CARBON DIOXIDE EMISSIONS' AT MID AUCHENCARROCH EXPERIMENTAL SITE AND ENVIRONMENTAL IMPACT ASSESSMENT –UTILIZATION OF REMOTE SENSING AND DIGITAL IMAGE PROCESSING SOFTWARE FOR AN INTEGRATED LANDFILL GAS RISK ASSESSMENT

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

ABSTRACT

Sanitary landfills remain an attractive disposal route for solid wastes, as it is more economical than other alternative solutions. This paper analyzes the biological waste biodegradation at landfill sites in terms of landfill gas and carbon dioxide emissions production which are produced by experimental waste cells with different disposed waste composition and dynamic solid waste management and treatment biotechnology techniques. Risk assessment is made of landfill gas emissions based on characteristic field data from Mid Auchencarroch experimental site. Moreover, in the end is presented an efficient image processing computer software for landfill lyfe cycle analysis monitoring; landfill operation; investigation of probable landfill gas migration topographic areas; development of an integrated comprehensive geographic information system incorporating an intelligent environmental IT database; and operational investigation of landfill gas collection networks next to landfill boundaries. 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, digital image processing software, landfill topography, risk assessment software.*

INTRODUCTION

Nowadays, the necessities of our life are getting increased in time due to the nature of our civilization the associated environmental management problems are becoming more complex. The progress and the evolution of our civilization increased the waste volume in sanitary landfills, as well the landfill leachate and wastewater volume in wastewater treatment units. Efficient sustainable project management and spatial analysis solutions to the current environmental problems of our planet should be given as soon as possible so as to save the global environment [1,2,3,4,11,12,13,14,15,16,17,28]. There are several modern environmentl problems at landfill sites, like the continuously increasing waste production and civil energy consumption, odours, leachate and V.O.C's toxic emissions, landfill fires, greenhouse carbon dioxide gases and methane ones which influence on global climatic change of the environment, flora and fauna environmental impacts, ecoterrorism, industrial accidents, and others, which are related to the waste production by several anthropogenic activities [2,4,9,10].

Risk assessment numerical modeling software should be up continously up grated by the development of an integrated comprehensive geographic information system, incorporating an intelligent environmental IT database in order to satisfy the needs of an improved monitoring system [16]. Hence, a comprehensive digital geographic information system database is necessary utilizing properly a remote sensing or aerial photographs' monitoring system database in collaboration with an efficient digital image processing computer software.

The technology should be focused on the usage of digital databases for the quality assurance of landfill sites following the right environmental ISO standards (ie ISO 14001:2004), and utilizing properly digital image processing computer software. Frequent remote sensing observations of investigated landfills'

operation and relative G.P.S data collection are necessary for the right risk assessment and confrontation works to any hazards by landfill emissions [5,16,17,19,20,23,24,28].

According to the literature remote sensing is proposed as a useful technique for monitoring lamdfill sites for gas migration [5]. The presence of landfill gas in the root zone causes signs of stress to be visible within the vegetation, the stress generally taking the form of chlorosis or dieback. Is preferable that remote sensing could be used in conjuction with soil and geological available maps so as to identify high landfill gas concentration. A combination of remote sensing data, image processing comperative results, and spatial numerical modeling results are useful so as to extract integrated risk assessments of landfill gas migration and environmental systems investigation developing a comprehensive environmental software investigating the terms of ISO 14001 environmental standard (ISO 14001). However, satellite images by several electronic databases could be utilized properly in order to develop a digital ground model, which can be utilized for the production of accurate orthophotomaps, or the development of thematic maps utilizing them as backgrounds at particular multilevel layers for G.I.S. applications manually or via internet applications utilizing useful Java software applications [7,16,23,25, 28]

Sanitary landfill remains an attractive disposal route for household, commercial and industrial wastes, because, it is more economical than other waste disposal methods [4,16,27]. The selection of proper sites for sanitary landfills, or expansion of existing landfills, and the design, construction, maintenance and associated 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, other associated physical geographic indexes and landfill topographic characteristis related to any reclamation and monitoring works of landfill emissions for regional development. Moreover, quality assurance, landfill bioreactor life cycle analysis, risk assessment, integrated environmental investigation remote sensing systems and application of efficient lining methods to any associated landfill technical construction, reclamation or bioremediation works should take place in all stages of an integrated waste management and the use of efficient lining methods to any construction or other work, should take place properly for particular economic project management within monitoring, maintenance or other dynamic sustainable associated technical infrastructure works, avoiding any hazardous chemical treahts to the environment [1,2,,5,6,7,11,12,13,16].

