Risk assessment and comparison of short-term and long-term emissions for different treatment and disposal phases of MSW

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RISK ASSESSMENT AND COMPARISON OF SHORT-TERM AND LONG-TERM EMISSIONS FOR DIFFERENT TREATMENT AND DISPOSAL PHASES OF MSW

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SUMMARY: a research program including a comparison between short term and long term emissions of MSW landfill started in 2006. The goal of that program was to access the human health chronic risk of three different waste disposal processes (anaerobic with/without leachate recirculation, with/without aerobic pretreatment) and to provide new criteria for the disposal site. A methodological approach using both calibration of the short term fluxes by in situ measurements and the prediction of long term fluxes by the use of exponential decreasing functions was explored. The identification of contaminant species was made by qualitative and quantitative concentration measurements done in a first stage on the landfill gas, and the collection of chemical leachate load measurements. At this stage of the study, the work did not show specific chemical contaminant species for the different waste disposal.

1. INTRODUCTION

French regulation on waste disposal do not prescribe specific requirements concerning mechanical biological treatments and disposal phases for non-hazardous waste. The lacks of data concerning the behaviour of these types of waste during the disposal phase do not allow the definition of specific criteria and highlight the need of new tools for the assessment of chronic risks during the disposal phase. The developments of leachate recirculation also produce new time scale for the appreciation of the waste stabilization. Risk assessment concerning the human health chronic risks coming from these new types of waste will encounter new difficulties, especially concerning the definition of the major contaminant species, the fluxes rates of these compounds and the comparison between the equivalent stabilization time steps achieved. It is necessary to take into account the natural attenuation of the diffuse emissions of biogas and leachate. A better treatment of the diffuse emission could partialy balance the goals of the treatment before the disposal.

In order to build the comparison approach of these new types of waste management, a research program started in 2006, which includes the comparison of short-term and long-term emissions for three different treatments (anaerobic disposal with/without recirculation, aerobic pretreatment followed by anaerobic disposal) with the focus on the disposal phases of MSW. This program aims to use the combination of waste description parameters, the collect of new data coming from the analysis campaign on biogas and leachate, and available modelling tools concerning the emission of biogas and leachate. As previous work done concerning the gaseous emissions of closed landfills, the goals are to determine some combination of criteria in order to minimize the human health chronic risks and made feasible some comparison between the different type of waste disposal with the usual disposal regulation requirements. This paper presents the first results of that program conducted on four disposal facilities.

2. DESCRIPTION OF THE METHODOLOGICAL APPROACH

2.1 General approach

The methodological approach focuses on in situ landfills measurements in order to avoid the scaling difficulties coming from the direct use of the data coming from laboratory researches. In a first phase 8 different disposal facilities were visited, in order to collect different data and to define the more appropriate landfills for the characterization phase. A selection of 3 landfills was made in order to conduct new gaseous emission characterisation campaigns of VOC and major compounds. The identification of the contaminants for the three different types of waste disposal was done in a first step on each landfill.That step requires the collect of data from the litterature as well as new data issuing from old and new cells in order to define the short term and long term emissions of contaminants.

For each landfill disposal this work includes the identification of the major fluxes and trace compounds which lead to a health chronic risk and the selection of parameters in order to characterise the organic fraction and the stabilization processes.

The second step will use the results from in situ characterisation in order to select the more appropriate available tools coming from the laboratory research results in order to predict the evolution of the fluxes and stability parameters. The objective of that step is to provide informations concerning the assessment of the decreasing fluxes of the major compounds and contaminants for the three types of treatment and disposal in the short and long term perspectives.

The last step will be the risk assessment for the three types of waste, and key time steps during the exploitation phase and the aftercare periods. A special attention will be given at this point to compare the waste stabilization for equivalent time duration.

2.2 Identification of the health chronic risk contaminants

The quality and the composition of both the biogas and leachate evolve with time, and depend on the main intrinsic waste characterization.

