# LEACHATE EMISSIONS AT MID AUCHENCARROCH EXPERIMENTAL SITE & ENVIRONMENTAL IMPACT ASSESSMENT –EFFICIENT SPATIAL ANALYSIS UTILIZING REMOTE SENSING AND DIGITAL IMAGE PROCESSING SOFTWARE FOR LEACHATE MONITORING

## Telemachus C. Koliopoulos

Environmental Consultancy, Environmental Management Research, Technological Educational Institute of Athens, Greece.
Email: tkol@otenet.gr

## ABSTRACT

This paper combines and analyzes characteristic chemical indexes of the biological waste biodegradation at landfill sites in terms of landfill bioreactor leachate emissions, total organic carbon and pH magnitudes, which are produced at Mid Auchencarroch experimental landfill bioreactor cells with different disposed waste composition and dynamic solid waste management biotechnology techniques. Moreover, in the end is presented a useful and efficient digital image processing computer software for landfill leachate emissions monitoring; landfill operation; and investigation the magnitude of a probable leachate chemical accident next to landfill boundaries or image processing recognition of uncontrolled sites. This paper examines landfill gas emissions based on characteristic field data from Mid Auchencarroch experimental site. Useful conclusions are presented for efficient solid waste management units so as to avoid associated risks to any surrounded land uses next to landfill boundaries.
**Key words:** Landfill chemical emissions, geographic information databases, digital image processing software, landfill topography, risk assessment software.

## INTRODUCTION

Nowadays, the progress and the evolution of our civilization increased the landfill leachate and wastewater volume in wastewater treatment units, as well as the waste volume in sanitary landfills. Sanitary landfill remains an attractive disposal route for household, commercial and industrial wastes, because, it is more economical than other waste disposal methods [2,5,9,10,14,15,28]. Efficient sustainable solutions to the current environmental problems of our planet should be given as soon as possible so as to save the global environment and to protect public health by any chemical threats.

Modern computer software, IT technology should be focused on the usage of digital databases for the quality assurance of landfill sites following the ISO 14001 standards for environmental systems quality assurance investigation, utilizing properly digital image processing computer software and remote sensing databases and other relevant comprehensive digital databases. Continuous remote sensing observation of a landfill operation is necessary for relative risk assessment of landfill leachate emissions, project management of technical reclamation works and public health protection [1,2,3,4,17,29]. Computer client server IT internet applications and intelligent image processing software are necessary so as to process properly big quantities of image databases, remote sensing data, geographic information systems, development of orthophotomaps and digital maps [7,13,19,20,21,22,24,26,27,30,31].

The selection of proper sites for sanitary landfills, and the design, construction and operating practices used at these sites, should take into account the environmental impacts to neighboring land uses next to landfill boundaries, hydrological maps, geological maps and landfill topography's characteristis related to any associated reclamation and monitoring works of landfill emissions. Moreover, quality assurance, landfill bioreactor life cycle analysis, risk assessment and application of efficient accurate lining methods in emergencies to any associated landfill technical construction, reclamation or bioremediation works should take place in all stages of an integrated waste management applying efficient lining methods based

on right orthophotomaps to any necessary technical works, utilizing proper image processing software so as to avoid any hazardous chemical treahts to the environment [8,11,12,13, 23, 31].

## EXPERIMENTAL

According to the literature variations on landfill leachate emissions arise from factors affecting waste bidegradation. These factors vary between sites according to different disposed waste fractions, microbiological conditions, different physical and chemical properties of the disposed materials, different waste quantities disposed of to landfill each year and existing facilities for leachate recirculation.

In this paper are presented landfill emissions from the Mid Auchencarroch (MACH) experimental landfill is a UK Environment Agency and industry funded research facility. It has been capped since 1995. The experimental variables are waste pretreatment, leachate recirculation and co-disposal with inert material. In cells 1 and 3 there is pretreatment by wet pulverisation 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. The waste fractions which have been disposed into these characteristic landfill sites are different provoking several different chemical emissions to the environment [9,10,14,15,16]. The main aim is to evaluate the waste biodegradation of landfill chemical emissions of the four case studies based on the different conditions which exist.

