SUSTAINABILITY AND THE EU LANDFILL DIRECTIVE

H. SCHARFF

NV Afvalzorg Holding, P.O. Box 2, 1566 ZG Assendelft, The Netherlands

SUMMARY: The Annex II of the EU Landfill Directive specifies acceptance criteria for waste. These criteria have been developed by means of modelling. For modelling a source-path-threatened object approach was adopted. It is a risk based assessment using facts and not emotions. Arguments are presented that the approach has (indirectly) established final storage quality criteria. Thus the development of the method can give a substantial contribution to the eventual definition of sustainable landfill. Also it is an approach that is applicable in many sectors and industries that pose a threat to the groundwater quality. It enables comparison of the impact that different industries have on groundwater quality. The method could enable fair and more balanced overall environmental protection policies. It should therefore be warmly welcomed by both regulators and operators in the waste management industry. This paper leans heavily on the work of DHI (Denmark), BRGM (France), Golder Associates (UK) and ECN (Netherlands) carried out for the TAC Subcommittee on the Landfill Directive, but is not necessarily endorsed by these organisations. The paper solely represents the views of the author.

1. INTRODUCTION

The UN Bruntland Committee has stated that … *sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs*. From this definition, it follows that each generation should solve its own problems. Very often a period of a maximum of 30 years is adopted. An internationally accepted definition of sustainable landfill does not exist. The Bruntland Committee definition can however indicate what can not be considered sustainable landfill.

The EU Landfill Directive (CEC, 1999) was adopted on 16 July 1999. It was the result of a long negotiation process, which was initiated by the European Commission in 1999. In general, legislators consider landfill bodies to be black boxes from which various undesirable emissions occur. In most EU member states the ‘black box thinking’ has resulted in the adoption of precautionary measures that wrap the landfill in an impermeable shell. This is remarkable since the EU Landfill Directive does not require it. Article 2 of Annex I states that measures shall be taken to control (not prevent!) water from precipitations entering the landfill body. Article 3.3 of Annex I states that if the competent authority after a consideration of the potential hazards to the environment finds that the prevention of leachate formation is necessary, a surface sealing may be prescribed. In other words an impermeable top liner is not mandatory. Article 3.3 continues with recommendations for the construction of a surface sealing. It would seem that in drafting national regulations many EU member states have mistaken these recommendations for minimum requirements.

External emissions will not occur if the landfill shell remains intact. From this perspective landfill containment seems to be an environmentally safe option, but it requires a large investment and a long-term commitment, especially for the long-term maintenance and replacement of the landfill capping. As a result of containment, the potential for harmful emissions continues. Contaminants may be released at some indeterminate point in the future. Considering the Bruntland Committee definition this seems to be the exact opposite of sustainable landfill.

During the negotiations on Annex II of the EU Landfill Directive a substantial part of the discussion was focused on principles, criteria, test methods, and limited values associated with the acceptance of various types of waste at various categories of landfills. It was not possible to reach an agreement on these issues. The matter was therefore deferred to Annex II: “Criteria and procedures for the acceptance of waste at landfills”. Annex II initially only outlined principles. A committee of representatives from the Commission and member states with specific knowledge on landfilling was established. This so called TAC Subcommittee on the Landfill Directive was allotted the task to specify methods, parameters and limit values (Hjelmar et.al, 2001).

The setting of environmentally based criteria and limit values for waste to be accepted at landfills requires attention to and combination of several aspects influencing the release of contaminants from the landfilled waste and their subsequent short and the long term impact on the environment. Various experiences, different approaches, existing regulations, and policies within the member states and the European Community were taken into account during the process. Some member states already had established test-based national systems for classification of waste to be landfilled. Other member states had systems in various stages of preparation. Some member states had general rules for acceptance at various classes of landfills and others rely on case by case evaluations. There was agreement that setting of criteria and limit values should be based on actual risks to the environment caused by the landfilled waste. There was further agreement that for certain types of waste and landfills it might be feasible to base the development of acceptance criteria related to the impacts on groundwater and surface water on scenario calculations using mathematical models. It was obvious to the TAC Subcommittee that this approach was the simplest and most straightforward when applied to inert waste landfills. In later stages the work was extended to hazardous waste and certain types of non-hazardous waste. This paper will focus on the inert waste landfills. The reason is that the Landfill Directive does not require artificial barriers or aftercare for inert waste landfills. That represents the situation that sustainable landfill projects aim for after a certain period of actively influencing the processes within the landfill.

