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Soil covers and Landfill Management for Agricultural Food Protection

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Abstract

The soil cover, management of landfill emissions and waste biodegradation is reviewed for agricultural food and public health protection. The aim is to better understand the role of soil cover, waste pretreatment, biodegradation processes on the landfill gas migration and bioremediation in relation to landfill emissions management techniques. The variations of landfill gas migration next to landfill boundaries are evaluated. The field data confirm that waste pretreatment and leachate recirculation are sustainable and accelerate the waste biodegradation protecting agricultural resources and public health from toxic chemical hazards.

Keywords: pollution control in landfill biotechnologies; efficient biodegradation systems; monitoring schemes for food protection; efficient designs for sustainability; bioremediation; public health

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1. INTRODUCTION

Landfills are a major anthropogenic source of methane (CH4) and are estimated to contribute about 6-12% of global methane emissions to the atmosphere. Engineering solutions such as landfill gas extraction systems have been used in new landfill sites to collect and recover methane before it is emitted into the atmosphere supporting sustainable development of our society and protecting environmental resources [12,13,14,15]. However, in old landfills without gas extraction systems, methanotrophs present in the cover soils oxidize methane, forming biomass and CO2. It is estimated that about 22 Tg of methane per year is oxidized in landfill cover soils [64]. Biogas generation is influenced by several parameters [28,31,34,35,36,40,41,42,44,54,55,56,71] including moisture content, waste material characteristics, hydrological and geotechnical characteristics, the availability of nutrients and microbes, temperature, pH, and the presence of inhibitors such as oxygen, metals and sulphates. The production will not ensue if any of the values of these is within a range of threshold values. The influence of these variables, the enhancement of gas yield, methane oxidation and stabilization processes in landfills have been the focus of numerous studies [6,31,32,33,34,41,44,51,52,58,65]. It was found [31,41,72,73] that gas production in sanitary landfill bioreactors increases with increased moisture content up to saturation. Hydrological and geotechnical parameters should be evaluated, utilizing properly GIS tools for efficient landfill

Sustainable solutions are necessary due to world's population increase not only for environmental protection but also for food safety at agricultural land uses, other anthropogenic activities from landfill emissions and associated chemical toxic hazards for public health [21,25,44,45,61,76]. Gases found in landfills include methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), hydrogen (H_2), hydrogen sulfide (H_2S), nitrogen (N_2), oxygen (O_2) and trace gases. During the first phase, which is relatively short, biodegradable organic materials react quickly with oxygen forming carbon dioxide, water, and other byproducts (e.g. bacterial cells). Carbon dioxide is produced in approximate molar equivalents to the oxygen consumed. Oxygen depletion marks the onset of anaerobic microbial processes, which persist much longer. The anaerobic phase is the main phase over the greater part of the landfill life. The latter phase is more significant in terms of methane gas formation. The various stages of landfill gas generation are presented in Figure 1.1.

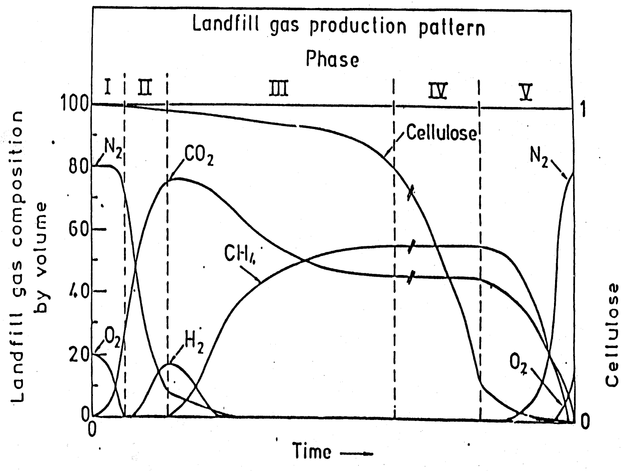


Fig. 1.1. Various stages of landfill gas generation.