Leachates may be classified respectively by young, intermediate and aged ones according to the different compositions; however the distinction between the different trace contaminants present into the landfill biogas (LFG) with the time scale and the type of waste is more scarce in the literature (UK EPA (2004), Hillier J. & al., 2004). The more recent work conducted in France was undertaken by FNADE (2007) and present the characterisation of the LFG coming from ten different landfills. This recent work gives new data for LFG trace contaminants without attenuation by the cover. These informations can be used to determine the quality of the biogas issued by the leaky biogas wells. We usually have LFG concentration measurements concerning the VOCs only in the LFG main line, which are not representative of the emissions occurring in a new cell during exploitation and just after the completion of temporary cover. The lack of these data is partially reduced with the release of the results of the ELIA program (Lornage R & al., 2005) for recent waste, and the data collected previously from “old” landfills (Bour O. & al., 2005). The data coming from three new old landfills and new cells of pretreated MSW will complete this set of data and will help to do some selection of the major trace compounds. Previous studies concerning the attenuation of sulphide and BTEX compounds in the landfill top cover showed that a large fraction of these compounds can be oxidised

2.3 Definition and modelling of the contaminant fluxes decrease

Surface flux emission rate campaigns were realized on three landfills without LFG collection. In order to provide qualitative and quantitative data concerning the methane, carbon dioxide and TVOC emissions, the flux box campaigns were conducted on a deposit aged selection area of these landfills. Scarce data concerning the quality of leachate were also collected and a more complete data set concerning leachate load will be collected in 2007. The first goals will be to use data coming from the LFG and leachate characterization without those coming from the solid fraction of waste which are more difficult to sample in the case of closed cells with a final cover. All these data will allow to compare the LFG major compounds fluxes and make first assumptions for the scheme of the decreasing emissions used for the risk assessment study (See figure 1).

If the decrease of the LFG methane production during the anaerobic stage is well known, the importance of the flushing provided by the leachate recirculation will need some simplifications for the uses of the previous LFG production model. For example, the recirculation of the leachate will generally increase especially the fluxes in the preferentially flows pathways and provide an accelerated degradation of only a waste fraction.

Concerning the mechanical biological pretreatment, the focus will be put on the aerobic pretreatment which is the more frequent case in France. This treatment not only allows a fast decrease of the methane potential but also allows an increase of the organic fraction which is available for the anaerobic stage. The combination of the two processes could produce more LFG emissions in the short term period of the disposal if the duration of the aerobic treatment does not provide a sufficient decrease of this organic fraction. Parameters of the leachate like BOD, TOC, NTK will be measured in order to calibrate the amount of organic fraction available for the anaerobic phase. A focus will also be made on the natural attenuation of gaseous and leachate emissions emitted by the landfill body

2.4 Risk assessment for the short term and long term emissions of the disposal phase

Contrary to the long term emissions which are usually only limited by passive attenuation, short term emissions depend on the efficiency of the active LFG and leachate collection and treatment. An early optimized LFG collection will drastically decrease the gaseous emissions. Some assumptions concerning the percentage of biogas collection must be done in order to build an equivalent generic scenario for each type of waste. The in-situ measurements done in the previous stage on each type of waste will not reflect the median emissions without a correction factor concerning the site specific exploitation phase.

Concerning the long term emissions, the regulation requirements give a framework for each scenario. Depending on French regulation, only must be considered scenarios for the final cover and the passive barriers system at the bottom of the landfill.

We also need to use data related to the evolution of heavy metals. Due to the low concentrations of heavy metals in waste, and the high variability associated with the low concentration naturally occurring, we prefer to consider the level of protection offered by the thickness and the clay content of the layers, which usually better control the migration of the heavy metals by the adsorption processes.

We need to use both qualitative and quantitative parameters in order to compare both situations.

The study will also consider parameters describing the maturing process of the organic fraction, in order to compare the evolution of non-treated waste and composted waste during the long-term landfilling.

Finally the human health risk assessment will be done in order to make comparisons between the different waste type of disposal for the short term and long term period.

3. PRELIMINARY RESULTS

3.1 Identification of the health chronic risk contaminants and definition of the contaminant fluxes

Experimental data gathered from the characterization of three old landfills was used to describe the behaviour of MSW in the long term for two types of waste.

