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Evaluation of Iso-Butyric acid and Acetic acid in Landfill Leachate Emissions-Mid Auchencarroch Experimental Design

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The biodegradation of Mid Auchencarroch experimental landfill project is studied in four different cells. This paper analyses the effects of waste pretreatment and different waste management techniques on characteristic organic acids emissions and biomass biodegradation stages. The variations of the examining experimental landfill emissions are presented and analyzed. The experimental Mid Auchencarroch's data confirm that waste pretreatment, co-disposal with inert material and leachate recirculation are sustainable and accelerate the waste biodegradation, protecting public health from associated landfill emissions' risks.

Key Words: Landfill biotechnology, Landfill organic acids, Solid waste biodegradation, Solid waste management, Public health, Experimental landfill design.

INTRODUCTION

Sanitary landfill method is preferred as an attractive disposal route for municipal solid waste, not only because it is more economical than alternative solutions but also it provides 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, which can be exploited by landfill gas recovery installations to produce electricity and to supply bio-fuels.

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, soil and ground water pollution[6-8].

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A successful sustainable development is required in a continuous change, which is harmonized to the life cycle of our society, bearing in mind its necessities in time[9,10]. Hence, the problem is transferred to the dilemma on how can be managed and treated solid waste better. Landfills' emissions should be controlled by the use of proper spatial numerical models, digital databases and the establishment of monitoring boreholes, avoiding any spatial environmental impacts to flora and fauna and public health of the surrounding topographical area next to landfill boundaries[8].

The use of controlled landfill projects is necessary for quick site stabilization of landfill gas and leachate emissions, avoiding any long term emissions to the environment. The use of controlled batch anaerobic bioreactors accelerates waste biodegradation in short periods, minimizing any associated environmental risks due to landfill emissions[8,11-13]. Any uncontrolled dumps have to close so as to avoid any threats to the public health and to protect the environment.

EXPERIMENTAL

This paper assesses the long term behaviour of Mid Auchencarroch experimental landfill site, which is located nearby Glasgow 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, Department of Trade and Industry Funded Research Facility. The experimental variables are waste pretreatment, leachate recirculation and co-disposal with inert material. It has been capped since November 1995. The project consists of four cells each of nominal volume 4,200 m^3. The disposed waste synthesis for the untreated and pulverised 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 %, 2 %[8,14].

The wet-flushing bioreactor landfill model is seen as the method of achieving the goal of sustainability. This project attempts to develop and assess techniques to enhance the degradation and pollutant removal processes for Municipal Solid Waste (MSW) landfill. 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 20 % by volume. The MACH landfill gas and leachate data, which were used for the present paper, cover simultaneously the 22 month period of waste biodegradation at MACH site[8,14].

RESULTS AND DISCUSSION

Evaluating and analyzing the MACH landfill gas and heat generation emissions, it has been found that methanogenesis was achieved in the first 105 d time period since site was capped. The peak landfill gas production after 1996 and the progressive reduction of methane, carbon dioxide (vol %) concentration in time, verify that quick site stabilization has been achieved in time[8,15]. All the MACH cells were stabilized in short time period according to the experimental results of BOD, COD and TOC leachate emissions[3,8]. The leachate concentration parameters change with waste input materials, landfill age and landfill conditions in time. This paper analyzes characteristic leachate organic acid concentrations and trends which were monitored at MACH experimental site, making useful conclusions.

The landfill biomass biodegradation stages are five. In phase I, hydrolysis stage takes place, where biological decomposition occurs under aerobic conditions, because a certain amount of air is trapped within the landfill. In phase II, the hydrolysis stage takes place, where proteins are decomposed to amino acids, hydrocarbons are decomposed to sugars and fats to polyalcohol and fatty acids. In phase III there is the production of organic acids, volatile fatty acids (VFA), where one of the most characteristic one in this stage of acidogenesis is the iso-butyric acid. In phase IV there is the production of organic acetic acid, during the stage of acetogenesis. In phase V there is the final maturation of landfill biodegradation, where landfill emissions have low magnitudes. The main characteristic organic acids' concentrations, which can be used for the evaluation of biomass biodegradation, in landfill leachates are the iso-butyric acid and acetic acid, during the acidogenesis and acetogenesis stage, respectively. The concentration variation of the latter acids in time determines the landfill biomass biodegradation stages[5,8].