Source: [73]

Phase I is the initial adjustment phase. In Phase I, biological decomposition occurs under aerobic

designs so as to protect public health, community health in emergencies from associated risks [7,8,9,10,18,19,20,21,22,23,25,60,66,67,69,74].

conditions, because a certain amount of air is trapped within the landfill. In Phase II, identified as the transition phase oxygen is depleted and anaerobic conditions begin to develop. As the landfill becomes anaerobic, nitrate and sulphate, which can serve as electron acceptors in biological conversion reactions, are often reduced to nitrogen gas and sulfide. In Phase III, the acid phase, the microbial activity initiated in Phase II accelerates with the production of significant amounts of organic acids and lesser amounts of hydrogen gas. In Phase IV, the methane fermentation phase, a second group of microorganisms, which convert the acetic acid and hydrogen gas formed by the acid formers in the acid phase to CH_4 and CO_2, becomes predominant. Phase V, the maturation phase, occurs after the readily available biodegradable organic material has been converted to CH_4 and CO_2 in Phase IV. The rate of landfill gas generation diminishes significantly in Phase V, because most of the available nutrients have been removed with the leachate during the previous phases. Depending on the landfill closure measures, amounts of nitrogen and oxygen can be found in the landfill gas [3,).

Many researchers have been pointed out that temperature is an important factor of chemical, physical and biological phenomena in a sanitary landfill [6,26,31,32,33,34,41,44]. Methane production in landfills can be optimized by temperature control. The optimum temperature for methane production has been reported as 41 and 42 ^{o}C in anaerobic digestion of waste reactor [41,44,45,72].

Findikakis *et al.* [35] developed a model for calculation of LFG production and transportation rates. The model is based on an approximation of biochemical processes controlling gas generation. The function used consists of a rising hyperbolic branch and a decaying exponential branch. The use of a hyperbolic function was suggested by experimental data from the Mountain View Landfill.

El-Fadel [31,35] developed a model describing the dynamics of the microbial landfill ecosystem based on a physical, chemical and biological characterisation. The output of the model was compared with experimental data deriving from an on-site control cell. There is a good correspondence between model output and experimental data after a lag time of 400 days.

Findikakis and Leckie [34] produced a first-order model in which gas production is directly proportional to substrate utilisation. Several models produced in the past like a triangle-shaped function with linear increasing and decreasing gas production phases, and a modified triangular function [35] with a hyperbolic increasing phase and exponential decreasing phase. More estimates of gas generation rate can be obtained by simulating the chemical, physical and biochemical reactions in the waste ecosystem [31].

However, glucose decomposition could be taken as an indication for landfill gas and heat production but not for the final LFG production estimation as the biodegradation of the waste mass has to take into account all the disposed biodegradable waste components.

2. EXPERIMENTAL SET UPS - MATERIALS AND METHODS

The progress and the evolution of our civilization increased the waste volume in sanitary landfills, as well the wastewater volume in wastewater treatments. The environmental pollution became hazardous the last years. The technology has been focused on the environmental protection developing methods and systems of effective waste management and energy recovery. The increasing of the SWM recovery rates influences the waste management systems, the waste composition streams, costs and emissions from treatment and disposal activities.

Sanitary landfill remains an attractive disposal route for household, commercial and industrial wastes, because, it is more economical than other waste disposal methods [73]. Optimum sustainable designs and efficient project management are necessary in agricultural; reclamation works and access to associated sanitary units so as to minimise construction costs and environmental emissions [39,59,61,62,63]. These enable cost effective engineering to prevent leachates entering the water table from landfill sites. Efficiently managed landfill sites also generate considerable volumes of methane gas (CH_4), which can be recovered producing electricity. The selection of sites for sanitary landfills, and the design, construction and operating practices used at these sites, should:

- be consistent with local land use conditions and zoning codes;
- assure that bird populations do not pose a hazard to aircraft;
- protect flood plains, wetlands, and other ecologically sensitive areas;
- protect archeological, historical, and other culturally sensitive areas;
- protect against problems caused by unstable geological settings;
- provide for best practices in design, construction, operation and closure; and
- minimize impacts on air or water quality

and not to otherwise adversely impact upon public health, safety and welfare.

