Assessment of long-term emissions from landfills as part of the landfill aftercare completion procedure

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ASSESSMENT OF LONG-TERM EMISSIONS FROM LANDFILLS AS PART OF THE LANDFILL AFTERCARE COMPLETION PROCEDURE

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SUMMARY: Modern landfills are designed and constructed in a way that emissions can be avoided to a large extent within the operational phase and after closure of the site during the aftercare period. Financial reserves are built up during the operational phase to warrant funds for the aftercare phase. Most aspects of the potential environmental impacts of landfills are well controlled. However, current practice leads to extended and indefinite timescales for the aftercare and the related funding security for this aftercare period. There seems to be consent in the scientific community that criteria for completion of aftercare are best derived from local site-specific assessment of risk due to leachate emissions. As the impact can occur over very long periods of time, this assessment should not be based on observations and historical data alone. This is particularly true when attempting to predict future behaviour and impacts. A certain degree of modelling will, therefore, always be needed to enable reasonable and justifiable choices and decisions. Performance based completion criteria involve more detailed knowledge on the landfill processes, their uncertainties and the potential impact on the environment. A decision scheme outlining a generic approach to determine whether the conditions for stopping the aftercare have been met is proposed.

1. INTRODUCTION

Modern landfills are designed and constructed in a way that emissions can be avoided to a large extent within the operational phase and after closure of the site. Financial reserves are built up during the operational phase to warrant funds for the aftercare phase. Most aspects of the potential environmental impacts of landfills are well controlled. Over the last 20 years, an increasing awareness has developed that the downside of containment engineering (lining and capping the landfill) is that it has created timescales of at least centuries before landfills will reach a point where no active management, monitoring or inputs of energy or materials are needed (Beaven et al., 2014). The extended timescales for aftercare and the uncertain funding security for the aftercare period are two main concerns that need to be resolved. In addition, with the current practice of landfill capping and lining, the emission potential of the landfill may remain unchanged and as a result potential problems with future emissions will be shifted to

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coming generations. For this reason, initiatives are taken to find methods to determine the duration of the aftercare period and to shorten this period by applying different technologies aiming to reduce the emission potential (e.g. leachate recirculation, flushing and/or aeration).

To be able to introduce measures to shorten or finalise the aftercare period, it is necessary to know what the functional end-point criteria are that a given landfill site needs to meet. For the long-term impact (>50 years) of landfills, the emissions by leaching are probably the most important. Gas emissions are mostly relevant during shorter time scales. The required level of aftercare measures is generally based on the site-specific performance of the landfill and, to a certain extent, the expectations with regard to the future performance. According to e.g. the EU Landfill Directive (1999/31/EC), the aftercare period must continue for as long as may be required by the competent authority taking into account the time during which the landfill could present hazards to human health and the environment (HHE).

In practice, an assessment of whether or not a landfill can present a hazard will involve the definition of one or more Point(s) of Compliance (POC) in relation to the leachate plume below or downstream of the landfill where specific groundwater, soil and/or surface water quality criteria must be met. These requirements imply that (site-specific) aftercare completion criteria need to be defined in order to have clear targets for the landfill operator as well as clarity for the competent authorities on whether or not the aftercare can be considered as completed. It is relatively simple to demonstrate that the landfill emission complies with defined criteria at a given point in time, especially for those landfills were emission is low due to flux reducing measures (surface sealing). But the competent authority also needs to secure that this situation will remain unchanged in the future. For example surface sealing may deteriorate over time, resulting in an increased flux that might in turn leads to exceeding acceptable emissions.

It is clear that these factors, and their consequences, are associated with many uncertainties. Also, the longer the time scale at which projections are being made, the larger the uncertainties tend to become. However, this only stresses the need for both a qualitative and quantitative estimate of the most likely future development, and the need to know more about the associated uncertainties. It is at this point that “modelling” can help. The role of modelling is to enable a quantification of the most likely scenario, in other words, to render the uncertainties explicit. It should be noted that “modelling” is a broad term and it can be applied using very simple approaches (extrapolation of the existing situation; short timescales), or using more advanced approaches when needed (longer timescales, in which more factors and processes are taken into account). Some main principles of determining the aftercare completion criteria are discussed below.