Below, the landfill biodegradation rate is evaluated, based on the MACH site experimental field data, according to the most characteristic biodegradation organic acids of the produced leachate emissions. In Figs. 1-4 are presented the iso-butyric acid concentrations and their trends in time, in the leachate emissions of MACH cells, in the 22 month period since waste mass has been disposed into the landfill.

Moreover, in Figs. 5-8 are presented the biodegradation rates of chemical oxygen demand (COD) and acetic acid concentrations in leachate emissions of MACH cells, for the same time period as in the above figures, in the 22 month period since waste mass has been disposed into the landfill. COD could be characterized as the most hazardous leachate characteristic in relation to groundwater and site spatial contamination[5,8].

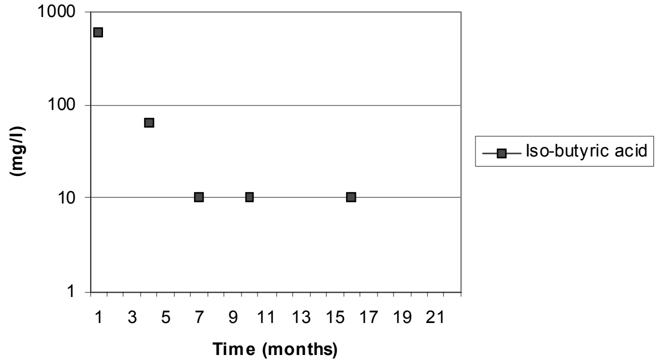

Fig. 1. Mid Auchencarroch's iso-butyric acid concentrations *vs.* time for Cell 1

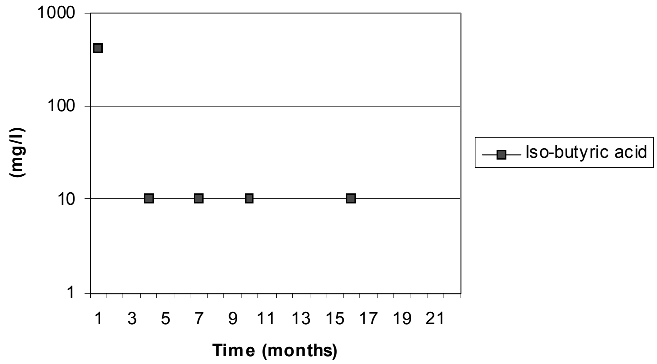

Fig. 2. Mid Auchencarroch's iso-butyric acid concentrations *vs.* time for Cell 2

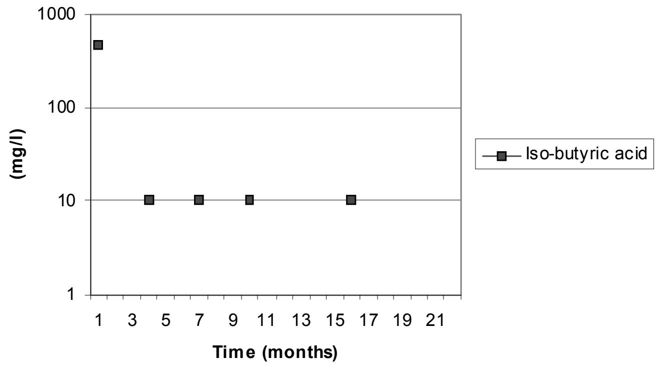

Fig. 3. Mid Auchencarroch's iso-butyric acid concentrations *vs.* time for Cell 3

