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Evaluating Landfill Chemical Emissions- Mid Auchencarroch Experimental Design

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The biodegradation of Mid Auchencarroch experimental landfill project is studied in four different cells. The aim is to better understanding the effects of waste pretreatment and landfill management techniques on leachate emissions and waste biodegradation processes. The variations of characteristic leachate indexes of landfill mass are presented and analyzed. The experimental Mid Auchencarroch's data confirm that waste pretreatment and leachate recirculation are sustainable and accelerate the waste biodegradation, protecting public health from probable hazardous landfill emissions.

Key Words: Landfill emissions, Landfill biotechnology, Solid waste biodegradation, Solid waste management, Public health, Experimental landfill.

INTRODUCTION

Sanitary landfill remains an attractive disposal route for municipal solid waste, because it is more economical than alternative solutions. It is accepted that the landfill biodegradation processes are complex, including many factors that control the progression of the waste mass to final stage quality[1-5]. The landfill gas and leachate generation is an inevitable result of the solid waste biodegradation in landfills and their study is necessary for future efficient designs, controlling air and groundwater pollution[3,6,7].

Landfilling technologies have been strongly developed in the last decade. Large sanitary landfills are preferred because these provide better opportunities for potential hazard control and an increasing potential for resources' recovery. Leachate treatment units should be used for water supply in irrigations networks and associated regional development public works. Efficiently managed sustainable landfill sites can generate considerable volumes of methane gas (CH_4), which can be exploited by landfill gas recovery installations to produce electricity. Characteristically, 1 m^3 of landfill gas (LFG) is equivalent to 0.6 m^3 natural gas, 0.6 L oil, 0.8 kg carbon, 2 kg wood and 6 KWh[5,8].

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The use of controlled landfill projects is necessary for quick site stabilization of landfill gas and leachate emissions, during waste biodegradation. The use of controlled batch anaerobic bioreactors accelerates waste biodegradation in short periods, minimizing any associated environmental risks due to landfill emissions[3,9-11]. Any uncontrolled dumps have to close so as to avoid any threats to the public health and to protect the environment.

A plethoric flow and use of resources characterize our society in an unsustainable way. Waste management is the discipline which is concerned with resources once society no longer requires them. A successful sustainable development requires a continuous change and harmonization to the life cycle of our society, bearing in mind its current-future necessities[12,13]. Therefore, the problem is transferred to the dilemma on how can we manage our waste better. Landfills' emissions should be controlled avoiding any environmental impacts to flora and fauna and public health of the surrounding area from landfill boundaries.

EXPERIMENTAL

This work assesses the long term behaviour of Mid Auchencarroch experimental landfill site in Scotland, based on characteristic landfill biodegration parameters, making useful conclusions. The experimental landfill Mid Auchencarroch is a field scale facility, constructed in order to assess a number of techniques that promote sustainable landfill. Mid Auchencarroch (MACH) experimental landfill, is an Environment Agency, DTI and industry funded research facility. It has been capped since November 1995. The experimental variables are waste pretreatment, leachate recirculation and co-disposal with inert material. The project consists of four cells each of nominal volume 4,200 m^3. The disposed waste synthesis for the untreated and pulverized waste input is respectively: Paper-Card: 27 & 34 %; Plastic film 6 & 7 %; Dense plastic 5 & 8 %; Textiles 3 & 3 %; Misc.combust. 3 & 3 %; Misc. non-combust. 0.5 & 2 %; Glass 5.5 & 7 %; Putrescibles 38 & 24 %; Ferrous metal 6.5 & 8 %; Non-ferrous metal 1.5 & 2 %; Fines 4 and 2 %[3,14].

In cells 1 and 3 there is pretreatment by wet pulverization and in cells 2 and 4 the disposed waste is untreated. In cells 1, 2 and 3 there is recirculation of leachate and in cell 1 there is addition of inert material around 20 % by volume. This project attempts to develop and assess techniques to enhance the degradation and pollutant removal processes for Municipal Solid Waste (MSW) landfill. The wet-flushing bioreactor landfill model is seen as the method of achieving the goal of sustainability. The MACH landfill gas and leachate data, which were used for the present work, cover simultaneously the 22-month period of waste biodegradation at MACH site[3,14].

Experimental results - Potential landfill emissions

Evaluating and analyzing the MACH landfill gas emissions, it is clear that methanogenesis was achieved after 1996 as the carbon dioxide emissions reduced and the methane emissions increased. The peak landfill gas production after 1996 and the progressive reduction of methane, carbon dioxide (vol %) concentration in time, certify that quick site stabilization achieved. The best biodegradation exists at cell 3 as the pretreatment by wet pulverization since the recirculation of leachate expedite the biodegradation and methanogenesis[3]. Landfill gas peak production and peak temperature reached in the first 105 d of waste disposed at MACH site. Table-1 presents the landfill gas production characteristics for MACH cells[3,15].