The produced landfill emissions, gases and leachates, are as a result from the waste biodegradation of the organic material which has been disposed into the landfill mass. Dynamic numerical simulation models based on field data, like SimGasRisk one, should be combined with efficient digital image processing software for better evaluation of chemical landfill emissions' trends in time and development of proper digital databse for digital mapping of particular emissios in time, making effective spatial analysis on given topographies in time. Moreover, efficient dynamic lining methods should take place based on the results of dynamic robust numerical simulation spatial models, improved monitoring data by remote sensing applications and any other available digital spatial data (i.e. 3D digital spatial databases, signal processed aerial photographs, G.P.S. data, G.I.S thematic maps, utilization of simgasrisk numerical spatial model with image processing software, development of digital orthophotomaps etc.) so as to be taken the right maintenance and reclamation works in emergency cases at landfill topographies, protecting public health and any nearby landuses next to landfill boundaries [6,8,11,12,13,20,23,24,31].

During each biodegradation stage there are several different bacterial colonies, which exist under particular favourable physical, biological and chemical conditions for them during the life cycle of a labdfill bioreactor. During the methanogenesis stage pH equals to 7, neutral environment. On the other hand, during the hydrolysis and acetogenesis stages the pH has low values indicating an acid environment and the COD, TOC values have big magnitudes during an initial time since the waste was disposed and later they are decreasing in time. Inestigating the landfill bology, the biodegradation stages, which exist within landfill life cycle and its respective biogas and leachate stabilized chemical emissions, include the hydrolysis, acidogenesis, acetogenesis, methanogenesis and mature stage [16,28].

Efficient landfill designs, managements and proper biotechnologies should be used in landfill bioreactor manufactures taking into account different waste syntheses, physical, biological, chemical properties, landfill topographical characteristics and improved monitoring systems. The utilization of the robust SimGasRisk simulation numerical modelling software is necessary combining its results with efficient digital image processing software utilities so as to register spatial landfill emissions behaviour in a proper geographic database for taking relative measures in time [16]. Digital image processing software are necessary for a comprehensive investigation of environmental systems. Below in figures 1, 2, 3 and 4 is presented a comparative presentation of the T.O.C. leachate emissions and pH values of leachate in time for each MACH cell respectively.
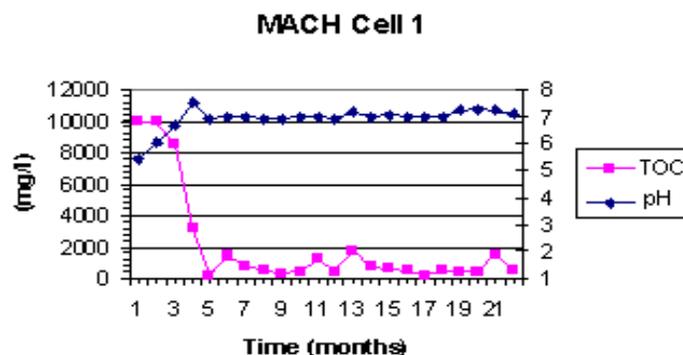
**MACH Cell 1**



**Fig.-1 :**Leachate characteristic emissions, T.O.C concentration vs pH
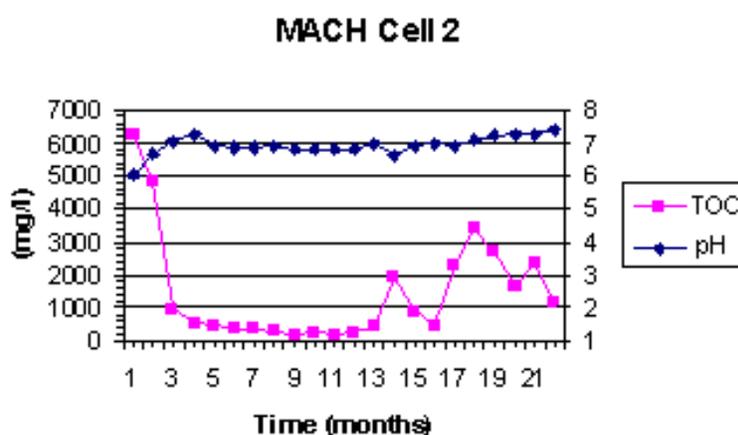at Mid Auchencarroch experimental cell 1 site

**MACH Cell 2**



**Fig.-2:** Leachate characteristic emissions, T.O.C concentration vs pH
at Mid Auchencarroch experimental cell 2 site

According to the above presented results, TOC concnentrations achieved in short time period while pH values were approximately to 7 in short time, which means that methanogemesis stage took place rapidly. MACH's experimental field data showed that waste can be treated properly by the application of efficient sustainable landfill design biotechnologies like MACH one.