The work resulted in Council Decision 2003/33/EG of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 and Annex II of Directive 1999/31/EC on the landfill of waste (CEC, 2003). During the process it was demonstrated that it is possible to use a scenario and transport modelling approach to establish a direct relationship between the behaviour of inorganic contaminants released by leaching from waste in a landfill, their migration through the underlying soil and the downstream aquifer and the resulting impact on the groundwater quality at specified target points (Hjelmar et.al, 2001). Using groundwater quality criteria and hydrogeological models source criteria can be determined in terms of maximum allowable peak concentrations of the various contaminants in the source term. When waste-waste interaction is not taken into account for inert waste, then these maximum allowable peak concentrations are considered applicable to the individual wastes arriving at the landfill. This is considered acceptable since by definition inert waste is not very reactive. Quality criteria imposed on the groundwater at the target points may, by reverse modelling, be “back-calculated” to corresponding limit values for the result of leaching tests performed on the waste to be landfilled.

2. APPROACH FOR ESTABLISHING CRITERIA AND LIMIT VALUES

The major potential impact of waste placed in an inert waste landfill is believed to be migration of leachate and subsequent contamination of groundwater and possibly also of surface water. The approach used in the development of criteria for the acceptance of waste at landfills for inert waste is best described in terms of a series of consecutive steps. First a decision is made concerning the primary target(s) or point(s) of compliance. That is the quality of the groundwater at one or more point(s) downstream of the landfill. Quality criteria are then selected for the groundwater and the physical characteristics of the landfill and the environment scenarios are selected and described. The environment scenario includes the net rate of infiltration and a hydrogeological description of the saturated (aquifer) and unsaturated zones upstream, below and downstream of the landfill. The source of the various contaminants is subsequently described in terms of flux of contaminants as a function of time based on leaching data and the hydraulic scenario defined. One or more models are selected to describe the water flow and the transport of contaminants from the base of the landfill through the unsaturated and saturated zones to the point of compliance. Attenuation factors are then used to perform a “backwards” calculation of the values of the source term corresponding to the selected groundwater quality criteria for each contaminant at a particular point of compliance. The final step consists of transforming the resulting source term criteria to a limit value for a specific test. The stepwise procedure is outlined by the following stages:

- Choice of primary target(s) and principles
- Choice of groundwater criteria values
- Choice and specification of the landfill scenario
- Description of the source of potential contamination
- Choice and specification of the environment scenario
- Performance of “forward” model calculation to determine attenuation factors
- Application of model results to criteria setting
- Transformation of the resulting source term criteria to results of specified leaching tests

It should be noted that the procedure involves numerous simplifications and generalisations of complex and diverse physiochemical processes. This is justified by the need to have an operational and relatively simple system, which can be used for the development of general criteria. Each step is briefly discussed below.

2.1 Choice of primary target(s) and principles

It is convenient to express the primary environmental criteria in terms of a required groundwater quality. Not only because the groundwater can be contaminated itself, but also because the contaminated groundwater can be a potential conduit of a leachate plume to surface water. It is necessary to define the point(s) of compliance. These are the locations in the aquifer where the groundwater must fulfil the quality criteria.

2.2 Choice of groundwater criteria values

For the purpose of establishing criteria the acceptable groundwater quality had to be determined. These are more appropriate than drinking water standards. The latter only takes adverse effects associated with human consumption into account. Groundwater quality standards would take the entire ecological system into consideration. Unfortunately no internationally established groundwater quality standards exist. Therefore the point of departure was a combination of several minimum standards for drinking water quality, among which the EU Drinking Water Directive (CEC, 1998) and the WHO drinking water criteria (WHO,1996) were the most important. A (real or imaginative) drinking water well was therefore selected as point of compliance (Figure 1).