An integrated waste management policy should be based on five points: waste prevention, recycling and recovery of waste, design optimization of final disposal of waste, control of waste shipment and proper sustainable management-ecological, curative actions. Quality assurance should take place in all stages of an integrated waste management and the use of proper lining methods, where it is necessary, should take place for particular project management within monitoring, maintenance and reclamation, bioremediation or other sustainable technical infrastructure works [28,43,45,67].

Separate collections will influence rates, yields and global amounts of landfill gas, such as the separate collections of organic wastes like garden wastes or of used papers and old used newspapers. The main objective of the above waste policy is to ensure high standards for the disposal of waste, stimulating waste prevention via recycling and recovery. The reduced waste will maintain revenues and operators will need to take into account waste identification, sorting, material separation, and recycling or composting facilities.

However, the waste biodegradation could be described using stoichiometric calculations for different waste fractions giving indicative results of landfill emissions. The general anaerobic transformation of solid waste can be described by means of the following chemical reaction and respective equation constraints for the examining chemical mass balances

$$C_aH_bO_cN_d + \left(\frac{4a-b-2c+3d}{4}\right) H_2O \rightarrow$$

$$\left(\frac{4a+b-2c-3d}{8}\right) CH_4 + \left(\frac{4a-b+2c+3d}{8}\right) CO_2 +$$

$$dNH_3$$

or

$$C_aH_bO_cN_d + (2t-c)H_2O \rightarrow (a-t)CH_4 + tCO_2 + dNH_3 \qquad (1)$$

Where

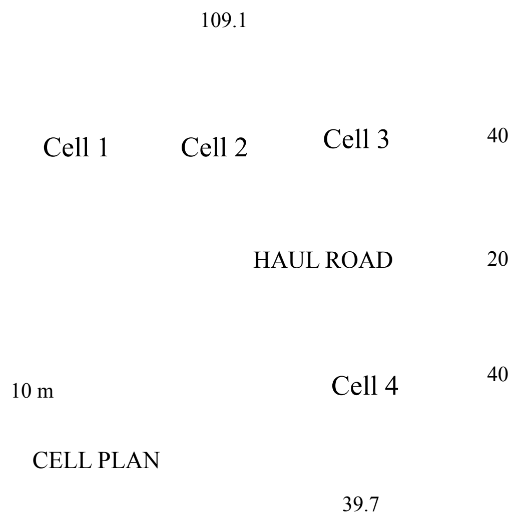
$$t = \frac{4a-b+2c+3d}{8} \quad \wedge \quad A = \{a, b, c, d\} \subset R^+$$

Therefore, from the above equation, there are the following constraints, which should be followed in the stoichiometric calculations

$$\frac{c}{2} < t < a \text{ or } t \in (\frac{c}{2}, a), \quad (c < 2a)$$

The term $C_aH_bO_cN_d$ is used to represent, on a molar basis, the composition of the organic material.

Dynamic numerical simulation models based on field data should be used for better accuracy of chemical landfill emissions' magnitudes and their respective spatial analysis in time. Moreover, dynamic lining methods should take place based on the numerical simulation results and monitoring data so as to be taken the right maintenance and probable reclamation works in time on given landfill topographical characteristics. The produced landfill emissions, gases and leachates, should be monitored properly for public health protection. Landfill emissions are a a result from the waste biodegradation of the organic material which has been disposed into the landfill mass [41,42,43,45,71]. In figure 2.1 is presented the case study of sanitary engineering drawing at Mid Auchencarroch experimental landfill four-cell plan.



