NEW DUTCH LEGISLATION TO ALLOW RESEARCH OF NATURAL BIODEGRADATION AT LANDFILLS

W.J. KATTENBERG*, H.A. VAN DER SLOOT**AND T.J. HEIMOVAARA°

** Ministry of Infrastructure and Environment, PO Box 20901, 2500EX, The Hague, The Netherlands*
*** Hans van der Sloot Consultancy, Dorpsstraat 216, 1721BV , Langedijk, The Netherlands*
° Delft University of Technology, PO Box 5048, 2600 GA Delft, The Netherlands

SUMMARY: Biological stabilization of the waste body by irrigation and recirculation followed by aeration can lead to a significant reduction in emission potential. The Dutch Government stimulates a full scale ten years research program that starts in 2014 on three pilot landfills to verify this hypothesis. The aims of these measures are to decrease the eternal after-care effort and costs, and reducing the effects of transferring landfilled waste to future generations. Significant reduction can be quantified by using a model to calculate site-specific emission criteria (emission test values). Before starting the research program several preliminary studies are conducted and new Dutch legislation is developed and approved. Model development to describe a variety of scenarios and the consequences for the resulting emissions are discussed. The implications for possible use of the knowledge gained in other jurisdictions is highlighted.

1. INTRODUCTION

The Dutch Government promotes sustainable and innovative techniques that stimulate natural biodegradation and immobilization processes in landfills. Examples of such measures are infiltration and recirculation of water and leachate, as well as the injection of air. The aims of these measures are to reduce the emission potential of landfills and to decrease the eternal after-care effort. In the Netherlands a full scale ten years research program will start in 2014 on three pilot landfills. This research will verify if biological stabilization of the waste body by irrigation and recirculation followed by aeration will lead to a significant reduction in emission potential in full scale landfill bodies. The aim of these pilot projects is to provide sufficient evidence that stabilization of waste bodies is an effective means of after-care that eventually may lead to a situation where a landfill is released from after-care because the remaining emission potential in the landfill is so low that no substantial risk to the environment remains.

In 2010 the main question for the government was how to get full public support for this research work, or what is needed to convince society, politicians, government and citizens that this idea is worth the investment of public time and money. The main conclusion was to invest fully in creating a level playing field for officials, citizens and industry by providing them with

Proceedings Sardinia 2013, Fourteenth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 30 September – 4 October 2013

accurate and timely information and independent scientific evaluation of the proposed research program (Kattenberg et al., 2011).

To accommodate the research program the Ministry of Infrastructure and Environment launched a project in 2010 called: Introduction of Sustainable Landfill Management (ISL). The project was aimed at formalizing the cooperation between the landfill industry, the competent authorities (provinces) and the Ministry leading to a signed covenant and implementation of new legislation in 2014.

The main questions to be answered in the research program are:

- does sustainable landfill management lead to a significant reduction of emission potential from the landfill to groundwater,
- does this emission reduction also lead to acceptable emission levels, and
- by which method can this reduction convincingly be assessed and determined?

An outline of the policy process and of the preliminary researches and activities of the research program were presented at the Sardinia 2011 symposium. Now, most of the preliminary researches and activities are completed or almost completed.

This paper will give a short outline of following ISL-topics:

- Traditional versus sustainable approach
- New Dutch legislation
- Preconditions
- Emission Criteria (site-specific emission test values)
- Conceptual model, hypotheses and strategy for process monitoring
- The usefulness in international context.

Sustainable Landfill Management as presented in this research program may provide very useful information for the ongoing international discussion about future landfill practices and release from aftercare of existing landfills. Experimental programs to demonstrate that management practices work require a long time to actually prove their value, but at the same time when proven adequate do not need to be repeated everywhere.

2. TRADITIONAL VERSUS SUSTAINABLE APPROACH

Emission of potentially contaminating substances, present in the waste body, to the surroundings takes place via the landfill gas to the atmosphere and via the leachate to surface and groundwater.