2.3 Choice and specification of the landfill scenario

The landfill scenario chosen for the model calculations was intended to provide a simplified description of a “typical” inert waste landfill. It is a relatively small landfill, both with respect to volume, surface and height (Hjelmar et al.; 2001). Also no liner is considered present.

2.4 Description of the source of potential contamination

A description of the source of potential contamination is needed as input for the groundwater transport/attenuation model. The source will change in time, or in other words with progress of the leaching process. It is therefore desirable to express the source as a function of time or liquid/solid (L/S) ratio. It could be expressed as a time dependent flux in terms of mg of contaminants per kg of waste per unit of time. Some contaminants dissolve fairly easy and can be considered “availability controlled”. Other contaminants are mainly present in a form fixed to other elements. These can be considered “solubility controlled”. A distinction between these two “situations” is still being debated. As waste-waste interaction was assumed to have no significant influence, it is consecutively assumed that the landfill behaves similarly to a large column or lysimeter test. The estimation of the flux from the bottom of a landfill was therefore based on the results of laboratory or lysimeter leaching tests combined with the hydraulic information of the landfill scenario.

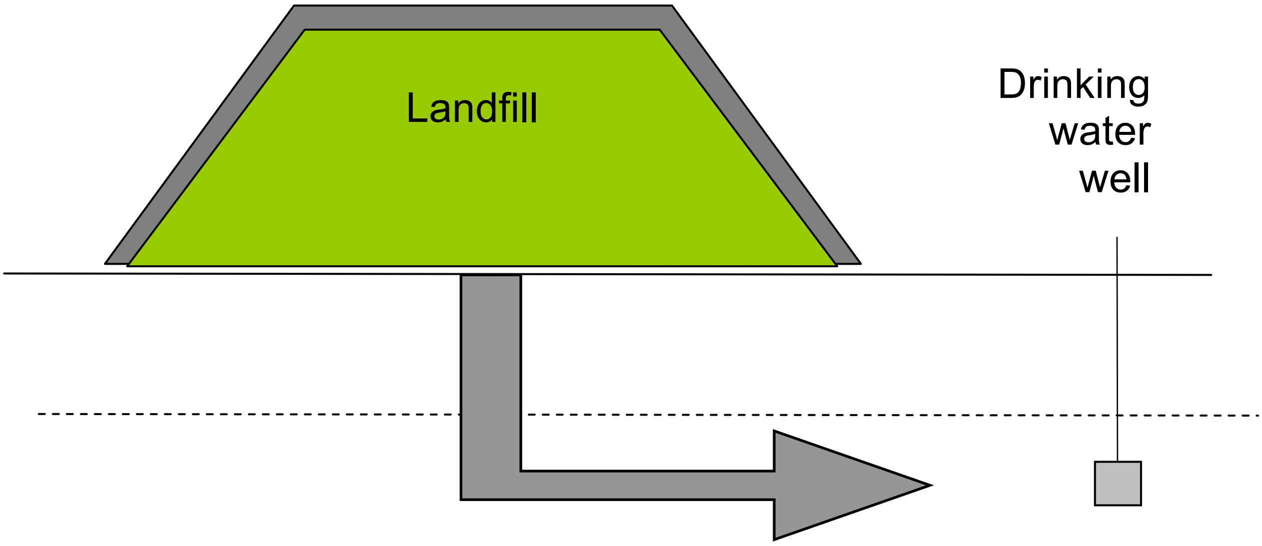

Figure 1: Landfill, groundwater flow and point of compliance

2.5 Choice and specification of the environment scenario

The environment scenario is intended to provide a simplified description of the characteristics of a “typical” landscape in which an inert waste landfill could be situated. There is particular focus on the hydrogeological properties. This includes precipitation, net rate of infiltration, flow and transport for saturated and unsaturated zones and choice of models to be used. During lateral transportation with the groundwater contaminants can be diluted and/or dispersed. On top of that interaction with the soil and constituents of the groundwater can occur. Only sorption was included in the modelling. The intention was to provide reasonably conservative estimations of the potential impact to the groundwater. For some properties more than one option was included in the model. But, considering the variability of climate and geology across Europe, such a simple scenario can never take into account all imaginable situations.