2. PRINCIPLES OF AFTERCARE COMPLETION ASSESSMENT FOR LANDFILLS

2.1 Scenario

When the status or development in relation to aftercare completion criteria is assessed for the emissions by leaching, the long-term impact scenario of a landfill can be generally represented as indicated in Figure 1. The leachate that contains potentially harmful substances can infiltrate the underlying soil system and the extent to which this will occur is, among others, dependent on the properties of the waste, design and operation of the site, properties of the liner systems and climatic conditions. The properties of the soil system will determine the transport through the soil towards the groundwater. Once the plume with contaminated leachate enters the groundwater, a dilution effect will occur and the contaminants will be transported to the POC (the POC could in principle also be placed directly under the landfill or located in a surface

water body). The competent authorities normally determine the location of the POC and the required groundwater quality criteria.

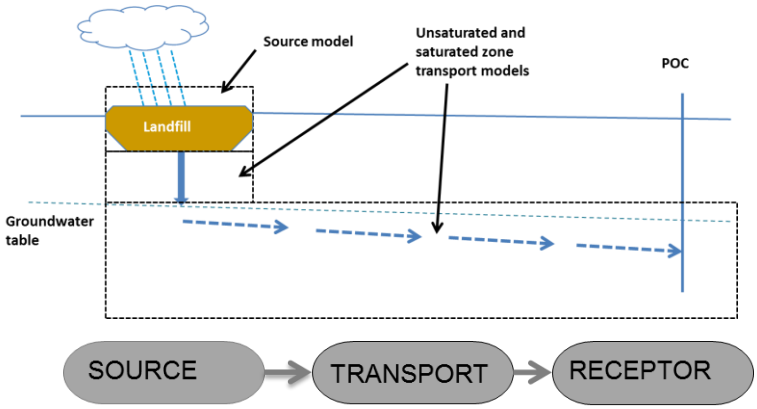

Figure 1. Schematic overview of a landfill scenario and the Point of Compliance (POC).

As already mentioned, covers can deteriorate over decades to centuries. Depending on soil properties and the location of POC, groundwater transport of contaminants to the POC might take (many) decades. Consequently a very long time-frame needs to be considered in the assessment. As can be seen from Figure 1, assessment of the long-term environmental impact of a landfill requires consideration of the complete chain of source, path and receptor. As the impact can occur over very long periods of time, this assessment should not be based on observations and historical data alone. This is particularly true when attempting to predict future behaviour and impacts. A certain degree of modelling will, therefore, always be needed to enable reasonable and justifiable choices and decisions. As indicated above, It should be noted that "modelling" can cover a large variety of descriptions and assumptions with a broad range of complexity.

2.2 Assessment of compliance with criteria

The route to determine whether aftercare has been completed could consist of several steps, e.g.:

- starting out conservatively and based on available knowledge of landfill conditions and current (and historic) data on the quality and quantity (flux) of the leachate. After this first assessment the data gaps might be filled and, to the extent necessary, increasingly comprehensive calculations should be performed to determine whether the emissions are acceptable in a defined site-specific scenario. In addition, it should also be assessed whether these emissions can be expected to remain acceptable in the long-term or how long it would take to obtain acceptable emissions.
- When the predicted long-term emission of one or more substances exceeds the groundwater criteria (or criteria in soil or surface water), it becomes opportune to derive emission limit values ("desired" leachate quality) for the leachate to obtain knowledge on how the current leachate quality relates to the "desired" leachate quality. In that second step, the groundwater quality criteria are taken as the basis for the assessment and the resulting acceptable emissions from the landfill (i.e. leachate quality) are calculated by backward modelling. As a result, the landfill operator may compare the status of the current leachate quality to the derived limit values.
- A logical third step in the assessment would be to estimate the time required to meet the emission limit values and to consider additional active or passive measures (e.g. leachate recirculation and/or aeration) to minimise this time period. Literature data from field

experiments can be used as a basis to estimate the emission reduction potential. Finally, monitoring and modelling of the actual emissions within the operational phase (and possibly extended into the post-closure phase) is needed to verify assumptions made on the leachate quality.

