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DETERMINATION OF GUIDANCE VALUES FOR CLOSED LANDFILL GAS EMISSIONS

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SUMMARY: In order to promote active landfill gas collection and treatment or natural attenuation, it is necessary to identify trigger values concerning landfill gas emissions in the preliminary stage of a risk assessment. The determination of these values is the first goal of a work which includes a large regulation review and the study of a generic inhalation exposure scenario for the most common reuse of French Municipal Solid Waste (MSW) landfill surface, namely a recreational area without residential buildings. The health risk levels of this scenario are lower than the usual levels and enable to determine trigger values for methane production rate. These results and the methane oxidation rate in the landfill cover allow for the determination of residual methane surface emission rates. The combination of these parameters with on-site specific measurements enables the promotion of natural attenuation or active landfill gas treatment.

1. INTRODUCTION

The French Agency for Environment and Energy Management and the French Ministry of the Environment and Sustainable Development are currently defining criteria concerning the regulation of residual emissions of Landfill Gas (LFG) from definitely closed Landfills. The determination of these criteria is to be based on risk assessment studies as well as on European and National regulation and practices related to closed Landfills for non-hazardous wastes.

Landfill gas emissions decrease after the end of landfill exploitation during the aftercare phase. The need for LFG treatment at low production levels depends on different parameters concerning the LFG source, the type and the composition of the cover, and the human receptors for LFG trace contaminants. Health risk and odour level assessment related to the landfill gas emissions represent one of the most important stage of the environmental management of landfill site with a residual organic compound fraction.

The European risk assessment and risk reduction practices are various, especially concerning risk reduction. The LFG residual risks depend mainly on the guidance values for collecting and treating landfill gas. These values also determine the type of landfill surface reuse after the exploitation phase.

A research program concerning LFG odour and risk assessment began at the end of 2003. The purpose was to build methodological guidelines for LFG risk and odour assessment. The

research program consisted in two parts : completing the review of practices, and proposing guidance values especially for the case of closed landfills.
These stages of the study were conducted with the collaboration of SOLAGRO and Riquier Etudes environment.

2. REGULATION AND GUIDELINES REVIEW

2.1 Regulations and guidelines related to residual emissions of closed landfills

In a first stage, a review of the European regulations in 12 countries has been made. This review has concerned especially the LFG collection and treatment for definitively closed landfills. The study has been carried out by consulting the regulation, and owing to the answers to an inquiry sent to 130 correspondents.

In the European countries, regulation is based on : the EU directive 1999/31/EC concerning landfilling of wastes, and the prescribed methane limit value in air (usually approx. 1% of methane).

The UK EPA has produced a series of guidelines related to the management of landfill gas. Two documents give a lot of information :

- Guidance on the Management of Landfill Gas (UK EPA, 2002) ;
- Guidance for Monitoring Landfill Gas Surface Emissions (UK EPA, 2003).

These guidelines give indications concerning the different stages of hazard identification, risk screening stage and risk assessment, methods for monitoring the surface emissions and criteria for closing and post-exploitation. In a first tier these guidelines propose to calculate the approximate gas flow and compare with the trigger values of 50 – 100 m^3 (CH_4)/h. A predicted methane flow that exceeds these values indicates that flaring, or other treatment processes, is needed. The other stages of the tiered risk assessment are a simple or complete quantitative risk assessment.

Concerning the monitoring of LFG surface emissions, prescriptions are given if measurements values obtained with an FID are greater than 100 ppmv on the landfill surface, and 1 000 ppmv above cracks, during the preliminary annual survey stage. In this case, a regular surface emission survey has to be defined and the new trigger values are 0,05 m^3 (CH_4)/ha/h for the closed landfills surface and 5 m^3 (CH_4)/ha/h for the temporary cover. These values are relatively low but can be reached on sites managed according to the best practices. If the flux boxes measures exceed these trigger values, corrective actions have to be implemented in order to minimize the emissions.

Prescriptions are given concerning the site odour assessment, which detail how odour monitoring should be undertaken.