In order to prevent such emissions, modern sanitary landfills in the traditional approach are equipped with a range of barrier systems to limit these emission routes as much as possible. The sanitary landfill is equipped with an impermeable bottom liner to prevent leachate from migrating to the groundwater. A drainage system is installed above the bottom liner to control the water level in the landfill and to capture the produced leachate in order to treat it before discharging it in the environment. Landfill gas is captured and treated or burned, sometimes in combination with energy production. After operational life of the landfill, a surface sealing is applied to the surface of the landfill.

In the Netherlands this surface sealing is required to limit infiltration of precipitation as much as possible. As a result, leachate production will be minimized. The idea behind this concept is that when the bottom liner fails, the presence of the surface sealing will limit leachate production to such an extent that a bottom liner is no longer required.

The alternative after-care concepts being investigated in the Sustainable Landfill Management approach (Kattenberg et al., 2011), are based on a different approach. Instead of only placing our trust in the presence of adequate barrier technology, attempts are being made to actively enhance the natural stabilization of the waste in the landfill. The ambition is to reduce the contaminating potential of the waste to such a level that the resulting emission levels are such that no threat occurs to the environment (Bareither et al., 2010; Barlaz et al., 2010; Cossu et al., 2003; Mathlener et al., 2006b; Reinhart et al., 2002; Ritzkowski et al., 2006; Valencia et al., 2009). The principle of waste stabilization is based on the degradation of organic matter present in the landfill by increasing the local water content. The approach is based on a combination of irrigation (adding extra water) and recirculation of the captured leachate in order to reduce the heterogeneity in water distribution within the waste body. If necessary, the leachate can be treated before recirculation.

Irrigation and recirculation enhances the methanogenic degradation of organic matter by micro-organisms present in the landfill. This type of operation is also called a bioreactor. In order to further reduce the amount of organic matter present it is an option to aerate the waste body. The idea is that the amount of organic matter and the rate of methane production after these stabilization measures is so low that the corresponding emissions are low enough not to pose a threat to the environment when the installed barrier systems fail.

3. LEGISLATION

Last year the Dutch Parliament approved a temporary Decree of the Ministry of Infrastructure and Environment dated July 12th 2012 that allows a sustainable landfill management approach in a full scale ten years research program on biological stabilization of the landfill by irrigation, recirculation and aeration, that starts in 2014 on three pilot landfills (Decree published: Staatsblad 2012 350).

This Decree provides the framework rules and outlines of the research program, the measures to be applied on the pilot landfills and the environmental conditions. At this time the Dutch government is developing a ministerial regulation which implements the Decree in further specific detail.

The aim of research program is to investigate whether long-term treatment of the waste body by irrigation and recirculation, and/or subsequent aeration over a period of approximately ten years, are sufficiently effective to reduce the remaining emission potential in the landfill to a level that does not pose an undesired risk to the environment. In that case, the landfill might be released from aftercare or the aftercare measures can be adjusted to the actual remaining risk (e.g. less monitoring, less stringent requirements on top liner).

The most important point in the Decree is permitting the addition of water (infiltration) and air (aeration) to the waste body.

The Decree also suspends the legal obligation of applying a surface sealing at the pilot landfills until after the evaluation of the research program, and until after the moment that the sustainable landfill management approach has been completely evaluated. If the ISL approach is proven to be successful the temporary legislation will be introduced permanently. The decree also applies to approximately 15 other landfills that are potentially eligible for the sustainable landfill management approach in the future. If the sustainable landfill management approach fails, the old obligation to apply a surface sealing is reinstated.

The following landfills are identified as pilotlocation:

- Kragge II, city: Bergen op Zoom, company: Attero
- Wieringermeer, city: Hollandse Kroon, company: Afvalzorg;
- Braambergen, city: Almere, company: Afvalzorg.

