RISK ASSESSMENT METHODOLOGY FOR AFTER-CARE OF LANDFILLS BASED ON THE PROBABILISTIC APPROACH

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SUMMARY:

The costs of after-care of landfills consists of regular costs for monitoring and maintenance, and a sum to cover environmental risks in the after-care period. Before 2003 the financial impact of environmental risks of landfills in The Netherlands, in general, was covered by a fixed percentage of the regular after-care costs. This system did not include site-specific aspects. For this reason the Association of Dutch Provinces (IPO) decided to introduce the probabilistic risk assessment method. The probabilistic risk assessment method is being used to estimate the costs of environmental risks, such as a large and uncontrolled contamination of groundwater or local damage of top cover. The probabilistic risk assessment method is objective and requires input from landfill engineer experts. Proper documentation of input data is needed as well as communication with landfill operators is of vital importance to achieve a broadly based acceptance.

1. INTRODUCTION

The responsibility of after-care of existing landfills and recently closed landfills in The Netherlands is delegated by law to the Provincial Authority. For the existing landfills and landfills closed after March 1995, the relevant Province is responsible for the after-are, which includes organisational and administrative aspects, as well as the financial control.

The obligation of the operator of a landfill is to prepare an after-care programme. The after-care programme describes all the measures that need to be taken to protect the environment in the future, such as monitoring, control and maintenance. The Association of Dutch Provinces (IPO) is using a Checklist for after-care programmes since 1997, in order to examine the submitted after-care programmes objectively. The after-care programmes result in a calculation of the financial resources to be deposited by the operators into the Provincial After-Care Fund. The financial resources become available during the operation period by provisional tax assessments. The final tax assessment follows during the handing-over procedure of the landfill to the province.

Based on experience and new studies the existing Checklist was reviewed and reformulated (IPO, 2002). An additional checklist was made for the after-care programmes of contaminated sludge disposal sites in the same period. Part of the reformulated Checklist for landfill sites is the assessment of potential environmental risks and its financial impact on the Provincial After-Care Fund.

In the former Checklist the financial impact of environmental risks was covered by a fixed percentage of the regular after-care costs (monitoring, control and maintenance). The use of a fixed percentage conflicts with a site-specific approach:

- landfill sites with a high level of protection generally have a low risk profile but high regular after-care costs (e.g. due to high costs of future replacement of the top cover and monitoring). The fixed percentage results in a high budget to cover the lower potential risks;
- landfill sites with a low level of protection sometimes have a high-risk profile but low regular after-care costs. The fixed percentage results in a low budget to cover the higher potential risks.

Research has been carried out to select a site-specific risk assessment method to avoid the above-mentioned conflict, including an interview with a prominent insurance company. The selection (IPO 2001) has been made out of simple and more complex methods, used for example in civil engineering (CUR, 1997), in surface water pollution risk estimations and in processing industry design. Finally two methods have been compared in more detail: a quick scan method and the probabilistic risk assessment method.

The quick scan method was expected to be less complex and, therefore, cheaper and easier to understand. The probabilistic risk assessment method was expected to be better reproducible and more objective (IPO 2001). Therefore the Association of Dutch Provinces (IPO) has decided to develop the probabilistic risk assessment method for the new Checklist for After-Care Programmes.

2. OBJECTIVE

The objective of the development of the probabilistic risk assessment method is to standardise the risk assessment method for after-care for each individual landfill and to include the input of site-specific aspects. The risk assessment method shall be made available for provincial Authorities, Dutch landfill operators and their consultants.

3. THE METHOD

3.1 Approach

The financial impact is made up of:

a) the likelihood (probability) that an ‘unwanted event’ occurs that affects the environment, and if so,
b) how often and at which point of time it happens; and
c) the costs to undo the effects of such an ‘unwanted event’.