TABLE-1
LANDFILL GAS CHARACTERISTICS OF MID AUCHENCARROCH CELLS

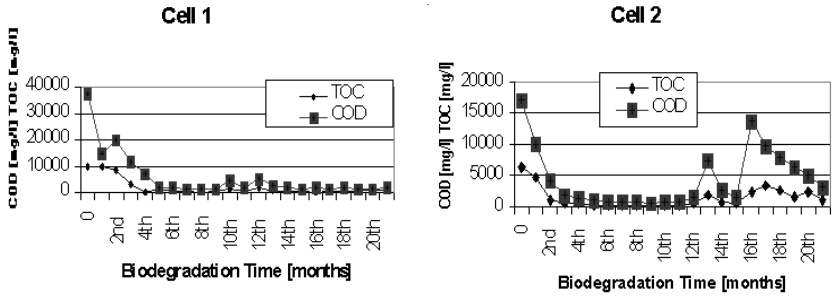
Landfill site case study	Landfill gas methane yield (L gas/kg/MSW)	Landfill gas yield (m^3/hr)	Leachate re-circulation
MACH Cell 1	21.53	8.2	Yes
MACH Cell 2	22.67	9.0	Yes
MACH Cell 3	21.30	7.8	Yes
MACH Cell 4	21.65	7.4	No

On the other hand, the estimations of the main leachate concentration parameters change with landfill age for the particular sites in time[3,5] (Table-2).

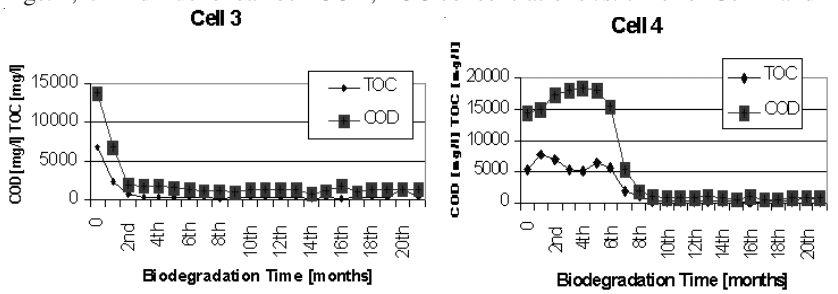
TABLE-2
LANDFILL LEACHATE CHARACTERISTICS IN TIME

Parameter	0-5 year	5-10 year	10-20 year	< 20 year
BOD_5 (mg/L)	4000-30000	1000-4000	50-1000	< 50
COD (mg/L)	10000-60000	10000-20000	1000-5000	< 100
NH_3 (mg/L)	100-1500	300-500	50-200	< 30
pH	3-6	6-7	7-7.5	6.5-7.5
Cl^- (mg/L)	500-3000	500-2000	100-500	< 100
SO_4^{2-} (mg/L)	50-2000	200-1000	50-200	< 50

For the MACH the biodegradation rate is evaluated according to the most indicative characteristic biodegradation parameters of the produced leachate emissions. Figs. 1-4 present the Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) concentration trends in time for the 4 MACH cells. COD could be characterized as the most hazardous leachate characteristic in relation to groundwater and site contamination[3,5].



Figs. 1,2. Mid Auchencarroch COD, TOC concentrations *vs.* time for Cell 1 and 2



Figs. 3,4. Mid Auchencarroch COD, TOC concentrations *vs.* time for Cell 3 and 4

In Figs. 5-8 are presented the biodegradation rates of BOD and COD concentrations in leachate emissions of MACH cells.