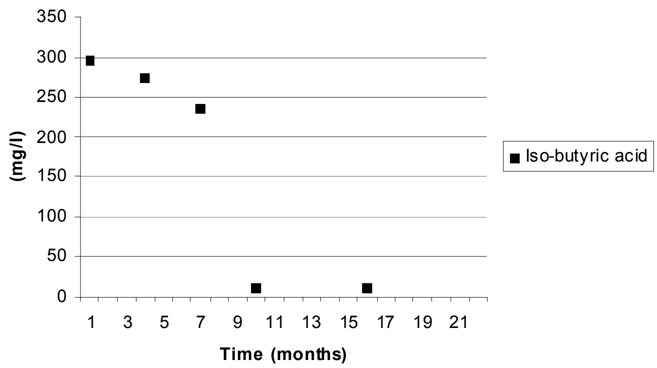

Fig. 4. Mid Auchencarroch iso-butyric acid concentrations *vs.* time for Cell 4

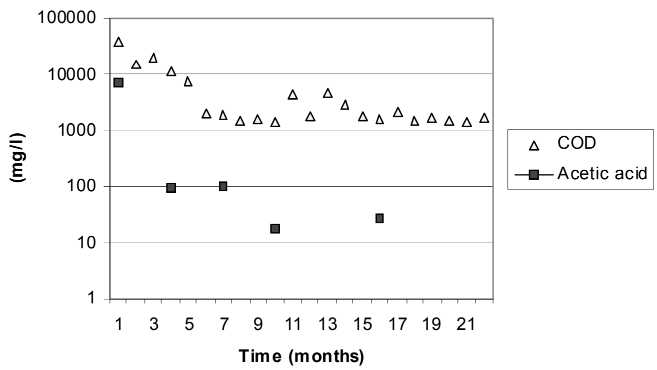

Fig. 5. Mid Auchencarroch's COD and acetic acid concentrations *vs.* time for cell 1

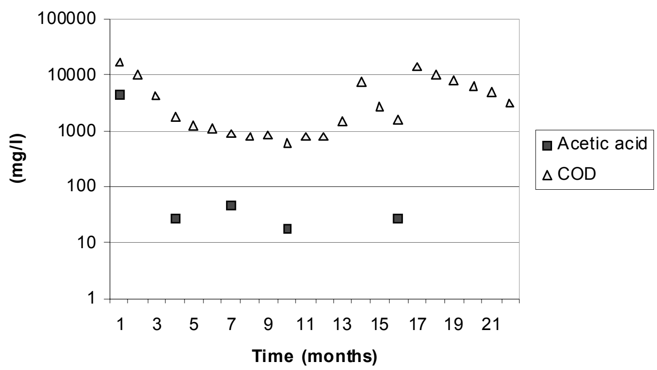

Fig. 6. Mid Auchencarroch's COD and acetic acid concentrations *vs.* time for Cell 2.

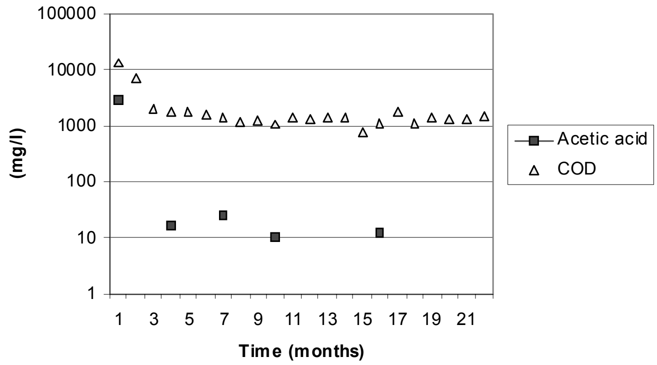

Fig. 7. Mid Auchencarroch's COD and acetic acid concentrations *vs.* time for Cell 3