EXPERIMENTAL

According to the literature variations on landfill carbon dioxide emissions arise from factors affecting biogas generation. 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 gas collection and flaring or recovery. The principal landfill gases are methane and carbon dioxide with trace concentrations of a wide variety of other gases, depending on the waste mix. The greenhouse gases in waste management are methane as well as carbon dioxide [13,17]. Efficient landfill gas networks for biogas exploitation and green house emissions minimization are necessary utilizing proper image processing software and G.I.S.-remote sensing technologies for maintenance and regional development works [17,19,21,22,25,28]. 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,,13]. 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 in relation to image processing software should be used for better simulation and

evaluation of chemical landfill emissions' quantitative trends and their respective spatial analysis on given topographies in time. Moreover, efficient dynamic accurate lining methods should take place based on the results of dynamic robust numerical simulation spatial models, monitoring data 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, simgasrisk numerical spatial model utilization, accurate orthophotomaps etc.) so as to be taken the right maintenance and probable reclamation works in time at particular landfill topographies, protecting public health and any nearby anthropogenic landuses next to landfill boundaries [6,8,11,12,13,16,19,2,20,24].

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 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 [9,10,15,16,27].

Efficient landfill designs, managements and proper biotechnologies should be developed and used in landfill manufactures taking into account different waste syntheses, physical, biological, chemical properties and landfill topographical characteristics, spatial landfill emissions behaviour. A robust simulation biogas risk numerical modelling (SimGasRisk) has been carried out for MACH experimental field data and its results are shown below in the next figures [16].

The relative SimGasRisk's numerical results could assist the detailed inspection of a landfill topography based on relative orthophotomaps, utilizing a proper image processing software for a well developed monitoring system according to sellected remote sensing photographs. Below in figures 1, 2, 3 and 4 is presented the cumulative carbon dioxide emissions flushing out in time versus hourly carbon dioxide production and daily carbon dioxide production of each MACH cell respectively based on the waste input characteristics given to the simulation biogas risk assessment numerical model, SimGasRisk [16]. However, both carbon dioxide and methane emissions present similar trends to the biogas production trends of each MACH cell respectively, verifying that MACH experimental site stabilized in short time avoiding any long term chemical toxic threats (Rasayan 1; e-J Tei, AJCH). Therefore, the produced V.O.C's gases will follow the same trends in time, presenting approximately an 1% volume production. Investigating particular meteoroligal conditions, and geographical characteristics on a given landfill topography and utilizing orthophotomaps in peak time of biogas production can be developed thematic maps presenting G.I.S. with tresholds risk contours in order either to avoid the expansion areas of existing landfill sites or avoid the existence of anthropogenic activities next to hazardous areas where there are high frequencies of landill gas emission on the air [14,15,16].

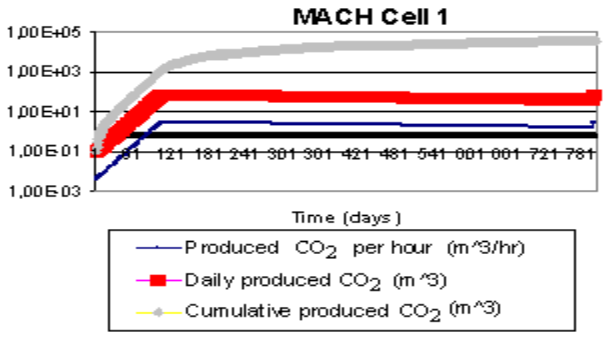

Fig.-1: Cumulative flushing out carbon dioxide in time vs daily produced methane at Mid Auchencarroch experimental cell 1 site, y axis in logarithmic scale

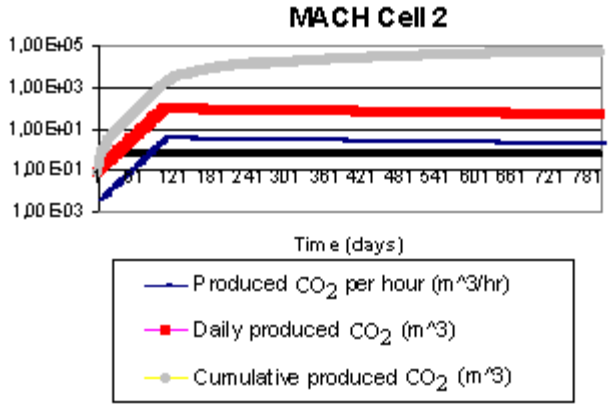

Fig.-2; Cumulative flushing out carbon dioxide in time vs daily produced methane at Mid Auchencarroch experimental cell 2 site, y axis in logarithmic scale