2.6 Application of model results to criteria setting

This involves “backwards” calculation from the points of compliance to the source.

2.7 Transformation of the resulting source term criteria to results of specified leaching tests

This gives the final result: the limit values.

3. DISCUSSION

The requirements defined for inert waste landfills of the European Landfill Directive and its acceptance criteria provide a good basis for a first evaluation of sustainable principles in landfills. The inert waste criteria do not necessarily have to be met from the start of the landfill activities. They may be defined as conditions to be reached when the active period of leachate treatment has expired. This implies that management in the operational period and/or during a limited period of aftercare can ensure the reaching of the desired end condition. The approach followed for the establishment of acceptance criteria should receive a very warm welcome by the landfill industry. Maybe the method needs further development and refining. Maybe the results, i.e. the height of the limit values, can be debated. But the principles are very valuable. The method enables an assessment of the actual impact of landfills based on facts. In the recent past a limited number of environmental scandals has strongly influenced the public opinion on landfill. Combined with a lack of knowledge of the processes occurring in landfills, this has (understandably) resulted in an overreaction by regulators. The approach followed for the acceptance criteria is a first step to obtain regulations that are more and more based on facts instead of emotions. It might support an improvement of the image of the landfill industry, of its recognition as a useful and important option in integrated waste management systems.

The Annex II (CEC, 2003) allows member states to deviate from limit values based on a site specific risk assessment. This implies that the same approach could be used with site specific data of the landfill question. But moreover site specific data and scenarios for industrial activities other than landfill can be used in the method as well. The processes occurring in the unsaturated and saturated zones below a source of (potential) contamination are the same irrespective of the activity. This implies that the approach followed for establishing acceptance criteria for landfills, has also supplied an instrument to compare the impact to soil and groundwater of various industrial activities (Figure 2). This in turn enables regulators to determine in which situation it is most effective to stimulate further reduction of impact. A further advantage for the landfill industry might be in the realisation by regulators that for landfills further reduction of contaminants and more rigorous measures are required than for other industries. The method enables more fair and more balanced overall environmental protection policies.

In the process of determination of acceptance criteria for inert waste landfills a source term for the landfill has been calculated. No liners or aftercare are required for landfills for inert waste. It can not be concluded otherwise than that the Annex II considers the emission resulting from the landfilling of inert wastes as an acceptable emission. Although it may not have been intended: the method has given a definition of final storage quality with respect to groundwater pollution. Let us imagine that a definition of final storage quality would be adopted in terms of the quality for which no environmental controls are considered necessary. That would imply that maintenance of the isolation measures and aftercare can be ended if it can be shown that in a landfill (irrespective of the nature of the waste) the source term has reached a level of emission below the level associated with the acceptance criteria for inert waste. Let us assume furthermore that it is possible by actively influencing landfill processes to reach that situation of acceptable emission within one generation (30 years). In that case the development of the method has given a substantial contribution to the eventual definition of sustainable landfill.