The choice for these pilot landfills is based on technical and organizational reasons. From the technical point of view it is important to know the type of waste present in the landfill and sufficient infrastructure should be present at the landfill in order to prevent emissions during the pilot projects. The pilot sites have been chosen to ensure that locations and waste material differ in important aspects with respect to each other, so that both leachate infiltration and aeration can be tested for a variety of conditions. Organizationally, it is important that the landfill operator is willing to participate in the program and bear the cost of the experiment (10 to 14 million €).

The legislation also indicates the physical boundaries of the cells (landfill sections) of the pilot landfills, where the measures will actually be implemented. The waste in Kragge II is dominated by domestic waste. At Wieringermeer the composition is dominated by industrial and construction and demolition waste. At Braambergen the waste is dominated by more inorganic materials such as contaminated soil and soil residues.

The sustainable Landfill Management approach fits within the European Union regulations, in particular within the Landfill Directive. The Landfill Directive does not require the prescription of a watertight surface sealing at the landfill. The Landfill Directive provides space for the competent authority (namely in 3.3. and 3.4 of Annex 1) to assess whether a surface sealing must be applied to prevent leachate formation. Based on an evaluation of the environmental risks the competent authority may waive the application of a (waterproof) surface sealing or deviate from the recommendations of the Landfill Directive about the surface sealing.

This means that the Landfill Directive prescribes no further technical requirements for the surface sealing and leaves it to the Member States to give further interpretation here. The sustainable landfill management approach does not lead to greater environmental impact, but is specifically intended to reduce impacts and risks to the environment in the long term.

4. PRECONDITIONS

An environmental precondition has been set that the deployment of technology must not lead to uncontrollable situations or additional environmental pressure, for example due to imperfections in the infiltration of leachate or aerating of the waste body. For this reason, the Dutch government demanded that the bottom liner must be fully functional for at least the duration of the pilots (2014-2024). Moreover, almost all the current environmental regulations in the permit will still apply.

Landfills are only eligible if the landfill is suitable for the sustainable landfill management approach. This for example does not apply to certain types of hazardous waste landfills (due to other leachability criteria).

Postponement for applying the capping does not mean that the landfill is open at the top. After landfill completion the surface is covered with a temporary sealing that counteracts odor and blowing about of debris. These requirements are the same under the current environmental regulations.

The execution of the pilots in 2014 can only take place when the research costs are fully financed by the industry in advance, the competent authorities support and agree upon the proposed research approach, and finally a covenant between all related organizations has been signed. Key players in this approval process are the provinces in their role as competent authorities. The provinces are also the future risks carriers of the cost of after-care of landfills. Careful scientifically based risk analysis of the sustainable landfill management approach are therefore crucial for them.

Another important precondition is that prior to the start of the pilots absolute clarity must be given by the authorities about the final result to be achieved by the pilots in 2024 and how this result is measured. The landfill owners stated that this clarity can be achieved by the development and determination by the Dutch government of Emission Test Values (ETV's) in the Dutch Landfill legislation before the start of the execution of the pilots.

5. EMISSION CRITERIA

The aim of these pilot projects is to investigate whether long-term treatment of the waste body by irrigation and recirculation, and/or subsequent aeration over a period of one or more decades, are sufficiently effective to reduce the remaining emission potential in the landfill to a level that does not pose an undesired risk to the environment. In that case, the landfill might be released from aftercare (Kattenberg et al., 2011), or the aftercare measures can be adjusted to the actual remaining risk potential (e.g. less monitoring, less stringent requirements on top liner).

In order to judge whether the leaching of contaminants from a (treated) landfill has reached an environmentally "acceptable" level to release the landfill from aftercare, emission criteria (or Emission Test Values, ETV's) need to be established. To this end, a generic methodology is developed to calculate site-specific emission criteria that are expressed as maximum concentrations (µg/l) of target contaminants in the landfill leachate, while considering free infiltration of rainwater. Presently, site-specific emission criteria are being calculated for the three pilot landfills in the Netherlands. The methodology is based on a "source-path-point of compliance" approach, and takes into account site-specific factors that influence the transport rate of leached contaminants on the "path" between the "source" (the landfill) and the downstream point of compliance (Dijkstra et al., 2013).