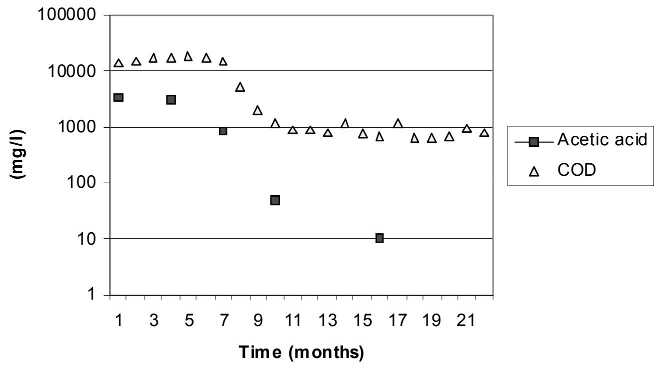

Fig. 8. Mid Auchencarroch's COD and acetic acid concentrations *vs.* time for Cell 4

The field data of the above Figs. 1-8 are analyzed in the next Tables 1-3 for COD, acetic acid and iso-butyric acid, presenting the maximum, minimum and average magnitudes of the respective chemical concentrations in (mg/L), for each MACH experimental cell.

TABLE-1
MAGNITUDES OF COD CONCENTRATIONS AT MACH EXPERIMENTAL CELLS

MACH cell	COD max (mg/L)	COD min (mg/L)	COD average (mg/L)	Leachate recirculation
Cell 1	37162	1380	5757.8	Yes
Cell 2	17131	600	4519.8	Yes
Cell 3	13720	735	2206.6	Yes
Cell 4	18350	620	6144.8	No

TABLE-2
MAGNITUDES OF ACETIC ACID CONCENTRATIONS AT MACH EXPERIMENTAL CELLS

MACH cell	Acetic acid max (mg/L)	Acetic acid min (mg/L)	Acetic acid average (mg/L)	Landfill gas methane yield (lt gas/kg/MSW)
Cell 1	7245	26.5	1496.5	21.53
Cell 2	4470	27.0	917.0	22.67
Cell 3	2895	12.0	591.7	21.30
Cell 4	3330	10.0	787.2	21.65

TABLE-3
MAGNITUDES OF ISO-BUTYRIC ACID CONCENTRATIONS AT MACH EXPERIMENTAL CELLS

MACH cell	Iso-butyric acid max (mg/L)	Iso-butyric acid min (mg/L)	Iso-butyric acid average (mg/L)	Pretreatment of waste by wet pulverization
Cell 1	602.5	10	139.5	Yes
Cell 2	425.0	10	93.0	No
Cell 3	465.0	10	101.0	Yes
Cell 4	295.0	10	146.6	No

According to the above results of COD, acetic acid and iso-butyric acid concentrations, it is clear that there was the greatest depletion of carbon at MACH experimental cell 1. Moreover, MACH cell 4 presents higher average COD, acetic acid and iso-butyric acid concentrations in time than the rest experimental cells due to the fact that there has been disposed higher waste fraction of biodegradable carbon content in it than at rest MACH cells. 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.

According to the examining experimental field data the magnitudes of iso-butyric acid concentrations have reached low values in the first months for cell 1, 2 and 3. The latter fact shows that acidogenesis biodegradation stage was integrated in short time period. Cell 1 presents higher iso-butyric acid concentrations than cell 2 and 3 in the first three months due to the fact that different waste input materials have been disposed into the landfill mass and there is also in cell 1 co-disposal with inert soil material, which does not exist in the rest cells. In cell 4 there were found higher long term iso-butyric acid concentrations than the rest cells. In the first 8 months due to the fact that there has been disposed high waste fraction of biodegradable carbon content without any leachate recirculation in it. However, according to the above field data of acetic acid leachate emissions, it is clear that the acetogenesis stage was integrated between the first 8 and 11 months for all MACH cells. As acetogenesis is nearly integrated, the methanogenesis stage is followed providing satisfactory landfill gas yields based in the results of Table-2. The latter facts verify that quick site stabilization was realized at MACH.

Risk assessment

The use of monitoring field data and utilization of collected data into digital databases are necessary for the development of risk assessment numerical models for further analysis of landfill biodegradation. This will help to simulate better landfill emissions in time in order to take the right measures in time for the protection of public health, minimizing any environmental impacts. Based on the results of Tables 1-3, it is clear that high involved risk of environmental contamination by leachate and landfill gas emissions exists in MACH cells where high fermentable and untreated waste fractions have been disposed in.

