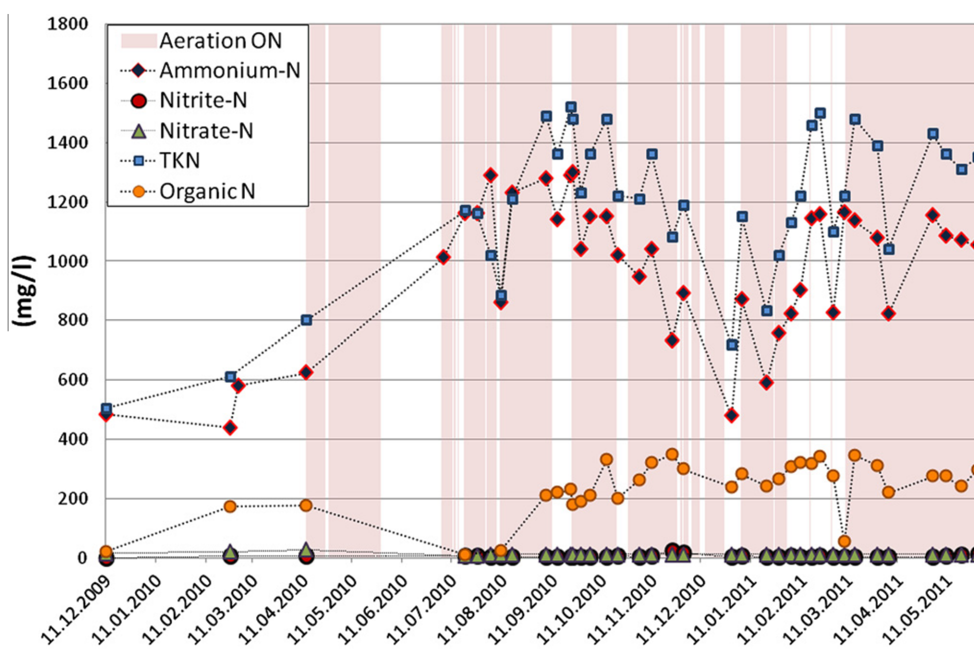

Fig. 14. Nitrogen concentrations (NH_4–N, NO_3–N, NO_2–N, TKN, and organic N) in leachate during aeration.

released. Under aerobic conditions biodegradation rate is increased resulting in increased BOD concentrations. As BOD increases, the rate of oxygen depletion increases resulting in lowered ORP values.

3.4. Nitrogen compounds (TKN, NH_4–N, NO_3–N, NO_2–N and organic-N)

Before start of aeration, NH_4–N and TKN loads in leachate were around 0.2 kg/h and 0.17 kg/h, respectively, where both concentrations were around 600 mg/l (Figs. 13 and 14). With start of aeration, NH_4–N and TKN loads increased up to 1.2 kg/h and 0.9 kg/h whilst the concentrations of NH_4–N and TKN were increased up to 1300 mg/l and 1500 mg/l, respectively. The initial increase was due to increased mobilization of organic and inorganic nitrogen compounds as well as release of already NH_4–N and TKN containing leachate in the pore spaces of waste. After 1 year of operation both NH_4–N and TKN loads were decreased to 0.3 kg/h, however, related concentrations were still at their elevated levels. Accordingly, no significant appearance of nitrite and nitrate was observed.

The TKN (Total Kjeldahl Nitrogen) value represents a total nitrogen concentration, which is the sum of organic nitrogen compounds and ammonium nitrogen. Organic nitrogen is the organically bound fraction and includes natural materials such as proteins, peptides, nucleic acids, urea and numerous synthetic organic materials. As most of the nitrogen in leachate is found as NH_4–N, organic nitrogen can be determined by the difference between TKN and NH_4–N (Saxena, 2009). As illustrated in

Fig. 13, NH_4–N and TKN concentrations have similar and close trends during aeration which is an indication that the organically bound nitrogen was hydrolyzed into ammonium nitrogen (Öncü et al., 2011).