The method, using Monte Carlo fault tree analysis, consists of a five-step approach to estimate the quantitative financial risks:

A. The development of a fault tree;
B. The estimation of each risk factor;
C. Risk calculation;
D. From possibility to expectation;
E. Determination of the financial impact.

Before the new method will be used, the costs of an ‘unwanted event’ have to be determined. An ‘Unwanted event’ is defined as: ‘an event that might happen, even taken into account that the level of after-care is sufficient and based on the actual state of knowledge’. In this case only events are involved that will have a negative impact on the environment: pollution of groundwater, soil and/or atmosphere.

Starting point is that there are no relations between (lack of) regular maintenance and the ‘unwanted events’. In this way the landfill operator who hands over the budget and responsibility of after-care to the Province will not have to pay for eventual future mismanagement in execution of the after-care activities in advance. Financial risks related to the redevelopment of a landfill site and risks of improper fund management are not included, as they are not the responsibility of the landfill operator.

Furthermore exceptional risks are excluded from the financial risks, such as earthquake damage (in The Netherlands) or a plane crash. In both cases other funds should cover relevant costs.

In the Dutch After-Care Checklist the defined ‘unwanted events’ are:

a) a large and uncontrolled contamination of groundwater;
b) a local damage of top cover; and
c) an advanced date of replacement of top cover due to an overestimated life time expectancy.

Any other ‘unwanted event’ is covered by the site-specific after-care programme because it can be defined in advance.

For (a) and (b) fault trees are developed for the Dutch situation. For (c), the risk of advanced date of replacement of top cover, the Association of Dutch Provinces decided to use a less advanced method. Research shows that estimation of life expectancy of mineral liners and geosynthetic liners is complex and the influence of local factors on life expectancy is still unknown. The development of a fault tree is not realistic without knowing all factors on life expectancy. The less advanced method (probability range multiplied by costs multiplied by capitalisation factor) is integrated in the risk model.

The actual costs of an ‘unwanted event’ is determined for each event. The costs of decontamination of groundwater (a) have to be estimated based on available geohydrological data. Detailed groundwater contamination model studies are preferred but not necessary because the size of such an uncontrolled contamination of groundwater cannot be predicted in advance.

3.2 Steps to be taken

In Step A the final risk factor of an ‘unwanted event’ will be determined by defining all individual risk factors (input parameters) which influence the event, such as leakage of top cover in combination with the failure of bottom lining. The advantage of defining a fault tree is that the relationships between the individual risk factors can be visualised. An example of a fault tree is given in Figure 1.