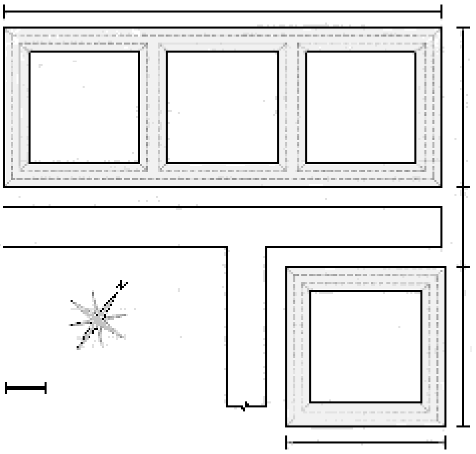


Fig. 2.1. Drawing of sanitary experimental Mid Auchencarroch experimental site cell plan.

Source: [44,79]

However, Table 1-1 presents the biodegradation stages which exist within landfill life cycle and its respective biogas and leachate stabilized chemical emissions [31,35,41,44,71,72].

Table 2.1. Landfill biodegradation stages

Degradation stages of $C_aH_bO_cN_d$ chemical organic substrates with big molecular weights, like fats, hydrocarbons and proteins.

Stage I :	**Hydrolyisis,** production of fatty acids with long molecular chains, polyalcohols, sugars and degradation of aminoacids. There is acid environment.
Stage II :	**Acidogenesis,** production of hydrogen, carbon dioxide and organic acids, like propionate and butyrate acids. There is acid environment ($3 \leq pH \leq 6$).
Stage III :	**Acetogenesis,** production hydrogen, carbon dioxide and the acetic acid, organic acid. There is acid environment within biomass ($pH<7$).
Stage IV :	**Methanogenesis,** biogas generation and production of several landfill gases is taken place in this stage, according to the waste input materials, which have been disposed into a landfill mass. There is neutral environment within landfill mass ($pH \simeq 7$). For an anaerobic bioreactor could be found the next biogas compositions: Methane (45-80 vol %), carbon dioxide (30-60 vol %), sulfureous (0.1-5 vol %), volatile gases (0.01-0.6 vol%), oxygen (0.1-1 vol%), carbon monoxide (0-0.2 vol%), hydrogen (0-0.2 vol%).
Stage V:	**Mature,** final fate of landfill mass behaviour, almost there is not more gas and leachate biodegradation in this stage ($6.5 \leq pH \leq 7.5$). There are several hydro-geotechnical properties, in this stage, which interact with the chemical elements which have not been degraded yet within landfill mass. Monitoring, maintenance, lining of

reclamation or bioremediation works, quality assurance and probable investigation of landfill emissions migration and bioremediation works should take place in all stages.

According to the experimental field data which were collected and measued from the leachates samples at MACH's cells, the COD and BOD magnitudes found that they were below 2000 (mg/l) for cell 1 in fifteen months, for cell 2 in twenty three months, for cell 3 in three months, for cell 4 in ten months, since the MACH site was capped [41,42,43,45]. The measured landfill gas yield was found between 7 and 9 m^3/hr for both MACH's cells in less than two-year period since the site was capped [41,44].

The latter measured field data and the measured methane and carbon dioxide emissions (vol%) in short time verify the quick MACH site stabilization in time, avoiding any long term environmental impacts to the environment and to the public health. Sampling data should take place in frequent time so as to set up proper risk assessment frameworks in case that there is biogas migration or leakage of leachates from landfill sites or associated sanitary engineering units i.e. biogas treatment units; composting units; waste water units. The collected data could be visualized in drawings as well as in project management proposals by the use of proper computer aided design, information technologies and GIS mapping technologies [18,44,46,69].

The field data and numerical modelling simulation results could be utilized properly computer technologies for applications in computer aided design and GIS geoinformatics applications. Moreover, the development of dynamic models is necessary not only to evaluate existing sites but also to propose efficient sustainable landfill designs [41,43,44,45,46,66].