Despite increasing trend of NH_4–N and TKN concentrations, related loads showed a decreasing trend. Similar to what explained in Section 3.1 (COD and BOD_5), this was due to the infiltration of precipitation.

According to Ritzkowski and Stegmann (2005), intermediate appearance of nitrite/nitrate is an indicator of nitrification processes. If nitrite/nitrate does not remain at an elevated level this is an indication for denitrification processes. The basic requirement for denitrification is a nitrate or nitrite pool which is created by nitrification. N_2O is mainly emerged by incomplete denitrification or incomplete ammonium oxidation (nitrification) (Huber et al., 2009). Since only nitrification products can be analyzed in leachate, increase in NO_2–N/NO_3–N concentrations in leachate can be linked with N_2O occurrence in exhaust gas. In leachate from BAIV, no increase in NO_2–N/NO_3–N and no decrease in NH_4–N were observed which would mean that there was no significant N_2O production (Fig. 14). Berge et al. (2007) and Price et al. (2003) also mentioned that excess or lack of oxygen in the system leads to N_2O productions. However, it is also hypothesed that this may not be an issue in landfills because of high residence time.

In BAIV, heterogeneity of waste and water accumulation complicates homogeneous air distribution. On the other hand, mean temperature profile up to 50 °C inhibits nitrification processes. After 1 year of operation, reduction in ammonium nitrogen concentrations could not be achieved due to the aforementioned constraints. Concurrently, no significant increase of NO_2–N and NO_3–N detected. However, in comparison to the anaerobic status of the landfill, NH_4–N and TKN discharge was increased resulting in reduced emission potential of landfill.

Depending on oxygen concentrations, temperature and pH, simultaneously occurring nitrogen reduction processes (volatilization, nitrification, denitrification and anammox reactions) could be realized in BAIV. It is not possible to differentiate to what extent each of these processes took place in the landfill, but nitrogen reduction potential via co-occurring processes is promising.

4. Conclusions

In this study, impact of intermittent in situ aeration method on leachate quality is investigated for the first year of operation. Leachate quality of BAIV is altered after 1 year of operation in comparison to the status before aeration. As well as pH and electrical conductivity, concentrations of COD, BOD_5, NH_4–N, TKN and chloride were increased where ORP values were decreased. These changes in leachate quality indicate accelerated microbiological activity and mobilization of compounds in the waste material which become subjects of further degradation.

The accumulated leachate volume in the landfill has significant influence on leachate quality; it creates difficulties in air distribution. On the other hand, dense areas inhibit both air and leachate flow. The strategy for such parts of the landfill will be intensifying high pressure aeration aggregates. In the second and third year of operation, aeration rate will be increased at the parts of the landfill with more stable temperature profile.

Except leachate accumulation, creating aforementioned problems, no other significant difficulties experienced during aeration. One of the major issues affirmed in the first phase is that continuous monitoring of the site has major importance on process control. Such a monitoring (i.e. emissions, temperatures, ambient conditions and etc.) allowed decision maker operators to react quickly according to the needs of the site.

Although leachate quality of BAIV is altered after 1 year of operation; it is expected that leachate quality will be enhanced during the later phases of aeration. Results of a recent field scale application demonstrated that, a considerable decrease in nitrogen contamination of leachate was ascertained after 1 year of aeration in spite of several decades (Heyer et al., 2005b).

Aerobic in situ stabilization technique cannot promise zero emissions but it reduces the efforts in the later phases of landfill aftercare (Gamperling et al., 2010). Waste decomposition is accelerated under aerobic conditions, thus leachate quality is expected to be enhanced whereas the emission potential of the landfill is reduced.

Based on the latter understanding, aerobic stabilization of BAIV will continue until December 2012. This 3 year project targets a more stable waste with lower emissions which enables shortened aftercare periods as well as leachate treatment costs. During the subsequent monitoring phase (2 years), long term influence of in situ stabilization on the landfill body will be monitored. Throughout the project, the influence of EISBER process on leachate quality as well as quantity will be investigated. Thus, optimization, control and efficiency of this method applied in section BAIV of Landfill Dorfweiher would introduce new prospects to landfill stabilization.

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