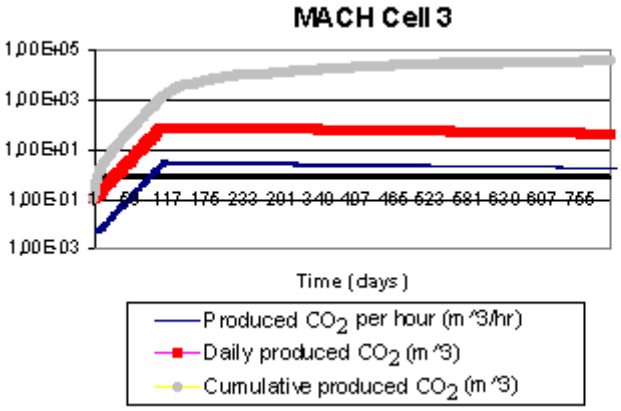

Fig.-3: Cumulative flushing out carbon dioxide in time vs daily produced methane at Mid Auchencarroch experimental cell 3 site, y axis in logarithmic scale

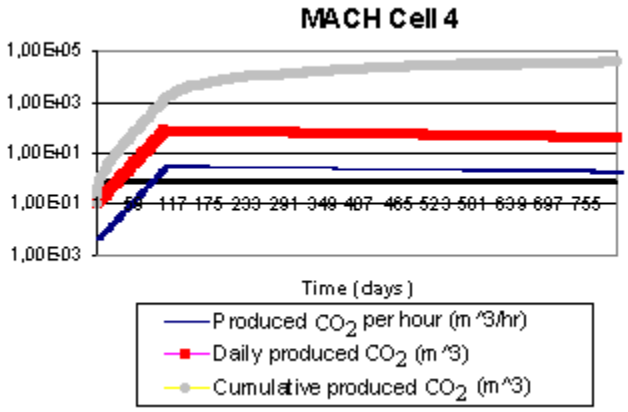

Fig.-4: Cumulative flushing out carbon dioxide in time vs daily produced methane at Mid Auchencarroch experimental cell 4 site, y axis in logarithmic scale

According to the above presented results, tremendous flushing out carbon dioxide emissions could be collected and be treated properly by the application of efficient sustainable landfill design biotechnologies like MACH one. Methanogenesis biodegradation stage exists in landfill waste material mass due to the methanogens bacteria, which are the most obligate anaerobic biological organisms known; they are inhibited or killed by trace amounts of oxygen. The methanogens could be divided in two types: Acetophilic and hydrogenophilic. Methanogens can only utilise a number of substrates, which are respectively; acetate and, hydrogen + carbon dioxide. These bacteria work in harmony with the acetogenic bacteria, maintaining a suitable environment in which the acetogens may continue to produce substrate for them. The products of methanogens are carbon dioxide and methane (Koliopoulos, 2000; Tchobanoglous *et al.* 1993). The two reactions can be shown below:

Acetate dismutation by Acetophilic Methanogens

$$CH_3 - COO^- + H_2O \rightarrow CH_4 + HCO_3^-$$

and the reduction of carbon dioxide by hydrogen & by Hydrogenophilic Methanogens

$$4\,H_2 + CO_2 \rightarrow CH_4 + 2\,H_2O$$

Higher cumulative carbon dioxide and respectively methane production rate exists in cell 2 than in the rest cells due to its different waste input and its waste materials conditions in comparison to the rest cells (ie different biodegrable waste fractions and leachate recirculation in landfill mass) (Rasayan 1).

Moreover, according to the above results and the measured field data the landfill gas production has been found between 7 and 9 m^3/hr for both MACH's cells in less than two-year period since the site was capped. The latter field data in comparison with the methane and carbon dioxide emissions (vol%) satisfactory trends in short time verify the quick MACH site stabilization, avoiding any long term environmental impacts and associated risks to the environment and to the public health [6,13]. MACH's experimental bioreactor design principles could be applied to any relative big scale bioreactors or to any proper shallow sequential batch bioreactor biotechnologies. Particular landfill topographic constraints and utilization of digital image processing principles, orthophotomaps and spatial analysis of remote sensing data for efficient project management of eco-design manufactures in emergencies should be taken into account carefully in order to collect properly big quantities of produced biogas to renewable energy resources' production units [13,19,23,28,29].

