RISK ANALYSIS AS A BASIS FOR OPTIMISATION OF LEACHATE TREATMENT

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SUMMARY: In order to obtain a prolongation of the legal consent, the landfill "Hooge Maey" must carry out elaborate remediation activities. A major line of action is the treatment of about one million m³ of leachate present in the waste body. In Flanders (Belgium), remediation projects are to be proposed within the framework of the BATNEEC principle. After biological treatment of the leachate, the effluent usually still contains a substantial amount of persistent COD (from the humic acid type). This study dealt with the risk assessment of the discharge into surface water of leachate treated by an aerobic wastewater treatment plant. It is investigated whether it is necessary, considering the BATNEEC principle, to have advanced post treatment implementing major costs. Five different ecotoxicity tests were performed but did not substantiate the potentially of direct negative impacts on the receiving ecosystem. Hence, this study indicates that in the specific case of the Hooge Maey landfill, there seems to be no direct need to implement a high tech post treatment after a proper aerobic sludge treatment.

1. INTRODUCTION

The landfill "Hooge Maey" represents the largest landfilling capacity in Flanders. In order to obtain a prolongation of the legal consent, elaborate remediation activities were imposed by the regulating authorities in Flanders (Belgium). One of them is the treatment of about one million

m^3 of leachate, rich in COD, present in the waste body. In order to remove the leachate, large leachate shafts have been drilled (depth 30 m and diameter 1 m). These allow to collect the leachate and to have it treated. In Flanders, remediation projects are to be proposed within the framework of the BATNEEC principle. After biological treatment (anaerobic or aerobic) of the leachates, usually a substantial amount of persistent COD is still present in the effluent. This COD consists of variable organics from the humic acid type. These complex molecules are known as potentially dangerous to the receiving ecosystem (Cabaniss & Shuman, 1988; Ma *et al*., 1999). They normally require specific and expensive removal techniques such as e.g. activated carbon, chemical oxidation by means of ozone, Fenton agents, hydrogen peroxide. Such effluent polishing techniques score low in relation to the cost efficiency of conventional biological treatment techniques. Moreover, the humic acids concerned can be seen as natural products that are released in large quantities by nature itself (e.g. in forest soils). Therefore a risk assessment study to provide data with respect to the putative impact of recalcitrant organics present in treated leachate, was set up. The leachate from the landfill was subjected to an aerobic treatment, which was representative for the conventional aerobic treatment stage in a biological treatment plant. It was investigated if the effluent of the thus treated leachate could cause negative impacts on the receiving ecosystem. Five different ecotoxicity tests were carried out.

2. EXPERIMENTAL STUDY

2.1 Experimental setup

2.1.1 Simulation of WWTP-effluent

Because this study wanted to investigate *a priori* the potentially negative impacts that treated leachate could have on the environment, the leachate had to be treated in that way that it was representative for a biological treatment process. Therefore, the leachate was subjected to the Zahn-Wellens aerobic activated sludge test. During this test, aerobic sludge of about 4 g VSS was added to 1 L leachate, whereafter it was aerated for 24 hours. Subsequently, the sludge was decanted and the filtered supernatant was used for further ecotoxicological studies, representing the “effluent” of a biological WWTP.

2.1.2 Dilution factors

The characteristics of the receiving water flow were incorporated in the study. Based on the knowledge of the flow of the receiving water flow and the expected effluent flow of the WWTP specific for the landfill, the expected dilution factors were calculated and integrated in the study. These data allowed to derive that the "average" dilution factor would be 1/122. In the "worst case scenario", a dilution factor of 1/44 could occur.

Thus, in this study, 2 different dilution factors were investigated, namely a "Highly Loaded Stream", in casu a dilution factor 1/50, representing the worst case scenario and moreover an "Extremely Loaded Stream", in casu 1/10, representing a stream which is about 5 times more loaded as the expected worst case scenario. As a reference, effluent of a regular domestic WWTP was incorporated in the assays.

To investigate the relative influence of the treatment with the Zahn-Wellens test on the one hand and the influence of the dilution factor on the other hand, both non-treated "raw" leachate samples and simulated WWTP effluent samples were subjected to the different types of ecotoxicity tests.

2.1.3 Types of ecotoxicity tests

Five different types of ecotoxicity tests were selected in order to investigate the overall risk assessment of biological treated leachate. Both nitrifying and methanotrophic bacteria were examined for potential inhibition. Both are well described as being sensitive towards pollutants (Gernaey *et al*., 1997; Arif & Verstraete, 1996). Moreover, molecular techniques were used to investigate putative estrogenic activity and genotoxicity (Routledge & Sumpter, 1996; Maron & Ames, 1983). Finally, sediment samples exposed to leachates were mentioned in terms of release into solution of heavy metals.