Based on the biomass's peak temperature and production, can be calculated the landfill gas migration by advection velocity, with discussion of associated risks and environmental impacts. A numerical modeling fast solution scheme of heat transfer in porous media could be realized for the lateral temperature regime in one meter clay width next to landfill boundaries, assessing probable gas migration spatial flows [41,42,43,45]. The governing equation of this phenomenon in four dimensions, 3-D in space and 1-D in time, is described by the partial differential equation (2), which is presented below:

$$\frac{\partial U(x,y,z,t)}{\partial t} - \beta\frac{\partial^2 U(x,y,z,t)}{\partial x^2} - \beta\frac{\partial^2 U(x,y,z,t)}{\partial y^2} - \beta\frac{\partial^2 U(x,y,z,t)}{\partial z^2} = \alpha \tag{2}$$

where

$\beta = k/\rho C_\upsilon$

k	thermal conductivity (kcal/day m °C)
ρ	density (kg/m^3)
Cu	heat capacity (kcal/kg °C)
U	temperature in spatial (x,y,z) location in clay material (°C)
t	time (day)
x, y, z	spatial location in x, y, z axis (m)
α	heat generation source term from landfill mass material (kcal/m^3 day)

The numerical solution of the above governing equation gives higher temperature inclination in the middle of the examining clay barrier, taking into account the temperature boundaries conditions next to the landfill mass in one meter width of a homogenous clay barrier and as height the landfill depth [41,43,44,45].

Taking into account the particular chemical and physical properties of the surrounded landfill ecosystem, the calculation of the biogas migration advection velocity adjacent to landfill boundary can be calculated and magnitudes' ranges of it in relation to peak biogas production gas pressure and geotechnical porous media properties [41,43,44,45]. At each examining landfill site, based on its topographical, geometrical elements, an effective influence vertical area zone should be taken into account for the batch bioreactor cells' biogas flux migration bearing in mind particular spatial conditions and waste material properties (i.e. cracks, dynamic loads, effective heights and lengths along biogas migration pathways). Therefore, a high risk for gas explosions and damage to properties under unfavorable conditions exists at sites with high biogas production, low waste density and respective landfill gas pressure.

Monitoring boreholes should be located next to landfill boundaries to allow measurement of landfill emissions and proper remedial action. In this way, buildings, other anthropogenic properties and surrounding landscapes will be protected. The uses of dynamic models, like SIMGASRISK one, are necessary not only to model, analyze and to maintain the biomass biodegradation of efficient bioreactor designs but also to diagnose particular produced landfill emissions and properly monitor, control them.

However, another risk analysis stage is to determine the proper locations for the lining of an efficient monitoring control system for biogas emissions' adjacent to landfill boundaries. Several efficient lining methods for public health's monitoring systems and maintenance ISO certification methods of manufactures and related infrastructures can be realized bearing in mind particular topographies, structural properties, construction materials, nearby infrastructures, sustainable designs, structures and landfill boundary locations or associated sanitary engineering projects locations [61,67]. The problem is transferred to the right location of the migrated landfill gases' monitoring boreholes of so as to line properly confrontation works and to take the right measures with good timing next to landfill boundaries.

During the lining of landfill boundaries should be taken into account the surrounded existing areas of ecosystems, land uses and other anthropogenic activities which are taking place there. The latter anthropogenic properties should be protected by an efficient lined monitoring control system of landfill gas migration and probable biogas pumping system. This could be achieved as a result of an additional computational risk assessment spatial analysis, which is analyzed below.

The associated risk assessment's spatial analysis could provide the right solution to the examining problem analyzing the particular factors and parameters which affect on it. Hence the thresholds of migrated landfill gas could be calculated by the applied engineering mathematics and the solution of diffusion-advection biogas's flux in a porous medium problem, which is described by the following equation (3).

$$R\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - V\frac{\partial C}{\partial x} \qquad (3)$$

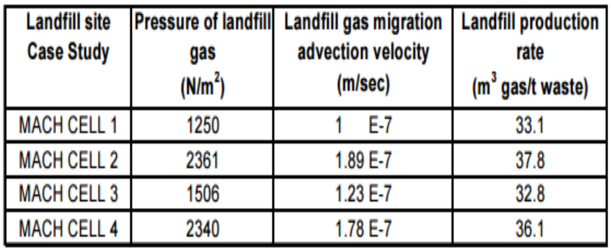
where,

C	gas concentration by volume
x	the distance along the migration pathway (m)
t	is time (s)
D	the diffusion coefficient (m^2/s)
V	velocity (m/s)
R	the retardation factor