Furtermore, the development of a digital image processing software is presented in this paper. Ditigal remote sensing images could be collected by several satellite databases in the internet (ie. SPOT, Landsat, IRS-1B etc.). Modern computer aided mapping software and proper digital image processing could be utilized for the development of a photomosaic based on edited orthophotomaps [5,7,17,18,20,21,25,27,28].

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 topographic area next to landfill boundaries depended on particular image characteristics:

- Development of orthophotos and orthophotomaps
- Use mean signal processing filter so as smooth noise [18]
- Region boundary determination by the use of Boundary-Following Algorithm [22]
- Distance measures based on given points on the map
- 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 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 landfill gas migration or operational needs of a landfill site. Proper quick and accurate lining methods can decided to be used based on accurate developed orthophotomaps for the right construction, operation, maintenance and emergency support of a biogas exploitation sustainable environmental system taking into account particular spatial characteristics of landfill topographies [6,8,11,12,13,18,19,23,28]. However, MACH experimental site case study clearly identifies the importance of site design and management in order to achieve optimal gas generation and rapid stabilisation of the site avoiding any long term associative risks and hazards to the environment.

A proper biogas emissions' remote sensing - image processing monitoring system should be existed investigating probable maintenance operational needs of any existing lined borehole monitoring network next to landfill boundaries. The lining of a dense monitoring system in space and frequent samples of landfill emissions in time should take place next to landfill boundaries. An initial investigation grid of boreholes should be installed at 5-10 m along adjacent to landfill boundary and on the latter location should be installed monitoring gas probes at 10-20 m across distance. The latter monitoring spatial network could be made denser properly taking into account different landfill topographical spatial data, particular landfill gas produced quantities, landfill physical and chemical properties and high permeable geological stratas. A biogas suction pumping network, operationally supported by renewable resources, should operate for safety reasons in order to adverse gas migration. The use of dynamic numerical simulation spatial models are necessary linking them properly with efficient geographical information systems, digital topographic databases, digital image processing software and spatial information systems' applications for the right monitoring, proper lining of any probable emergency confrontation works, public health and environmental protection, environmental quality assurance (ISO 14001), diagnosis and economic project management of landfills' chemical emissions treatment [13,16,18,19, 22,24].

RESULTS AND DISCUSSIONS

Based on the above presented results is 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 biomass biodegradation and carbon dioxide emissions in short time. Moreover, From the above presented results was clear that in the case of biomass bioreactors where there is big fraction of the disposed putrescible material into the biomass (ie compost units, sewage sludge digesters, associated agronomic applications etc) it influences the produced biogas quantity in time, which should be taken into account not only for any assosiative renewable resources energy exploitation systems but also for risk assement of surrounding land uses utilizing the above presented digital image processing software. However, the simulations which presented in this paper could be a useful tool combinig SimGasRisk numerical model modules and image processing software in order to have an integrated risk assessment of a landfill bioreactor site.

The monitoring measurements of both biogas and leachate emissions should be taken frequently and the collected field data, digital image processing results to be evaluated properly so as to make useful risk assessment results which are extracted by the use of the above presented comprehensive image processing computer software. In this way could be investigated efficiently the life cycle of a biomass bioreactor. The use of efficient dynamic lining methods is necessary to take place in space and time for any associative construction, maintenance, rehabilitation and bioremediation technical works on a given biomass bioreactor topography utilizing proper othophotomaps for emergency management (ie flood cases, fires, earthquakes etc.). The development of dynamic spatial models, linking them properly with any available spatial databases and digital image processing software, are necessary not only to evaluate existing sites but also to diagnose landfill life cycle so as to propose relative confrontation designs, taking right measures in any assosiative emergency cases. Long-term liability can be minimized if waste is quickly treated to a point that will not be occured further emissions. In this way will be protected not only the public health but also any surrounded infrastructure works or other anthropogenic activities and land uses next to landfill boundaries, avoiding any long term hazardous explosive biogas emissions and other

associated risks. The image processing collected data could be more useful if they are evaluated properly following the ISO 14001 standards making an additional geographic socio-economic analysis for an extended investigative environmental quality assurance of an examining landfill unit and further regional development of the area next to a landfill bioreactor site. The presented image processing software features could be used in any other relative geographical information system application for the development of an improved monitoring geographic database, for spatial analysis of image remote sensing databases related to problems within environmental impacts' confrontation (ie fires, downgraded areas by landfill emissions, regional development, rehabilitation of uncontrolled sites, reclamation works in emergencies, fume detection etc.) developing proper digital mapping of environmental impacts.

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