3. RESULTS AND DISCUSSION

3.1 Metabolic activity of sensitive groups of micro-organisms

3.1.1 The Nitrox® toxicity (Gernaey et al., 1997)

This test measures the toxicity to nitrifying bacteria, which are known as an essential component of surface water ecosystems. The test is based on the measurement of OUR (Oxygen Uptake Rate) after addition of nitrifiers and ammonium nitrogen to the samples. After some minutes, allylthioureum (ATU) is added, which inhibits the nitrification completely. The difference in OUR before and after addition of ATU is an indication of the nitrifying autotrophic activity (*Nitrosomonas)*. The results of the Nitrox® toxicity test are given in Table 1 and Figure 1.

Table 1 - Results of the Nitrox® Toxicity test, where C-NT = Control, non-treated; C-T = Control, treated; HLS-NT = Highly Loaded Stream, non-treated; HLS-T = Highly Loaded Stream, treated; ELS-NT = Extremely Loaded Stream, non-treated; ELS-T = Extremely Loaded Stream, treated.

	mg O_2/L.min			mg O_2/gVSS.h		% effect
	Total respiration	Heterotrophic respiration	Autotrophic respiration	Autotrophic activity	standard deviation	in accordance to C-NT
C-NT	0.19	0.06	0.13	24.61	± 3.28	
C-T	0.2	0.06	0.14	26.50	± 3.56	-7.69
HLS-NT	0.12	0.04	0.08	15.14	± 1.93	38.46
HLS-T	0.19	0.07	0.12	22.71	± 2.77	7.69
ELS-NT	0.07	0.03	0.04	7.57	± 0.90	69.23
ELS-T	0.15	0.06	0.09	17.03	± 1.89	30.77

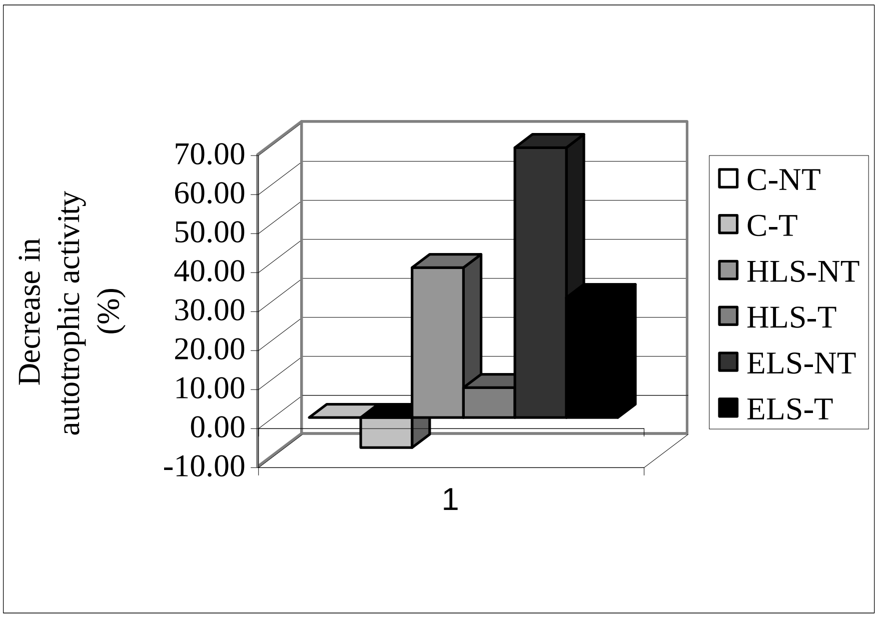

Figure 1 - Decrease in autotrophic nitrification activity in comparison to the autotrophic activity measured in the non-treated Control (C-NT), where C-T = Control, treated; HLS-NT = Highly Loaded Stream, non-treated; HLS-T = Highly Loaded Stream, treated; ELS-NT = Extremely Loaded Stream, non-treated; ELS-T = Extremely Loaded Stream, treated.

Table 1 and Figure 1 indicate clearly the detoxifying effect of the aerobic treatment on the leachate. Whereas non-treated leachate caused considerable decreases in the autotrophic nitrification activity, the decrease was significantly lower when the leachate was subjected to an aerobic treatment phase. From Table 1, one can expect in the worst case scenario (HLS-T), a decrease in autotrophic nitrification activity in the receiving ecosystem of about 8%. Even in a 5 times higher load as the worst case scenario, the EC_{50}-level was not reached.