Proper calculations should be made for estimation of the advection velocity of migrated landfill gas next to landfill site boundaries [43,45]. In Table 2.2, are presented the calculated numerical results of LFG emissions, applying all the above formulae to conditions in experimental MACH cells 1, 2, 3 and 4, for the crucial period where landfill gas peak production and peak temperature reached in the first 105 days of biomass biodegradation since MACH site was capped. Therefore, based on the above results in terms of LFG production and gas migration, respectively, a higher risk exists in cells 2 and 4 than in cells 1 and 3 for gas explosions and damage to properties under unfavourable conditions. Monitoring boreholes should be located next to landfill boundaries to allow measurement of landfill emissions [45].

Table 2.2. Numerical results of landfill gas

emissions. emissions and proper remedial action.

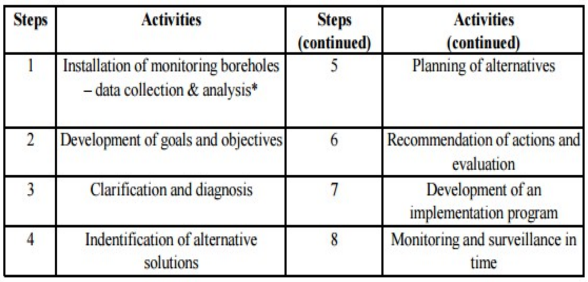


Landfill site Case Study	Pressure of landfill gas (N/m^2)	Landfill gas migration advection velocity (m/sec)	Landfill production rate (m^3 gas/t waste)
MACH CELL 1	1250	1 E-7	33.1
MACH CELL 2	2361	1.89 E-7	37.8
MACH CELL 3	1506	1.23 E-7	32.8
MACH CELL 4	2340	1.78 E-7	36.1

Source: [45]

In this way, buildings and surrounding landscapes will be protected. After the above analysis of quantified risk assessment elements, an additional risk assessment planning base is presented in Table 2.3. It should be followed during any examination of landfill study. The above presented risk assessment planning base should take place when LFG risks are quantified by numerical models such as the above presented one.

Table 2.3. Steps of risk assessment base for food safety and protection of agricultural resources.



Steps	Activities	Steps (continued)	Activities (continued)
1	Installation of monitoring boreholes – data collection & analysis*	5	Planning of alternatives
2	Development of goals and objectives	6	Recommendation of actions and evaluation
3	Clarification and diagnosis	7	Development of an implementation program
4	Indentification of alternative solutions	8	Monitoring and surveillance in time

Source: [45]

However, risk assessment is an analysis of the potential for adverse health effects. Risk assessment estimations of environmental impact controls are usually site specific, with no single preferred method available. Risk based approaches to landfill temperature control, allowing us to take the right emergency measures, are necessary for the environmental protection of building properties or architectural landscapes next to landfill boundaries. Below are presented the associated adverse impact issues of waste management units on users or owners of nearby building properties; outdoors, indoors spaces of anthropogenic activities that are located close to landfill boundaries or nearby architectural landscapes [7,21,22,23,43,45].

- Migration of Methane, Carbon Dioxide and VOC's - Public Health, Explosions, Toxicity to Plants, Landscape degradation, Loss of Building Properties;
- Illegal Roadside Dumping and Litter near Landfill - Aesthetics, Landscape degradation, Public Health, Economics;

- Truck Traffic near Landfill - Congestion, Air Pollution, Aesthetics,Public Health of Buildings' Residents;

- Odors - Dumping & Landfill Gas - Aesthetics, Public Health;

- Dust and Wind-Blown Litter - Aesthetics, Public Health;

- Landfill Fires - Gas Explosions - Aesthetics, Public Health.