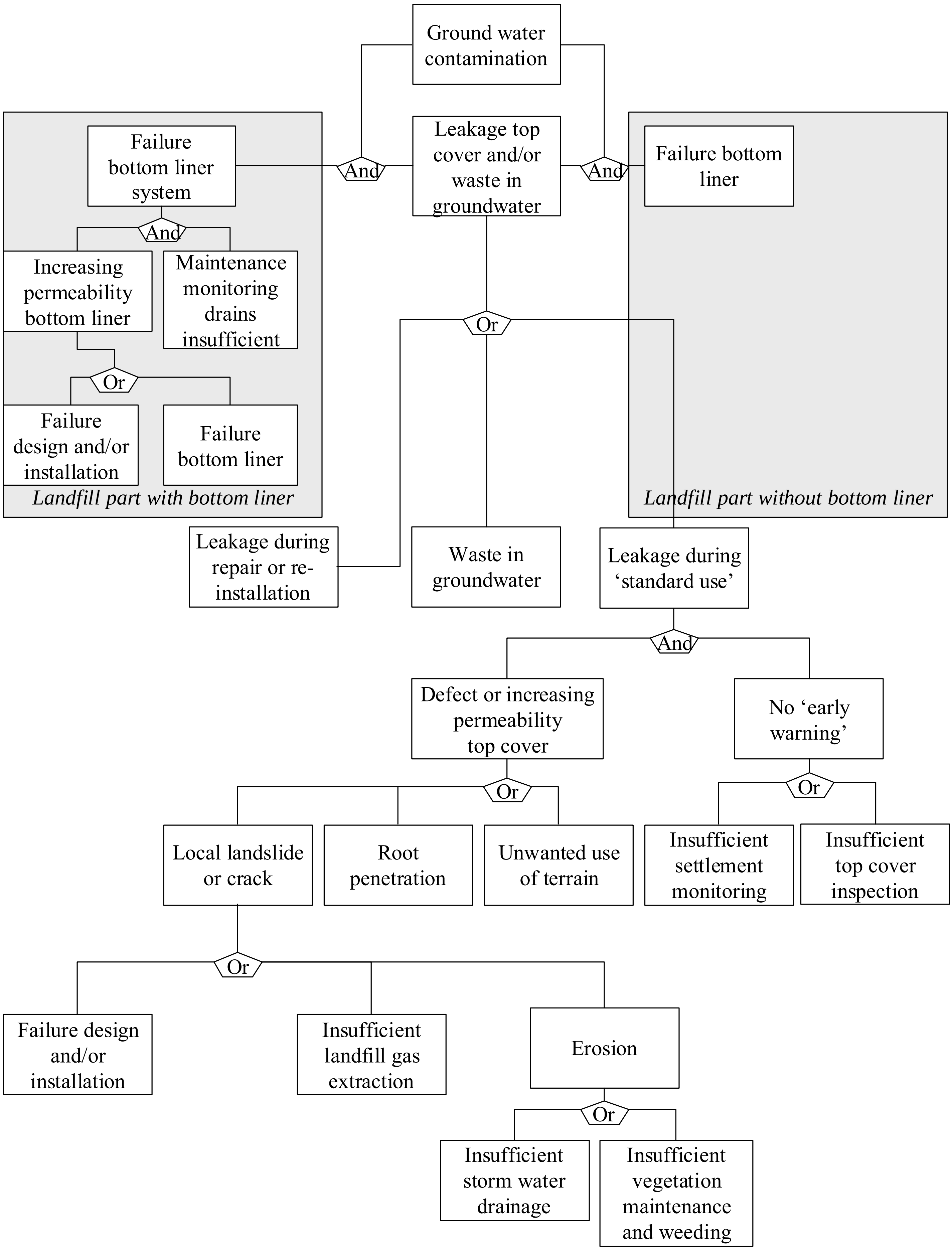

Figure 1: example of a fault tree

Two relationships between the individual risk factors can be distinguished: the “And” relationship when risk factors are related to each other, and the “Or” relationship when risk factors will have an independent result. Examples are given in Figure 2.

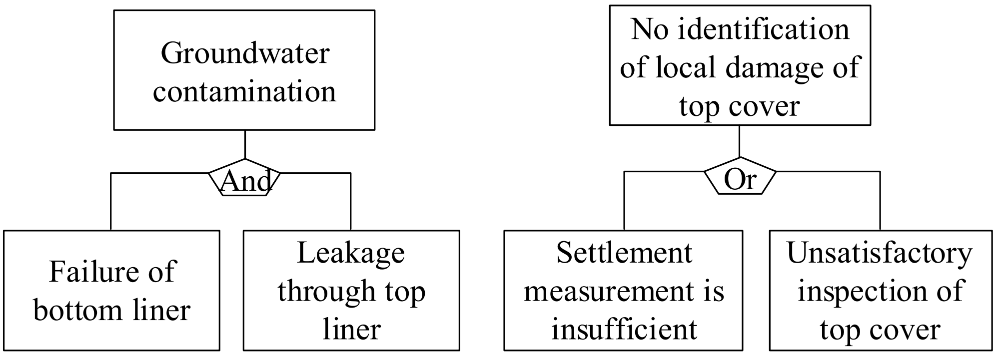

Figure 2: Example of relationships between individual risk factors

In Step B, the estimate of each risk factor needs the input of landfill engineering experts. The risk factor consists of an expected risk value for each individual risk factor of the fault tree, together with a probability distribution.