2.3 Assessment of the source term

While most conditions affecting the transport of substances to the POC at the receptor remain more or less constant over time, the source term will change over time depending on the conditions in the landfill (e.g. degradation and removal of substances) and the nature of the substances of concern. This implies that the description of the source term is complicated and should not be based entirely on monitoring data because that can only give information on the history and there is no guarantee that the observed trends will prevail over time. Consequently, modelling is needed to explain observations and, hence, to justify predictions of future behaviour. Modelling should be based on known processes in the landfill and data from monitoring, characterisation and on-site investigations of the waste in the landfill.

2.4 Decision scheme to determine if aftercare is completed

Figure 2 shows a conceptual decision scheme that outlines the steps in determining whether aftercare is completed. The scheme shows the procedure to assess the combination of the source, transport and receptor parts to determine whether the conditions for stopping the aftercare have been met. The procedure includes considerations concerning the so-called "bath-tub" effect, which may occur when leachate collection is discontinued and a new hydrological equilibrium is established within the landfill. It is suggested to monitor the potential consequences of this change of conditions, e.g. for a period of some years, before making a final decision concerning aftercare completion.

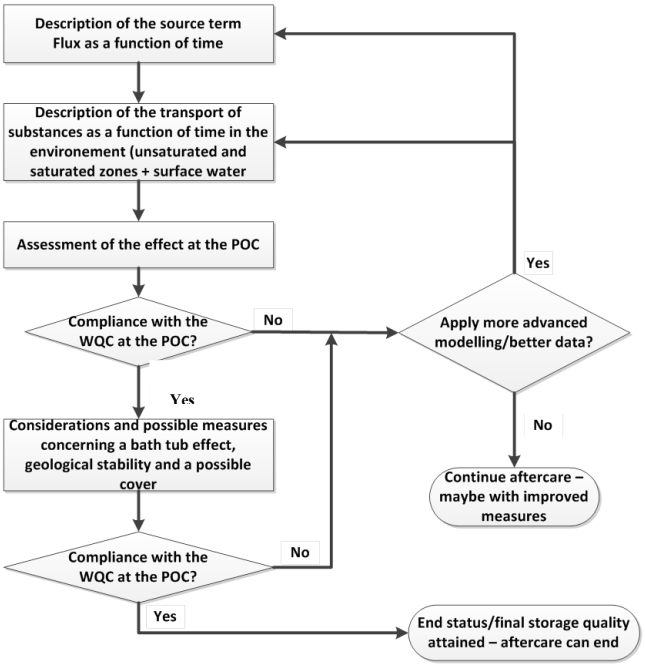

Figure 2. Overview of possible steps to determine landfill performance and aftercare completion.

3. CONCLUSIONS

Modern landfills are designed and constructed in a way that emissions can be avoided to a large extent within the operational phase and after closure of the site during the aftercare period. Financial reserves are built up during the operational phase to warrant funds for the aftercare phase. Most aspects of the potential environmental impacts of landfills are well controlled. However, current practice leads to extended and indefinite timescales for the aftercare and the related funding security for this aftercare period.

There seems to be consent in the scientific community that criteria for completion of aftercare are best derived from local site-specific assessment of risk due to leachate emissions. As the impact can occur over very long periods of time, this assessment should not be based on observations and historical data alone. This is particularly true when attempting to predict future behaviour and impacts. A certain degree of modelling will, therefore, always be needed to enable reasonable and justifiable choices and decisions.

Performance based completion criteria involve more detailed knowledge on the landfill processes, their uncertainties and the potential impact on the environment. A decision scheme outlining a generic approach to determine whether the conditions for stopping the aftercare have been met is proposed.

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