German and Austria regulation limit emissions by reducing the waste organic content. Federal German regulation especially consists in prescriptions about pre-treated wastes, e. g. the residual production of biogas (trigger values for GB21 tests : 20 and 30 Nl/kg dry materials). Some data have to be given concerning the comparison between residual emissions after pre-treatment of the waste and other practices :

- MSW landfill with a LFG good collection rate : 50 to 80 Nl/kg ;
- MSW landfill with a LFG poor collection rate : > 150 Nl/kg ;
- Pre-treated waste : 5,8 – 9 Nl/kg.

Finnish and Danish regulations also permit the use of residual LFG treatment by methane oxydation for low LFG production.

2.2 Guidelines related to LFG risks assessment

The regulation and guidelines related to LFG risks assessment have also be analyzed. The study focuses on the LFG risk assessment models and methods which could be used for closed landfills. Danish work (Bote & al., 2003) concerning the fires/explosion risks for houses on, or near a landfill, is available. This Danish report (Nilausen L. & al., 2001) gives a methodological approach with the focus on the sequence of events which can lead to fires/explosion risks. Data are given concerning the methane fluxes density which can generate a methane travel by gas advection in soil (with overpressure assumptions). This methodology could be used more specifically for accidental risks.

Concerning chronic risks, a specific gas risk assessment model (GasSim, Gregory R.G. & al, 2002) can be used to provide a management tool concerning the bulk and trace gas emissions and dispersions. Several checks between GasSim, LandGem data and site data have been done and are available. Concerning the source terms, the description of the three fraction model is similar to the ADEME model often used in France. GasSim uses a gaussian plume model for the atmospheric dispersion of the emissions. For the specific use of the studied scenario, that is to say modelling of dispersion and mixing of the LFG fugitive and diffuse surface emissions on the landfill top cover, the simple air box model seems more suitable, since the on-site exposure concentrations are higher than any exposure concentrations downwind from the source.

3. HEALTH RISK ASSESSMENT

3.1 Definition of the conceptual exposition scheme

The construction of a conceptual exposition scheme to the LFG emissions of a closed landfill corresponds to the worst case and the most likely scenario of LFG trace contaminants inhalation exposure. Building accommodations above closed landfills with middle-aged waste (20 – 30 years) surface are extremely rare, even for commercial or industrial purposes. The most frequent reuse is the development of recreational area with no residential buildings.

The worst case exposure scheme can be defined for a recreational area on the top of the landfill cover. The inhalation exposure can be assessed by taking into account the daily walkover of a child on the landfill surface. The walkover is similar to the concept used for the LFG emission preliminary survey stage. The breathable air corresponds to the mixing of residual LFG production flux with fresh air brought by wind, calculated with an air box model and a conservative wind velocity equal to 1 m/s (Figure 1).

To undertake a quantitative simplified health risks assessment for the inhalation path, a source term has to be calculated for a median size landfill site. A site with a total amount of collected waste of 100 kt in 10 years was chosen. The LFG emissions will be driven only on the top surface. In order to maximize the LFG trace contaminants concentration and to build a rather conservative scenario, a 10 meters thick deposit and a top surface of 10 000 m^2 will be taken into account.

3.2 Assumptions and health chronic risk calculation related to the exposition scheme

In the first part of the study the amount of LFG produced which has not been collected and treated with a generic approach has to be considered. The LFG emissions must be collected and treated for a period of 30 years in France after the exploitation phase. Nevertheless, it is common that the wells or another part of the collection system are not very effective.

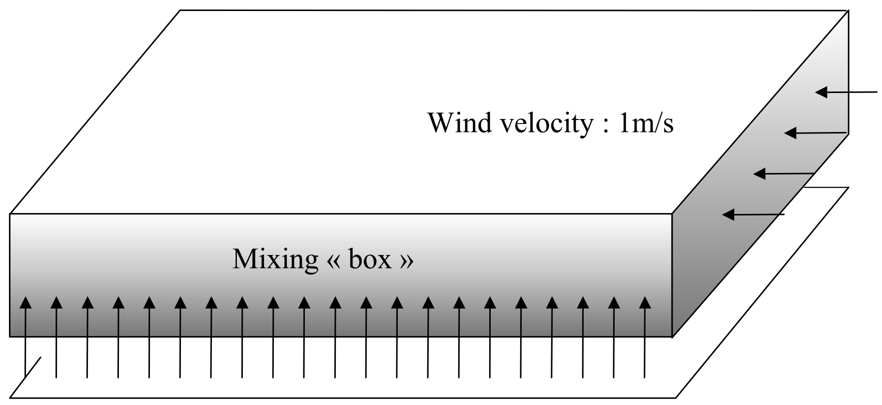

Figure 1. Scheme of the air box model for a recreational use of the landfill top cap.