The waste of the first old MSW landfill was crushed and landfilled in narrow thickness layers for the old cells aged of more than 10 years. This type of disposal could be compared with an aerobic pretreatment followed by an anaerobic stage. In situ LFG trace concentration measurements in these old cells provided a TVOC concentration of less than 2 ppmv in the LFG wells. Hydrogen sulphide concentration was less than 5 ppmv.

The waste of the second old deposit was more rapidly landfilled and the exploitation phase of each cell was approximately one year. Due to the lack of clay cap in the first decades, the level of leachate had allowed a saturation of more than 30% of waste volume. The non saturated zone of this type of waste could be compared with an anaerobic area. Some hazardeous waste was mixed with the non-hazardeous waste. The theoretical surface flux of the cells aged of more than 20 years is estimated of approximately 5 m^3 CH_4/h/ha. The LFG surface flux campaign realised on a selection of area does not show methane and TVOC fluxes but the measurements in the screening part of the boreholes which pass through the cover revealed a few spots of TVOC and the presence of methane. Trace of chlorine solvents was also be found in the leachate.

LFG surface fluxes measurements was also conducted on another old MSW landfill with a waste thickness of less than 10 meters and a 1 m soil cap. We also did not measure significant surface LFG fluxes of methane and TVOC. Laboratory measurements of the BTEX and chlorine solvents did not show any significant concentrations of these compounds.

For two old MSW disposals, with a theoretical production of methane of less than 5-10m^3 CH_4/h/ha, the LFG surface fluxes VOC emissions were not significant for an approximately 10m waste thickness disposal, aged of more than 20 years, and with a 1 m soil cap thickness.

A surface fluxes campaign was also conducted on the early anaerobic phase of a pretreated waste disposal with an aerobic phase of approximately 6-10 weeks followed with a maturation phase of 10-20 weeks.

Due to the recent disposal of the waste (3 weeks) and the mixing of the different fractions of the composted waste, the surface fluxes of methane and carbon dioxide remain relatively high (methane surface fluxes average of more than 100 ml CH_4/min/m^2) and show numerous peaks of carbon dioxide surface fluxes of more than 200 ml CO_2/min/m^2. These "hot spots" of carbon dioxide fluxes give also some evidence of a residual aerobic phase in the first 50 cm of the disposal.

Laboratory measurements were realized on gas sampled in the flux box located just on the surface of the waste. The qualitative measurements gave a lot of peaks without predominant chemical species. Quantitative measurements done on BTEX and chlorine compounds do not exhibit any significant concentrations. These LFG sampling campaigns will continue in 2007 with the leachate chemical load concentration measurements.

These first results do not exhibit new contaminants for the chronic risks at this stage concerning the pretreated waste, but this must be confirmed with other sites.

3.2 Modeling the decrease of the contaminant mass fluxes

The goals of the first steps are the definition of the site specific parameters and simple models which can be used in order to qualify the decrease of the global load (COD, BOD or TOC , total N) in the leachate and the decrease of LFG emissions. The specific contaminant mass fluxes will be linked to the global load of the leachate and to the LFG emissions. The LFG emissions can be assess in the short and long term by the French LFG production model (ADEME, French environment agency) based on first order kinetic equations. A calibration of the model results with the LFG collected is necessary to reduce the uncertainty of the LFG production predictions.

Although the liquid/solid ratio can be used for the long term (Allgaier G. & Stegmann R., 2003), in the short term period the leachate collected will depend a lot on the different surface area contributing to infiltration. This modeling phase must also handle the scarce data which are usually available. In order to comply with that constraint, a calibration of the leachate load with in situ measurements will be chosen. The use of a specific kinetic for the decrease of that load in the short term will need accelerated laboratory tests. Due to the large variation of the rainfall inputs, the in-situ measurements of the leachate contaminant load during one year are not expected to give sufficient informations to extrapolate an exponential decrease.