Frequent field data are necessary for monitoring schemes and reclamation works for identified hazards and risks from landfill emissions to agricultural and environmental resources next to landfill boundaries. Future research should investigate hydrological and geotechnical properties of landfilled materials so as to increase accuracy and possible parameters that are semantic in associated risk analysis scenarios.

Hence, according to the above, solving the diffusion - advection differential equation it yields the investigated risk assessment distances. A monitoring control system of probable biogas migration should take place along and across the calculated threshold distances [43,45]. The proper lining of an efficient and economic monitoring control system under stable conditions and supported sanitary engineering drawings for health inspection, monitoring and operational control of landfill emissions.

Moreover, methanotrophy, the ability to utilize methane as a sole carbon and energy source, is recognized within two bacterial phyla, Proteobacteria and Verrucomicrobia Methanotrophic Proteobacteria are subdivided into type I and type II methanotrophs belonging to Gammaproteobacteria and Alphaproteobacteria, respectively. Methanotrophs use the enzyme methane monooxygenase (MMO) to catalyze the oxidation of methane to methanol. There are two types of MMO, a membrane-bound particulate MMO (pMMO) and a soluble MMO (sMMO) [38,58,75].

Vegetation also has positive effects on final top soil landfill covers avoiding methane migration for nearby agricultural land uses since it improves agglomeration, thermal isolation against high temperature variability along with mechanical stabilization. Soils such as silt and clay are rich in fine-grained particles that can seal the surface layer of the soil surface when wet. This process can lead to blocked pores that restrain soil air diffusivity, and diminish methane oxidation due to limited oxygen concentration [78]. A well-developed vegetation zone should stabilize the particles and counteract this kind of vertical erosion. Additionally, plant roots can enhance the aeration of soil by creating larger macropores, which improve the oxygen's diffusion into soil as well as the supply of methane to bacteria. As a result, the methane oxidation potential of vegetated soils is expected to increase. Field data results showed that vegetation is important on methane oxidation so as to reduce methane emissions for landfill top soils [1,2].

Water content is a very important factor affecting methane oxidation in landfill cover soils. Bender and Conrad [79] reported optimal water content in the range of 20–35%. Boeckx et al. [80] and Czepiel et al. [81,82] reported a significant drop in oxidation capacity at water contents lower than 5% and credited that to water stress. Abichou et al. [1] showed that microbial activity seems to increase with increasing water content and reaches an upper limit or when the soil reaches a water content higher than 18–20%. Abichou et al. [1] reported that little to no bacterial activity (very low oxidation rate) was occurring when the gravimetric water content was lower than 10%. These results are consistent with other literature data indicating a maximum oxidation rate when the water content is in the range of 10–20% (gravimetric) [3,80,82,83].

Moreover, phytobioremediation techniques could take place not only as vegetation's importance on methane oxidation but also for the pollution control of chemical leachate concentrations on top soils next to landfill sites due to leakage; flood events etc. Figure 2.2. presents plant environment and phytoremediation interactions.

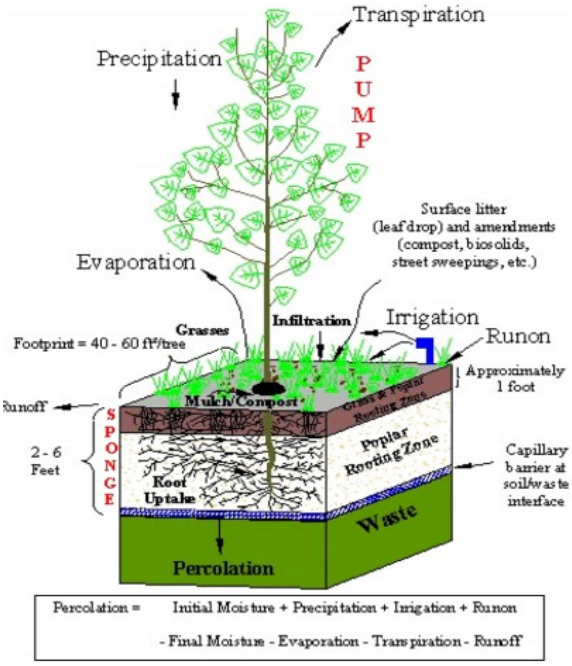


Fig. 2.2. Plant environment and phytoremediation interactions

Source: [48]