The collection rate will also be low due to mechanical constrains, biological clogging or leachate saturation of the waste in a conservative scenario.

The overpressure in the waste is also lower in the post-exploitation phase. The decrease of this overpressure will lead to LFG migration by diffusion (Figure 2). In this case, LFG can be assumed to be more difficult to collect. Fugitive LFG emissions will also be more representative than the drained LFG. Ten years after the end of the exploitation phase the LFG diffusion fluxes (estimated by the Fick's law) will be approximately at the same level as the advection fluxes for a one meter thick silty clay layer and LFG overpressure assumptions. This type of cover is representative of the composition of a median size landfill cover. In the case of predominant advective fluxes, lateral migrations and explosion/fire hazards could be the major risks if a target was in the surroundings of the landfill.

This fact can be used to consider the conservative assumptions that all the LFG produced in the landfill will be available to increase the concentrations of the LFG trace contaminants in air above the cap of the landfill 10 years after the end of the exploitation. The French model with 3 fractions (based on the IPCC and US EPA equations) was used to calculate the LFG flux.

The second set of parameters concerns the LFG trace contaminants. French guidelines for landfill health risk assessment are available (ASTEE, 2004). At least three compounds (benzene, 1,2-dichloroethane and H_2S) have to be considered, and complemented if necessary. For this study, 3 complementary compounds were considered : vinyl chloride, formaldehyde and acetaldehyde.

The data of a French LFG trace contaminants concentrations review (ASTEE, 2004) was compared with other data sets of trace contaminants concentrations, and especially the median concentrations proposed for the use of GasSim by Golder Associates in 2003 and 2004 and by Komex (Hillier J. & al., 2004) in late 2004. For each compound, the median concentration value was corrected with a factor which divides by approximately two, the gap between the median value and the maximal value of LFG trace contaminants. This correction is justified by the weakness of the French LFG trace contaminants data set. This correction factor reaches half a magnitude order for 5 of the 6 compounds. The summary of the LFG contaminant concentrations is presented in Table 1.

In this case, chronic risks by inhalation were lower than the US EPA and ATSDR toxicological reference values. Concerning the odour assessment, the concentration levels could reach and even exceed the threshold levels. Specific measures must be taken in case of observed odour.

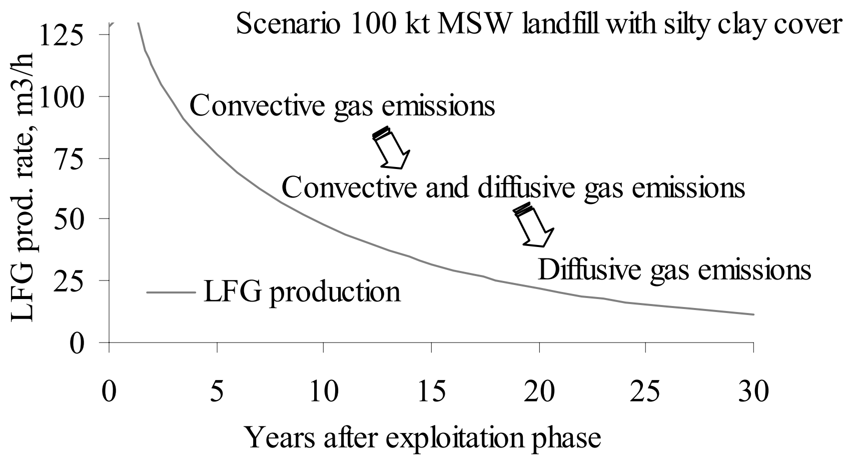

Figure 2. Comparison convective/diffusive fluxes for a silty layer

Table 1 : LFG trace contaminant concentrations used for the health risk assessment