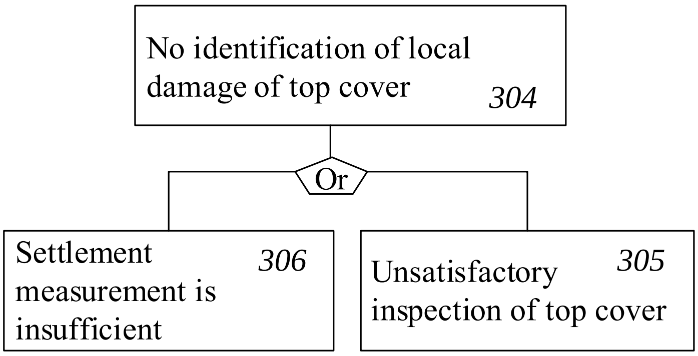

Figure 3: example of relationship between risk factors

This part of the fault tree shows that if not enough settlement monitoring is carried out OR visual inspections are not carried out sufficiently, a leakage of the top cover might occur without notice.

Suppose the probability of insufficient settlement measuring is p (306) = 0.3 and the probability of insufficient visual inspection is p (305) = 0.2, the probability of <u>not</u> observing damage (leakage) of the top cover is p (304) = 1 - (1 - 0.3)*(1 - 0.2) = 0.44.

Expert input is essential for the estimation of probabilities. Estimating a single probability is not realistic because exact knowledge of risk factors is not available. Therefore, an estimated range is more suitable.

If the risk of tearing of the top cover liner for example is about 15%, it can also be described as a risk between 10% and 20%, with a higher probability of occurrence coming close to 15%. In the risk model the distribution is termed a ‘triangular’ distribution [lit. 2], in which the 15% has the highest probability. The limits of the distribution, in this example 10% and 20%, can occur occasionally. The range reflects the uncertainty of the used figures. If more specific data or experiences are available, the range will be reduced. The data used for defining the actual range shall be documented to assure that assumptions are reproducible.

The estimation of probabilities will be carried out for separate after-care periods. The after-care periods are being chosen based on site-specific conditions, such as waste settlement, landfill gas extraction and life time expectancy of the top cover. The periods for an average municipal solid waste landfill are: 0-3, 4-15, 16-50 and 51-100 year. In the first and second period for example settlement related risks are larger than in later periods.

The aim of the model is to reach a high level of objectiveness of the input data and final outcome. Expert judgement is vital to assure a reliable outcome of the risk assessment.

Step C is the risk calculation based on the Monte Carlo analysis method. Every fault tree will be calculated about 5000 times in order to reach the final risk factor for the unwanted event.