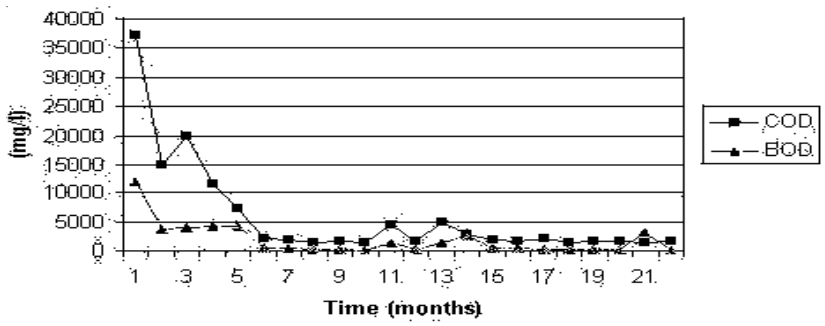


Fig. 5. Mid Auchencarroch COD, BOD concentrations *vs.* time for Cell 1

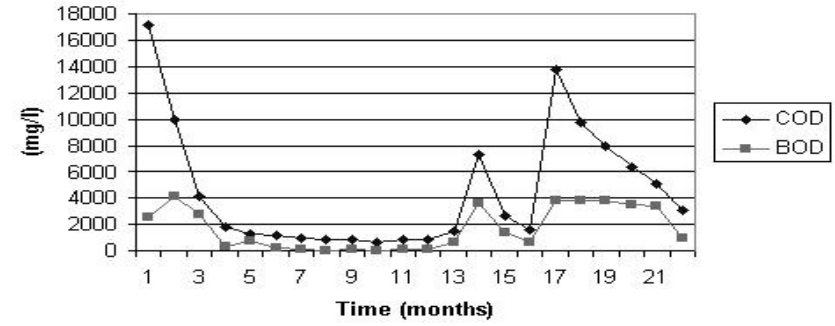


Fig. 6. Mid Auchencarroch COD, BOD concentrations *vs.* time for Cell 2

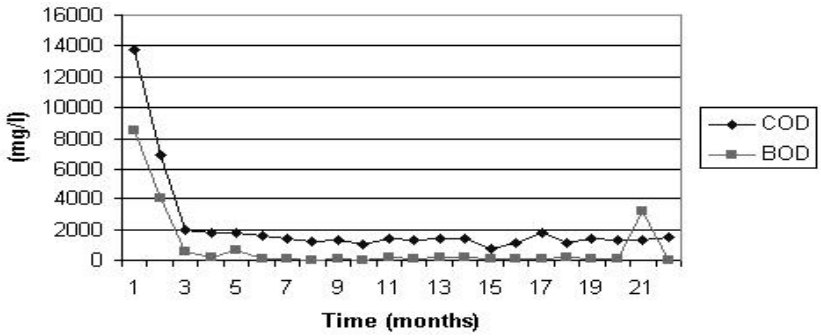


Fig. 7. Mid Auchencarroch COD, BOD concentrations *vs.* time for Cell 3

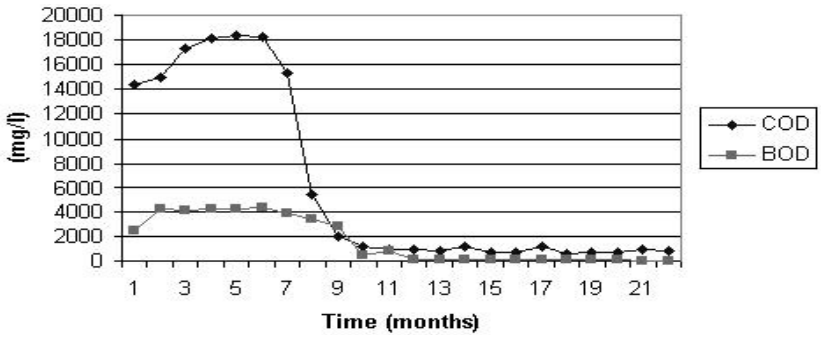


Fig. 8. Mid Auchencarroch COD, BOD concentrations *vs.* time for Cell 4

After proper evaluation of these results it is clear that there was the greatest depletion of carbon and COD pollutants at cell 1. Moreover, cell 4 presents higher COD concentrations due to the fact that there has been disposed higher waste fraction of biodegradable carbon content in it than at cell 3 and 2. Cell 2 presents temporarily high risk between the 15th and 21st month. The latter can be explained due to the fact that leachate recirculation began in November 1996. After that period chloride was rising sharply, indicating flushing out of soluble salts, which had already occurred in the pulverized cells and they exhibited a greater electrical conductivity effecting further chemical reactions. In the end, all the TOC and COD concentrations present great reduction after 1996. The latter fact certifies the quick Mid Auchencarroch site stabilization.

RESULTS AND DISCUSSION

A risk assessment is developed based on the particular characteristics of landfill gas and leachate emissions in an attempt to prove a prior assumption: *The development of Risk Assessment framework and relevant models will provide a more efficient means of understanding and managing contamination.*

Risk is a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence. Hazard is a property or situation that in particular circumstances could lead to harm (human, ecological, physical, financial, psychological and social). Risk assessment is an analysis of the potential for adverse health effects[3,16]. Risk assessment estimations to several environmental pollution subjects, most are site specific, with no single preferred method available. A risk assessment analysis of particular characteristic biodegradation parameters for MACH emissions is analyzed below.

Based on the data of Table-1, it is clear that high involved risk of environmental contamination by LFG emissions is presented in MACH cells where high fermentable waste fractions have been disposed in.

On the other hand, evaluating and analyzing MACH leachate emissions, it is clear that higher short-term risk of environmental contamination by leachates present cell 1 and 4 than 2, 3 ones. Cell 1 presents the highest short-term risk, as greater carbon and COD depletion rate exists in it than at the rest of the cells. However, Cell 4 presents higher short-term risk than at the rest of the cells from the point of view that it presents high constant COD values without any decrease in short-term. The latter exists due to the fact that not only is there no leachate recirculation at cell 4 for quick carbon depletion but also there is the high disposed putrescible waste fraction into it.

Conclusions

At Mid Auchencarroch it was clear that the co-disposal with inert material is sustainable as well as the pretreatment by wet pulverization since the recirculation of leachate expedite the waste biodegradation. According to the BOD, TOC and COD experimental field data, the best waste biodegradation existed in cell 3, as well good organic depletion presented cell 1, minimizing both their emissions and associated environmental risks in short time.

Long-term liability can be minimized when waste is quickly treated to a point where no further degradation will occur, protecting the environment from long-term biogas and leachate emissions. The experimental results showed that the use of the anaerobic landfill batch bioreactor design is sustainable and it should be used by landfill operators. Landfill emissions' environmental contamination control has to be improved based on the presented evaluations, taking into account different landfill conditions.

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