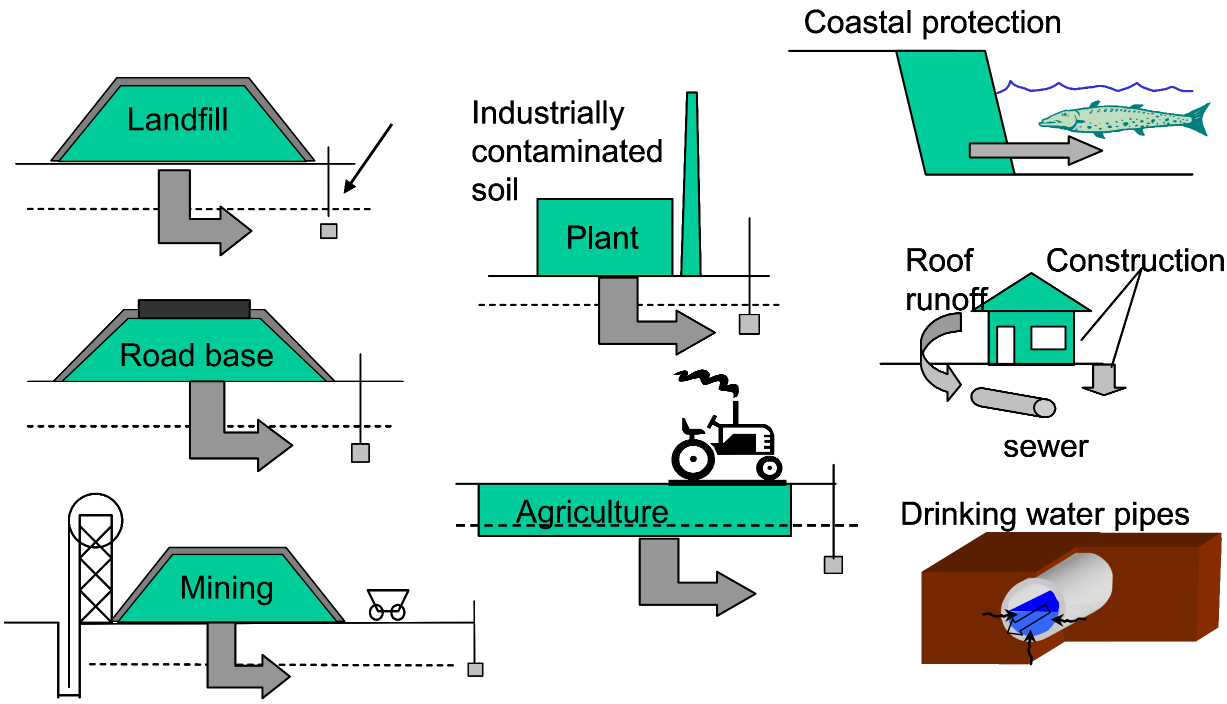

Figure 2: Similarities between different industrial activities (courtesy of ECN)

4. FUTURE DEVELOPMENTS

The goal of sustainable landfill is to reach a stable situation in equilibrium with the immediate environment, not posing any threat, not causing an unacceptable emission. To fully understand how this can be achieved more knowledge on processes in waste is required. Ultimately this knowledge has to be translated into verified assessment tools and prediction instruments. That is the only way to show and convince regulators and the general public that well operated landfills indeed do not pose a threat to the environment. Openness and intensive communication will be required to establish lasting trust of regulators and the general public. This might very well turn out to be a prerequisite to agree on ending maintenance and aftercare.

Knowledge and expertise that requires further development is related to waste characteristics. It would be extremely useful if a comprehensive database of waste characteristics becomes available. This not only allows comparison. It provides regulators with a better understanding of the range in which waste characteristics can vary. It will show for different waste types what the relevant parameters are to focus on. In that respect it might reduce the administrative burden and costs associated with unnecessary sampling and analysis. Most of all more knowledge is required of waste-waste interaction. Combination of carefully selected types of waste enables reduction of impacts as compared to the impact of the individual wastes. Progress in research (van Zomeren et al., 2005) has shown that it is possible to end the “black box” approach of landfills. In spite of the heterogeneity of the different types of waste, the behaviour of waste in a landfill body is very consistent. Data from all the different scales and types of experiments show relatively consistent pH-dependent leaching behaviour. Closer examination reveals that leaching of these contaminants is controlled by the same chemical processes e.g. solubility control by mineral phases, sorption to hydrous ferric oxide (rust) and complexation to organic matter. Knowledge of these processes allows the definition of technological design measures that enable us to control the processes that cause emissions. Combining characteristics of waste materials enables creating beneficial conditions for the leaching behaviour of contaminants.