Compounds	Concentration mg/m^3
Benzene	15
1,2 dichloroethane	15
Vinyl chloride	20
Formaldehyde	1,6
Acetaldehyde	18
Hydrogen sulfide	100

4. DETERMINATION OF GUIDANCE VALUES

4.1 Choice of criteria and values

The calculation of the landfill methane production is the most common method used for preliminary landfill desk studies. This parameter also determines a quantitative criterium. Concerning the choice of a trigger value, the LFG collection and treatment feasability for standard equipment (50 m^3 (LFG)/h) has to be taken into account, the absence of health risks for the generic scenario studied (1 ha, 100 kt MSW, 50 m^3 LFG/h) and the site specific parameters also have to be considered. Others site specific parameters are the LFG trace contaminant concentrations and the land surface used for the deposit.

Monitoring the LFG total NMVOC and hydrogen sulfide concentrations enables to reduce significantly the health risks with minimal *in situ* characterization works. The correction factor used in the health assessment can also be used to determine the low LFG production with higher LFG trace contaminant concentrations, and without exceeding common health risks levels, namely approx. 10 m^3 (LFG)/h. Measuring LFG trace contaminants can also be used for the odour assessment, even if the concentrations in odour units could be more easily compared with on-site odour assessment.

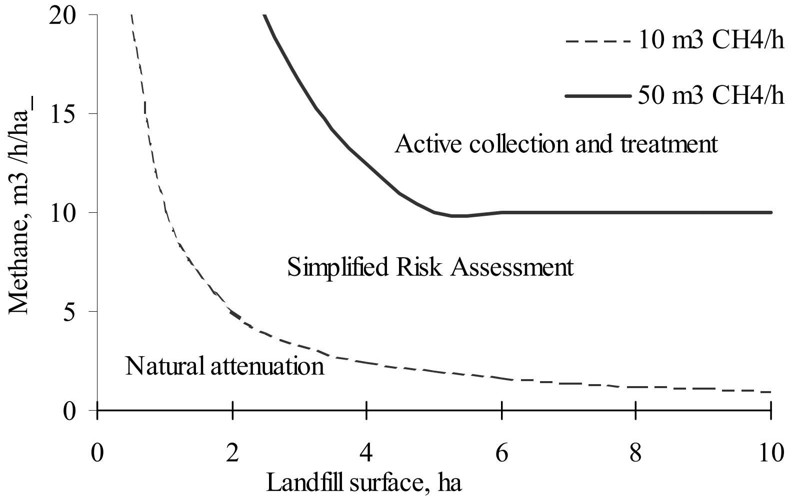

Figure 3. Definition of 3 areas for closed landfills

The landfill surface parameter was also chosen in order to estimate the surface emissions. This parameter could be linked with natural attenuation rate for covers which allow methane oxidation. An oxidation rate of 5 to 10 m^3 CH_4/ha/h (Stegmann & al, 2003) reduces a large fraction of the methane residual emissions 10 years after the end of the exploitation, according to the generic scenario studied. Other studies demonstrate that LFG trace contaminants can also be oxidised in landfill cover (Kjeldsen & al. (2003), Scheutz & al. (2003)).

4.2 Definition of 3 areas

A combination of the production rate and surface rate is needed for the large surface sites which could easily exceed a production rate trigger value.

Three areas (Figure 3) could be defined with the trigger values which lead to active collection and treatment, natural attenuation or a screening risk assessment, prior to the use of some specific prescriptions. Other site specific criteria like LFG total NMVOC and hydrogen sulfide concentrations will be used in the simplified risk assessment in order to precise the need for an active collection.

5. CONCLUSIONS

The aim of the methodological works includes the determination of trigger values in order to manage low LFG production in the case of closed landfill. The combination of the proposed parameters (methane production rate, methane surface emission rate, total NMVOC and hydrogen sulphide concentrations) does not give sufficient indications for the case of old landfills with methane migration risks and presence of houses on or near landfills.

The trigger values proposed in this study could be corrected with the progress of the best available LFG treatments and with a better knowledge of the probability distribution of LFG trace contaminant concentrations. Nevertheless, due to the large concentration probability distribution, this methodological work proposes to use on-site LFG trace contaminant measurements, in order to give a better prescription for the non defined area located between common prescriptions for natural attenuation and active collection and treatment.

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