3.1.2 The methane oxidation test (Arif & Verstraete, 1996)

A pollution sensitive group of soil and sediment organisms are the aerobic methane oxidizing bacteria. During this experiment, a healthy dry soil was brought to field moisture capacity by means of leachate liquor. Of those thus treated soils, 15 g were brought in a 100 mL flask which was closed from the atmosphere. Subsequently, 8 mL of methane was injected in the flasks, where after the CO_2 and methane concentration was followed with time. An increase in CO_2 concentration, without decrease of methane indicates that microbial activity is possible, although the most sensitive organisms (the methane oxidizing bacteria) are inhibited. An increase in CO_2 concentration and a concomitant decrease in methane concentration indicate that microbial activity is possible, including activity from the methane oxidizing bacteria. The results of this methane oxidation test are presented in Figure 2.

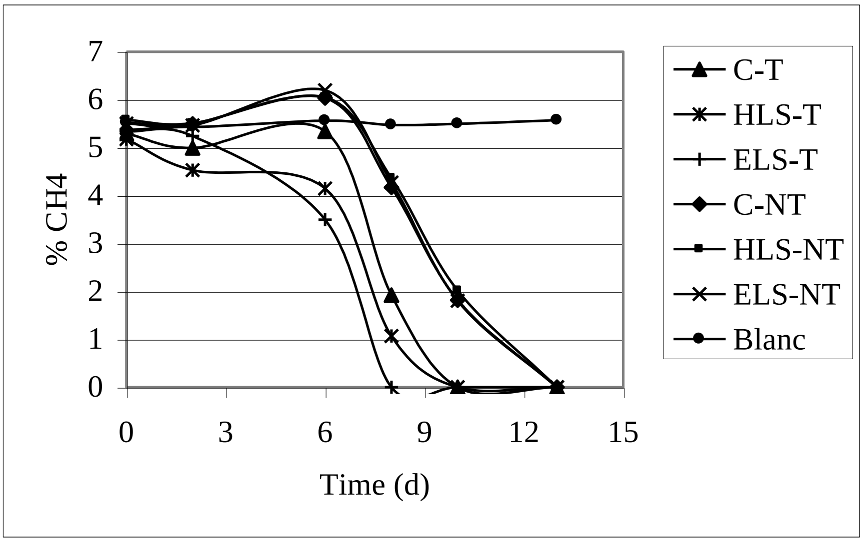

Figure 2 - Methane concentration in function of time during the methane oxidation test, where C-NT = Control, non-treated; C-T = Control, treated; HLS-NT = Highly Loaded Stream, non-treated; HLS-T = Highly Loaded Stream, treated; ELS-NT = Extremely Loaded Stream, non-treated; ELS-T = Extremely Loaded Stream, treated.

Figure 2 indicates that the leachate present in the landfill was not toxic to the sensitive methane oxidizing bacteria. Even upon moistening of the soil samples with the non treated raw leachates, the bacteria appeared to be not inhibited. In all cases, it was found that the kinetics of the methane oxidizing bacteria in soils subjected to non-treated leachate was somewhat slower in comparison to soils subjected to treated leachate, but not in that way that there was a significant negative impact detectable.

3.2 Molecular bio-assays

3.2.1 The Vitotox® toxicity test

The Vitotox® is a sensitive test to investigate if environmental samples can cause genotoxic or bacteriotoxic effects. This test is developed by the VITO (Flemish Institute for Technological Research) and is based on the Ames test (Maron & Ames, 1983). The organism *Vibrio fisheri* used in this test, is genetically modified in order to produce light (activation of a lux-gen) when there is any DNA-damage. The light production is dose dependent : the higher the level of DNA-damage, the higher the light production. Furthermore, the test can be upgraded to represent mammalian cells by incorporation of the S9-enzyme, extracted from pig livers.

In this specific experiment, both the Vitotox® with and without the S9-enzyme was carried out. In all cases (on treated and non-treated samples), there were no statistically significant genotoxic or bacteriotoxic effects detectable (data not shown).

3.2.2 The hER-yeast screen (Routledge & Sumpter, 1996)

The yeast species *Saccharomyces cervisae* genetically modified by integration of a DNA-part in the genome which codes for the human estrogen receptor (hER) was used. The hER-yeast screen is able to detect potential estrogenic compounds in concentration levels of ng/L.

The data obtained from this experiment also showed that no estrogenic activity was detectable in the leachate, raw and respectively treated.