On the other hand, evaluating and analyzing MACH's COD, acetic acid and iso-butyric acid concentrations in 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, acetic acid, iso-butyric acid 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 acetic acid, COD and iso-butyric acid concentrations in leachate samples without any decrease in the first eight months. 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 pulverisation since the recirculation of leachate expedite the waste biodegradation. According to the acetic acid, iso-butyric acid and COD experimental field data, a good organic depletion presented cell 1, minimizing any associated environmental risks in short time period.

All the acetic acid, iso-butyric acid and COD concentrations present great reduction in the first 12 months, showing that MACH site was stabilized successfully in short time period. Hence, anaerobic batch landfill bioreactors could be used as efficient landfill sequential batch bioreactor designs. Landfill emissions' environmental contamination control has to be improved based on the presented evaluations, taking into account different landfill conditions. The experimental results showed that the use of the anaerobic landfill batch bioreactor design is sustainable and it should be used by landfill operators.

The trends of the organic acids' concentrations under different landfill conditions should be monitored frequently in time next to landfill boundaries for mapping out any probable remediation works for emergency contamination and rehabilitation scenarios based on the surrounded geological strata and particular landfill topography details. Numerical models are necessary to be developed for the utilization of any useful collected spatial landfill field data in digital databases so as to take any right environmental protection measures in time. Therefore, in such way there will be protected the public health and will be minimized any hazards and associated risks to the environment.

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REFERENCES

1. G. Fleming, Monitoring the Methane Gas Generation from Different Classifications of Waste Using the Clay-Waste Sandwich Method of Landfill, CEMS (1990).
2. P. Kollias, Solid Wastes, Lichnos Publications, Athens, Greece (2004).
3. T.C. Koliopoulos and M.D.G. Koliopoulou, *Asian J. Chem.*, **19**, 3911 (2007).
4. A. Skordilis, Waste Disposal Technologies for Non-Hazardous wastes, ION Publications, Athens, Greece (2001).
5. G. Tchobanoglous, H. Theisen and S. Vigil, Integrated Solid Waste Management, McGraw-Hill Book Company, New York (1993).
6. D.O.E, Making Waste Work, White Paper, HMSO, London (1995).
7. G. Fleming, in ed.: R. Rudolf, Hydrogeochemical Engineering in Landfills, In: Geotechnical Approaches to Environmental Engineering of Metals, Springer, pp. 183-212 (1996).
8. T. Koliopoulos, Numerical Modelling of Landfill Gas and Associated Risk Assessment, Ph.D. Thesis, Deptartment of Civil Engineering, University of Strathclyde, Glasgow, UK (2000).

9. A. Vlavianos-Arvanitis, Biopolitics the Bio-Environment, B.I.O. Publications (1991).
10. T. Koliopoulos, *Internat. Solid Waste Assoc. Times J.*, **3**, 21 (1999).
11. D.O.E, Waste Management Paper No. 27, Landfill Gas, HMSO, London (1989).
12. P. Elliott, D. Briggs, S. Morris, C. Hoogh, C. Hurt, T.K. Jensen, I. Maitland, S. Richardson, J. Wakefield and L. Jarup, *Br. Med. J.*, **323**, 363 (2001).
13. R.H. Friis and T.A. Sellers, Epidemiology for Public Health Practice, Jones and Bartlett Publishers (2004).
14. C. Wingfield-Hayes, The Enhanced Landfill Bioreactor: A Sustainable Waste Management Option for the 21st Century? The Mid Auchencarroch Experiments, Ph.D. Thesis, Depteartment of Civil Engineering, University of Strathclyde, Glasgow (1997).
15. T.C. Koliopoulos and G. Fleming, in eds.: G. Kocasoy, T. Atabarut and I. Nuhoglu, Modelling of Landfill Gas Production of Treated and Untreated Waste-Mid Auchencarroch, In Proceedings of I.S.W.A Congress, Istanbul, Turkey, Vol. 2, pp. 1019-1028 (2002).

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