Emission criteria are the maximum concentrations (µg/L) of contaminants in the landfill leachate, that do not exceed the local groundwater quality criteria at the point of compliance.

Choices and decisions with respect to the model scenario are the result of cooperation between the National Institute for Public Health and the Environment (RIVM) and the Energy research Centre of the Netherlands (ECN), in consultation with the Landfill sector, coordinated by the Dutch Ministry of Infrastructure and the Environment. This is an iterative process, and involves many assumptions and site-specific factors, and therefore many policy-related choices.

The approach of calculating emission criteria, an overview of the most important assumptions and policy-related choices and their possible influence on the emission criteria are discussed in more detail in the paper of Dijkstra et al., 2013.

It is expected that the preliminary ETV's can be presented during the oral presentation session at the Sardinia Symposium of 2013.

6. CONCEPTUAL MODEL, HYPOTHESES AND FINAL EMISSION POTENTIAL

As the pilots will be carried out over a period of several years (up to a decade) it is important to monitor progress during the landfill stabilization activities. In order to identify the most optimal measurement strategy a conceptual model was developed with which several hypotheses were derived about expected patterns occurring during the stabilization period. Besides identification of the most optimal measurement strategy this information is used to optimize the implementation of the stabilization measures.

The initial conceptual model is based on a detailed but qualitative description of the processes occurring within the landfill body during the stabilization period. The following main topics are described:

- Unsaturated water flow including the consequences of preferential flow and rainfall dynamics are described in detail. The impact of infiltration followed by leachate recirculation on the landfill hydrology is also high-lighted including the exchange between the mobile and immobile fraction of the water present in the waste body;
- Biological degradation, starting with the hydrolysis of solid organic matter followed by stepwise degradation of dissolved organic compounds. In this description attention is, consumption of different electron acceptors and the production of methane. The behavior of

ammonium is also described in detail. Rate controlling factors for degradation and reaction rates are described and consequences for leachate quality are highlighted;

- Geochemical stabilization of the waste due to biologically mediated changes in redox and pH levels are described. The relationship between geochemical speciation of heavy metal compounds and the levels and types of dissolved organic carbon are high-lighted;
- The consequences of aerating the landfill body are described;
- The impact these processes have on landfill gas-production and on landfill settlement are indicated.

Using the qualitative description of the processes in the landfill body allows for defining a wide range of hypotheses on the behavior of measurable parameters given certain actions. A complete description of all hypotheses is to long for the purposes of this paper. As an example we will highlight some hypotheses we defined related to the infiltration and recirculation of water in the landfill body.

Infiltration and recirculation in the waste body leads to:

- an increase in the total water content of the waste body;
- an increase in the volume of the waste body participating in the flow;
- an increase in the exchange between the mobile and immobile fraction of water present in the waste body;
- which leads to an increased mobility of water and dissolved species in the waste body;
- which leads to changes in the concentrations in the leachate showing an increase in concentration of most species during recirculation;
- infiltration of fresh water after discharging part of the leachate will lead to sudden decrease in concentrations of most species;
- increased water content in the waste body leads to increased hydrolysis which is quickly followed by and increase in methane production, increased levels of biological oxygen demand in the leachate and increasing levels of ammonium;
- increased hydrolysis followed by an increase in methane leads to enhanced settlement of the waste body;
- etc.

Defining a wide range of hypotheses in the same way as illustrated above leads to a range of measurable parameters. This set of parameters has been used to define a monitoring program which will be implemented during the stabilization period in order to provide quantitative data on the behavior of the landfill. These data will enable further development of the conceptual model from a qualitative description to a more quantitative one. The final aim of this process is to develop an approach which allow us to estimate the remaining emission potential in the waste body. Quantification of this remaining emission potential is essential for deciding when to completely release a landfill from after-care.