The current European regulatory framework provides a start, but further development is needed to understand the impact of mixing different waste types. The modelling and prediction of the long-term release of contaminants based on the characteristics and amounts of waste entering a landfill is now within reach. This also implies the possibility of developing an assessment framework on when and how to end aftercare. The final goal is to build an expert system (Figure 3) that can be used by various parties.

The first version of this expert system is already available. Further development (e.g. verification and scenario descriptions) will enable quantification of the source term of any landfill based on site specific data. It will allow regulators and operators to assess the impacts of this source term in different site or region specific scenarios. It will be possible for regulators and operators to compare this impact with different regulatory frameworks. In combination with criteria for an acceptable level of emission as determined by the approach used for establishing acceptance criteria, it will become possible to define the situation that maintenance of the landfill isolation and aftercare can be ended.

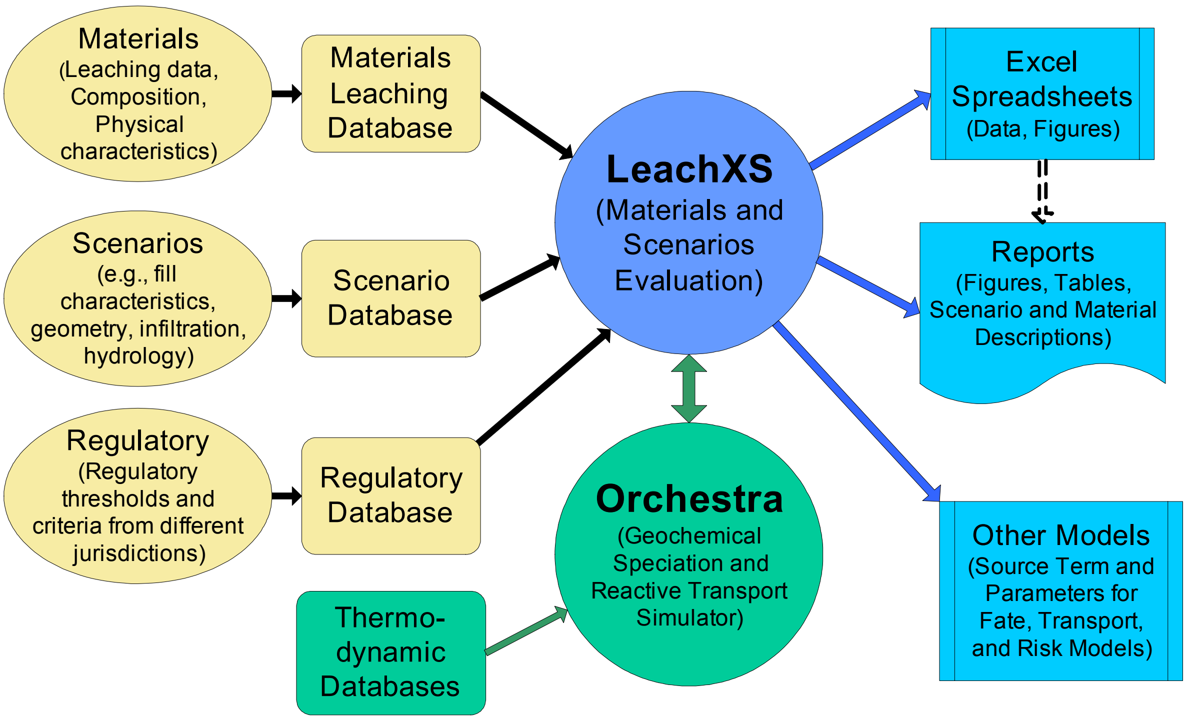

Figure 3: Schematic overview of the intended expert system
(courtesy of DHI/ECN/VanderBilt University)

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Much of the information on the approach followed for establishing acceptance criteria presented in this paper has been “borrowed” from the work of DHI (Denmark), BRGM (France), Golder Associates (UK) and ECN (Netherlands). The work was carried out for the TAC Subcommittee on the Landfill Directive. In the way it is presented here, it is not necessarily endorsed by these organisations. The paper solely represents the views of the author.

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