New comprehensive risk assessment methodologies are demanded utilizing proper image processing software for quick and accurate detection of leachate emissions flow and landfill site investigation in emergency cases These methodologies are necessary not only for leachate level control in ponds during floods on a landfill site but also for the investigation of non-controlled landfill sites with uncontrolled ponds next to them. In order to have a comprehensive spatial analysis is necessary the combination of numerical simulation results, field data and image processing software results [16,22,25,27]. Quick and accurate lining methods should be applied based on digital orthophotomaps backgrounds, making proper photomosaics for the right construction, operation, and maintenance in emergency cases of the leachate leakage due to floods, fires, earthquakes or other natural disasters. Below is presented an efficient environmental digital image processing software not only for a landfill site operational control but also for regional development of an area next to a landfill topography. The fulfilment of ISO 14001 standards of integrated biomass kit biodegradation units is becoming necessary in the present time both for private and public sector.
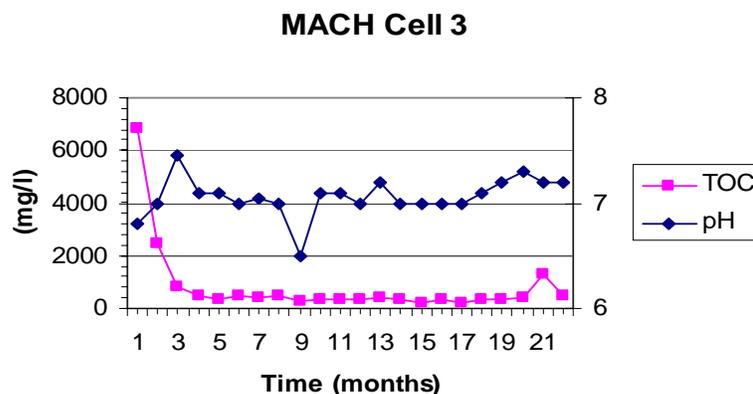
## MACH Cell 3

**Fig. –3:** Leachate characteristic emissions, T.O.C concentration vs pH
at Mid Auchencarroch experimental cell 3 site
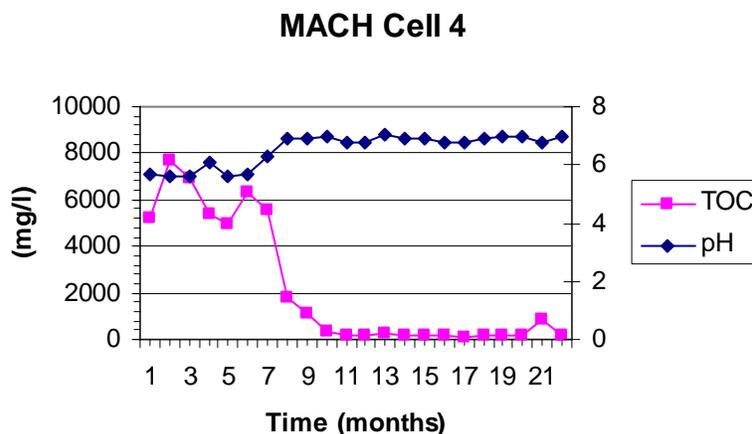
## MACH Cell 4

**Fig.-4:** Leachate characteristic emissions, T.O.C concentration vs pH
at Mid Auchencarroch experimental cell 4 site

Furtermore, the development of digital image processing software is presented in this paper. Ditigal remote sensing images could be collected by several satellite electronic databases in the internet (ie. SPOT, Landsat, IRS-1B etc.). Modern computer aided mapping software, could be utilized for the development of a photomosaic based on edited orthophotomaps. A hybrid image processing software is presented in this paper combining the next modules, for the determination of the particular spatial analysis environmental characteristics of a landfill topography depended on particular image characteristics:

- Development of orthophotos and orthophotomaps
- Region boundary determination by the use of Boundary-Following Algorithm [22]
- Edge detection applying Sobel method [22]
- Combination of SimGasRisk numerical modelling results with G.P.S data of a landfill site for a comprehensive G.I.S. database of risks surrounded landfill boundaries [16] and development of distance transforms, medial axis [22] so as to identify optical tresholds of hazards and to develop treshold maps for land uses' protection measures (Euclidean distance, structural distance, chess distance)
- Use mean signal processing filter so as smooth noise [18]
- Use median signal processing filter so as smooth noise [22]
- Use proper non-linear signal processing transformations for digital image contrast control [22]

- Combine proper methods to extract image characteristics like Otsu method, Reddi method, Kapur method [22]
- Use first order derivatives or second order partial differential equations in order to determine pinnacles, use Kirsch method, transformations for image brightness control, Marr and Hildreth method, log filter, zero bestriding method and variation control for pinnacles detection respectively [22]

Based on the above presented digital image processing software can be processed properly several remote sensing images so as to extract useful risk assessment results of leachate emissions, comparison of topographic terrain change or operational needs of a landfill site. One of the benefits of the presented digital image processing software is that can identify accurately the boundaries of leachate ponds on a given landfill topography, surrounded by a geological strata which has similar colour to leachates, which can not be detected by human eye, as it is not exactly the same. In figures 5, 6 has been applied indicatively the zero bestriding method and variation control for pinnacles detection, where efficiently can be detected particular topographic characteristics at two greek landfill sites. The processed image of the original satellite one can be used for further spatial analysis utilizing proper orthophotomaps.



**Fig.-5:** Using proper digital image processing methodology for detection of particular topographic characteristics at Ano Liosia landfill site outside from Athens city in Greece.

Therefore, the combination of dynamic numerical simulation spatial models and efficient digital image processing software is necessary so as to develop an improved monitoring system of environmental impacts and to line any probable emergency confrontation works based on proper orthophotomaps, G.P.S measurements and geographic information system database for public health and environmental protection, quality assurance, risk assessment and economic project management of landfills' chemical emissions treatment [1,3,7,8,9,11,13,14,15,16,18].

## RESULTS AND DISCUSSION

According to the MACH's experimental field data is clear that anaerobic design under favourable landfill's physical, biological and chemical conditions assists the pH environment to take neutral values in short time period. Moreover, total organic carbon T.O.C. concentrations were decreased in short time. The latter facts verify that methanogenesis stage achieved in short time period at MACH site as well as that MACH's biomass treatment biotechnology principles are sustainable. Moreover, the presented digital

image processing software is necessary not only for landfill leachate level control in leachate ponds, regional development proposals and proper combination with relative spatial analysis models in normal situations of an integrated biomass management unit but also it is useful for taking the right measures in emergency cases like floods or other natural disasters.



**Fig.-6:** Using proper digital image processing methodology for detection of particular topographic characteristics at Tagarades landfill site outside from Thessaloniki city in Greece.

## ACKNOWLEDGEMENTS

## REFERENCES

1. C.I. Efraimidis, Project Management, Symmetria Pubs, Athens, Greece, p.273 (2001).
2. EPA Manual–Ground Water and Leachate Treatment Systems U.S. Environmental Protection Agency, Washington, DC, EPA/925/R-94/005. pp. 119 (1995).
3. G. Fleming, Hydrogeochemical Engineering in Landfills. In: Geotechnical Approaches to Environmental Engineering of Metals, Rudolf, R. (ed.), Springer, pp. 183-212 (1996).
4. G.M. Foody, P.M.Atkinson, Uncertainty in Remote Sensing and GIS, John Wiley and Sons Publications, p.307 (2002).
5. Greek Ministry for the Environment, Physical Planning and Public Works (MEPPPW) National Allocation Plan for the period 2005 – 2007, Hellenic Republic, Athens, Greece, p. 60 (2005).
6. S. Kaparis, Special Subjects of Topography, Ministry of Education Pubs, Athens, Greece, p.208 (1993).
7. I. Kavoura, Programming with Java, Kleidarithmos Pubs, Athens, p. 681, (2003)