7. USEFULNESS WITHIN THE INTERNATIONAL CONTEXT

When the above described experimental verification program can demonstrate that the proposed management practices work, then that knowledge can be applied in other countries as well, since the type of landfilled waste suitable for this type of management practice and the type of landfills are not unique for the Netherlands. The amount of effort involved to demonstrate on full scale landfills, that the proposed management practices work, is quite significant and should not have to be repeated to prove their performance provided that the methodology to reach the conclusion on demonstrated performance is adequately scrutinized by external parties and accepted as proof of performance. For that purpose, the information gained in various steps in the process will be communicated widely to seek such acceptance among the various stakeholders. The difference between earlier work on management options for existing landfills (Heyer et al, 2005; Reinhart et al, 2002; LBP, 2006; Vigneron et al, 2005) and this work is the more integrated nature of all aspects (gas formation, field measurements, trace contaminants, ammonia, particulate and dissolved organic matter, integrated modeling of all types of emissions) involved.

REFERENCES

Bareither, C.; Benson, C.; Barlaz, M.; Edil, T. & Tolaymat, T. (2010). Performance of North American Bioreactor Landfills. I: Leachate Hydrology and Waste Settlement, Journal of Environmental Engineering 136 : 824.

Barlaz, M.; Bareither, C.; Hossain, A.; Saquing, J.; Mezzari, I.; Benson, C.; Tolaymat, T. & Yazdani, R. (2010). Performance of North American Bioreactor Landfills. II: Chemical and Biological Characteristics, Journal of Environmental Engineering 136 : 839.

Cossu, R.; Raga, R. & Rossetti, D. (2003). The PAF model: an integrated approach for landfill sustainability, Waste management (New York, N.Y.) 23 : 37-44.

Dijkstra, J.J.; Van Zomeren A.; Comans R.N.J.; Brand E. and Claessens J.W. (2013). Calculating site-specific emission criteria for sustainable landfills: the Dutch approach.

Heyer, K.-U.; Hupe, K.; Ritzkowski, M.; Stegmann, R. (2005): Pollutant release and pollutant reduction - Impact of the aeration of landfills. Waste Management, 25, 353-359.

Kattenberg W.J. and Heimovaara T.J (2011). Policy process of allowing research pilots for sustainable emission reduction at landfills in The Netherlands. Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium S. Margherita di Pula, Cagliari, Italy; 3 - 7 October 2011, CISA Publisher, Italy.

Landfill Bioreactor Performance, Second Interim Report Outer Loop Recycling & Disposal Facility, Louisville, Kentucky EPA/600/R-07/060 September 2006

Mathlener, R.; Heimovaara, T.; Oonk, H.; Luning, L.; van der Sloot, H. & van Zomeren, A. (2006b). Report for the Dutch Sustainable Landfill Foundation.

Reinhart, D. R.; McCreanor, P. T. & Townsend, T. (2002). The bioreactor landfill: It status and future, Waste Management & Research 20 : 172-186.

Ritzkowski, M.; Heyer, K.-U. & Stegmann, R. (2006). Fundamental processes and implications during in situ aeration of old landfills, Waste management (New York, N.Y.) 26 : 356-72.

Valencia, R.; van der Zon, W.; Woelders, H.; Lubberding, H. J. & Gijzen, H. J. (2009). Achieving "Final Storage Quality" of municipal solid waste in pilot scale bioreactor landfills, Waste management (New York, N.Y.) 29 : 78-85.

Vigneron, V.; Bouchez, T.; Bureau, C.; Mailly, N.; Mazeas, L.; Duquennoi, C.; Audic, J.M.; Hébé, L.; Bernet, N. Leachate pre-treatment strategies before recirculation in landfill bioreactors. Water Sci Technol. 2005;52(1-2):289-97.