3.3 The metal chelating activity

Humic acids can function as chelating agents, thus mobilizing different pollutants such as heavy metals and bringing them in an active form in the environment (Cabaniss & Shuman, 1988; Ma *et al.*, 1999). The experimental procedure used in this work, investigates the chelating activity of the leachate towards 4 metals (Pb, Cu, Mn and Cr) present in highly contaminated. The sediment contained 278 ppm Pb, 151 ppm Cu, 1.070 ppm Mn and 270 ppm Cr. The leachate was brought in intense contact for 120 hour with the contaminated sediment. Afterwards, the liquid phase was sampled by filtration, acidified to pH 2 and analyzed for Pb, Cu, Mn and Cr. The detection limit of Pb and Cu was 2 ppb, the detection limit of Cr and Mn 1 ppb. The results of the metal chelating test are presented in Table 2.

Table 2 - Concentrations of Pb, Cu, Mn and Cr (ppb) in the sediment and the liquid phase during the chelating test, where C-NT = Control, non-treated; C-T = Control, treated; HLS-NT = Highly Loaded Stream, non-treated; HLS-T = Highly Loaded Stream, treated; ELS-NT = Extremely Loaded Stream, non-treated; ELS-T = Extremely Loaded Stream, treated. The values in bold surpass the Flemish consents for waste water effluents. The consents for drinking water are also indicated.

	Concentration (ppb)			
	Pb	**Cu**	**Mn**	**Cr**
Sediment	278000	151000	1070000	270000
Forest water	0	20	3.8	6.2
C-NT	0	13	2.9	3.1
C-T	0	19	5.8	3.9
HLS-NT	3.7	33	12.8	6.1
HLS-T	5.2	31	10.5	5.9
ELS-NT	2.5	**313**	29.1	**61**
ELS-T	4.6	**82**	21.4	30
Leachate	**123**	**1455**	**300**	**900**
Vlarem II - norm (1)	**50**	**50**	**200**	**50**
Drinking water norm (2)	**10**	**2000**	**50**	**50**

(1) Vlarem II : Flemish Executive Directive for waste water effluents, dd. 01.07.1995

(2) European Council Directive, dd. 03.11.1998

Table 2 reveals that intense contact of *non-diluted raw leachate* with highly contaminated sediment resulted in a significant concentration of metals in the liquid phase. In all cases, the effluent consent of the Flemish Executive was exceeded. The values for Cr and Cu were some 20 – 30 times higher than acceptable. However, Table 2 reveals that intense contact of *aerobically treated leachate* (HLS-T, ELS-T) with highly contaminated sediment, gave only in one single case, i.e. ELS-T for one element i.e. Cu (82 ppb), a level above the legal consent. Yet, it should be noted that the Flemish effluent norm for Cu is extremely low (50 ppb). As comparison, in the European Council Directive for Drinking water (dd. 03.11.1998), the limit of Cu is 2000 ppb. In view of the latter European legislation, Flanders will change in the near future its consents to the levels set by the EU. It should also be noted that the amounts in the liquid phase under worst case scenario-conditions (HLS-T), were from the same order as those measured for the reference waters, i.e. effluent from a sewage treatment plant (C-NT, C-T) and forest water. In practice, this means that no negative influence can be expected from the discharge of the well-treated leachate on the discharge of metals from contaminated river sediments. Moreover, the treated effluent normally is discharged in a non-metal polluted stream at an average dilution of 1/122.

4. CONCLUSIONS

Non of the ecotoxicity tests applied in this study substantiate the hypothesis that the receiving ecosystem should be subjected to significant negative impacts due to the discharge of aerobically treated leachate from the landfill the "Hooge Maey". The sensitive molecular techniques to investigate genotoxicity and bacteriotoxicity (Vitotox®) respectively estrogenic activity (hER-yeast), did not signal any negative impact for all types of leachates tested. Also the methane oxidation test was free of disturbance. Under *worst case scenario*- conditions, the decrease in activity of autotrophic nitrifying bacteria amounted to 8%. Untreated leachate coming in contact with sediment containing heavy metals clearly gave rise to unacceptable levels of released heavy metals. Yet, intense contact of the treated leachate in *worst case scenario*– conditions, with highly contaminated sediment, resulted at no time in a surpassing of the norm of the Flemish Executives for waste water effluent streams. Interestingly, under those circumstances of aerobically treated leachate, the amounts of metals in the liquid phase were of the same order as those measured for the reference waters i.e. effluent from a sewage treatment plant (C) and forest water. Yet, for the treated extremely loaded streams, there was a surpassing of the effluent norm for Cu. However, the legal consent for Cu in Flanders is debatable. Indeed, the European Council Directive for Drinking Water has a higher consent.

Considering the five ecotoxicity tests performed, it can be concluded that the receiving ecosystem is not directly endangered by the discharge of properly aerobically treated leachate of the landfill the "Hooge Maey".

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