8.  C. Koliopoulos, Elements of Errors' Theory and Least Square Synorthosis of Geodetic Networks, ION Pubs, Athens, Greece, p. 332 (1990).
9.  T.C. Koliopoulos, *RASAYAN Journal of Chemistry*, **1(1),** 171-178 (2008).
10. T. C. Koliopoulos, *RASAYAN Journal of Chemistry*, **1(1),** 437-446 (2008).
11. T.C., Koliopoulos, G. Koliopoulou, C.Axinte, *M.O.C.M Journal*, **13(II),** 379-384 (2007).
12. T.C., Koliopoulos, G. Koliopoulou, C.Axinte, *M.O.C.M Journal*, **13(II)** 385-390, (2007).
13. T.C., Koliopoulos, G. Koliopoulou, C.Axinte, *MOCM,* **14,4** (in press) (2009).
14. T.C., Koliopoulos, G. Koliopoulou, A diagnostic model for M.S.W landfill's operation and the Protection of Ecosystems with a Spatial Multiple Criteria Analysis – Zakynthos Island Greece, Wessex Institute of Technology Transactions on Ecosystem and Sustainable Development (ECOSUD), W.I.T. Press Publications, U.K., pp. 449-462 (2007).
15. T.C., Koliopoulos, G. Koliopoulou, Evaluation of optimum landfill design: Mid Auchencarroch experimental landfill emissions, Wessex Institute of Technology Transactions on Computer Aided Optimum Design in Engineering (OPTI), W.I.T. Press Publications, U.K., pp. 231-239 (2007).
16. T.C., Koliopoulos, Numerical Modelling of Landfill Gas and Associated Risk Assessment, PhD Dissertation, Dept. of Civil Engineering, University of Strathclyde, Glasgow, U.K., p. 200 (2000).
17. D.A. Landgrebe, Signal Theory Methods in Multispectral Remote Sensing, John Wiley and Sons Publications, p.508 (2003).
18. A. Lev, S. Zucker, A. Rosenfeld Iterative enhancement of noisy images, *IEEE Trans. on Systems*, Man and Cybernetics, vol. SMC 7, pp. 435-442 (1975).
19. S.P. Mertikas, (2006) Remote Sensing and Digital Image Processing Analysis, ION Pubs, Athens, Greece, p.449.
20. Mobile mapping Solutions http://products.thalesnavigation.com/en/solutions/mobilemap/
21. S. M. Panas, Digital Signal Processing, University Studio Press Pubs, Thessaloniki, Greece, p. 221 (2001).
22. N. Papamarkos (2005) Digital Image Processing and Image Analysis, Gkiourdas Pubs, Athens, p. 425.
23. B. Rothery, ISO 14000 and ISO 9000 series of quality standards, Gower Pubs, U.K., p. 321 (1995).
24. The Global Positioning System http://www.colorado.edu/geography/gcraft/notes/gps/gps_f.html
25. J.L.Scnoor, Environmental Modelling, Fate and Transport of Pollutants in Water, Air, and Soil, J. Wiley & Sons Pubs, p. 752 (1996).
26. A.D. Styliadis, Development of platforms in Control Computer Graphical Environment, Applications in Geographic Information Systems, Ziti Pubs, p. 473, (2002).
27. G.P. Syrkos, Digital Signal Processing, Papasotiriou Pubs, Athens, Greece, p. 415 (2007)
28. G. Tchobanoglous, H. Theisen, S. Vigil, Integrated Solid Waste Management, McGraw-Hill Book Company, New York, USA, p. 978 (1993).
29. B. Tso, P.M. Mather, Classification Methods for Remotely Sensed Data, Taylor and Francis Publications, p. 331 (2001).
30. K. Yang, X.N.Zhou, W.A. Yan,D.R. Hang, P. Steinmann, Landfills in Jiangsu province, China, and potential threats for public health: Leachate appraisal and spatial analysis using geographic information system and remote sensing, Journal of Waste Management, vol. 28, issue 12, pp. 2750-2757 (2008).
31. D. Zerva, (1974) Lessons of Photogrammetry, Greek Geographical Military Service, Athens, Greece, p. 336.