Concerning the long term evolution of the leachate load, the rainfall data will be used with an hydrologic simulation in order to give an estimation of the infiltration rate in the landfill body. This value will be used in order to extrapolate the decrease of the leachate load by flushing (Heyer K-U, Hupe K. & Stegmann R., 2005).

The coupling of organic fraction decrease due to both the anaerobic degradation and the flushing will need a lot of assumptions concerning the kinetics of the different processes (hydrolysis, acetogenesis). This work could not be conducted for the three waste types, then a non coupled approach was chosen for the first steps of this work

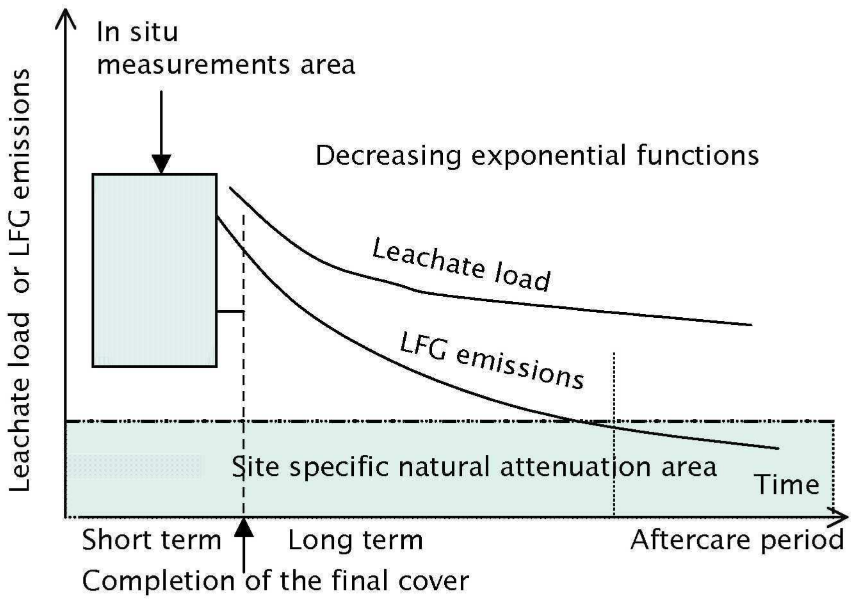

Figure 1. Scheme used for the calibration and the decreasing of the emissions for the risk assessment of the three different waste type

4. CONCLUSION

If the general decreasing tendency of the contaminant emissions can be assessed with site specific parameters in the long term for the three type of waste, the prediction of the decrease in the short term period will need data gathering on more parameters, a complete characterization of the waste and of the succession of the operation phases. The building of a generic scenario for the human health risk assessment for the three type of waste (anaerobic disposal with/without leachate recirculation and aerobic pretreatment) will need input data in order to calibrate the load of contaminant in the gas phase and the liquid phase during the short term period.

Concerning the contaminants, the qualitative and quantitative measurements done on a specific site with a pretreatment, and three others sites, do no show new chemical compounds. The range of the chemical species seems to be narrow but these first measurements should be confirmed with new measurements performed on another site. The source separation and the sorting provide a large range of the quality of waste.

As previously mentioned (Heyer K-U, Hupe K. & Stegmann R., 2005), in the case of old shallow disposal, the relative high waste humidity level provided by a medium rainfall volume of 600 – 1000 mm per year allows a quick degradation of the waste (with a relatively uniform circulation of the infiltration). With deeper disposal, some parts of the disposal exhibit a slower rate of degradation.

LFG emissions through the cover of one meter of soil on old landfill will decline rather quickly. We generally cannot measure significant LFG fluxes on old shallow waste deposits. The quality of the leachate evolves slower in the landfill body with a clay cap. An attenuation of the leachate load is compatible with the French regulation requirements for the second layer of the passive barriers (5 m thickness with a permeability lower than $1\ 10^{-6}$ m/s). A back analysis of the migration of the leachate load, taking into account the clay content and the CEC of that layer, should be done to improve the prediction of the model. An emphasis must also be done in the near future on attenuation processes in the nearest barriers layers, in order to compare the waste disposals.

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