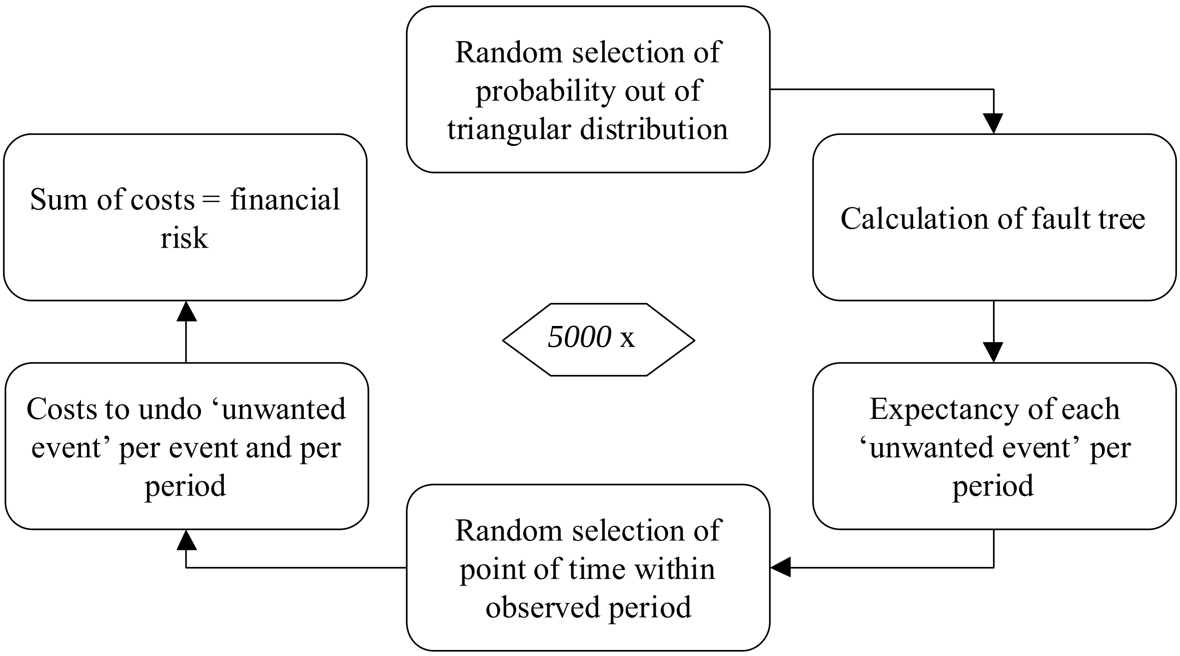

Figure 4: Repeating calculation

Step D calculates the expected amount of unwanted events within a given period, using the following formula:

$$\lambda = np$$

λ: the expectation within a time frame
n: the amount of years within the time frame
p: the yearly probability of an unwanted event

Example: if a time frame consists of ten years (n) and the yearly probability (p) is 0.11, it is expected that the unwanted event happens 1.1 times in the time frame. To generate a discrete number, a Poisson distribution is being used.

Finally, in Step E the determination of financial impact will be carried out. The costs of environmental risks are determined by picking the year(s) in which the unwanted event happens within the time frame at random. This is needed to calculate the Net Present Value (NPV) of the expected costs to undo the effects of each such an event. The total of NPV's for all events is the maximum budget needed to cover the potential risks.

The Association of Dutch Provinces decided to use the 95-percentile value of the total of NPV's to cover the costs of all potential environmental risks.

4. EXPERIENCES IN THE NETHERLANDS

The development of the probabilistic risk assessment method for after-care in The Netherlands started about 1995. Initially, it was developed for the waste management authorities in the Province of Limburg (AVL). Afterwards the method has been improved and has been used in the Province of Gelderland and the Province of South-Holland.

Intensive communication with landfill operators, in order to achieve sufficient acceptance of the method, has proven to be highly beneficial to implementing the method. In the Province of Gelderland, initially, the landfill operators did not accept the method. It was fairly new and not yet being used in most other Provinces in The Netherlands. Therefore the Province of Gelderland has not yet used the results of the method, waiting for selection of a method by the Association of Dutch Provinces.

The Province of South-Holland, based on the experiences in the Province of Gelderland, put considerable effort in intensive communication with the landfill operators, explaining the advantages and disadvantages of the method. This resulted in a more positive attitude of the relevant landfill operators towards the probabilistic risk assessment method.

5. CONCLUSIONS AND FUTURE PERSPECTIVE

The experience with the implementation of the probabilistic risk assessment method on several landfills in The Netherlands shows that the method:

- provides high transparency (input parameters are defined) and a systematic approach;
- takes the site-specific landfill and geohydrological conditions into account;
- needs input of landfill engineer experts for the estimation of the risk factors;
- has a user-friendly interface (Windows);
- needs supplementary documentation in order to be reproduced;
- shall be supported by a database of credible assumptions to improve the objectivity.

The method is suitable for use by all authorities responsible for after-care in The Netherlands and can find wide international application. Communication with the landfill operators is of vital importance to achieve a broadly based acceptance.

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