Exhaustive information on the state of the science and engineering of phytoremediation is available in McCutcheon and Schnoor [50]. These authors have approached the subject from the perspectives of biochemistry, toxicology, genetics, and pathway analysis. Their work covers the following aspects of phytoremediation: overview of science and applications; fundamentals of phytotransformation and control of contaminants; science and practice for aromatic, phenolic, and hydrocarbon contaminants; transformation and control of explosives; fate and control of chlorinated solvents and other halogenated compounds; design, modeling, field pilot testing; and latest advances.

Phytoremediation, collectively referring to all plant based technologies, uses green plants to remediate contaminated sites [48,70]. This technology draws its inspiration from the myriad of physical, chemical and biological interactions occurring between plants and the environmental media (figure 1). Phytoremediation is evolving into a cost-effective means of managing wastes, especially excess petroleum hydrocarbons, polycyclic aromatic hydrocarbons, explosives, organic matter, and nutrients. Applications are being tested for cleaning up contaminated soil, water, and air. Several features make phytoremediation an attractive alternative to many of the currently practiced in situ and ex situ technologies. These include: low maintenance costs and capital, non-invasiveness, easy start-up, high public acceptance and the pleasant landscape that emerges as a final product [48,70].

In the last several decades, phytoremediation strategies have been examined as a means to clean up a number of organic and inorganic pollutants, including heavy metals [3,4,17,30,70]. These soluble organic and inorganic contaminants, which move into plant roots or rhizosphere by the mass flow process of diffusion, appear to be most amenable to the remediation process. In several instances, plants and / or their attendant rhizosphere microbes have been shown to transform some chemical compounds to some degree [48,70,77]. However, the mechanisms by which plants stimulate the disappearance of hazardous organics from soil are not fully understood.

However, monitoring schemes are necessary in cases that vegetation on top soil does not exist or there are conditions that make favourable biogas migration. A sanitary drawing is presented in figure 2.3 for operational management of landfills and monitoring schemes of agricultural and environmental resources for agricultural food and public health protection from landfill emissions next to landfill boundaries.

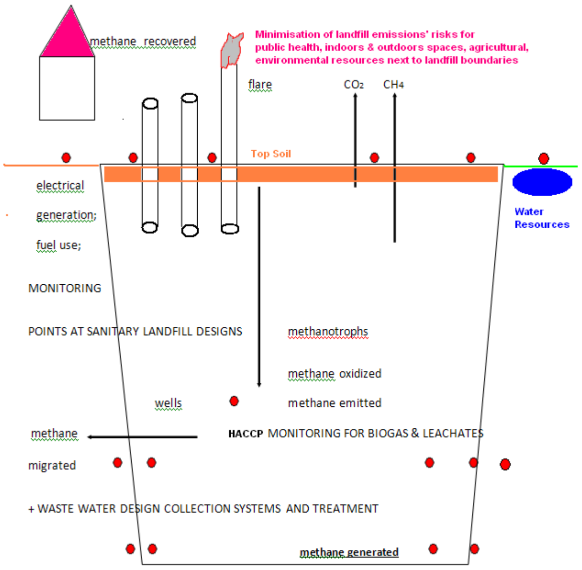


Fig. 2.3. Flow diagram and sanitary drawing for monitoring schemes of agricultural and environmental resources

Figure 2.4 presents a sanitary engineering drawing based on numerical results for given magnitudes of landfill emissions for the right monitoring area next to landfill boundaries. The latter area is the semi-circular one that presents risks of probable landfill gas migration to nearby anthropogenic activities next to landfill boundaries. The rectangular shape determines landfill boundaries.

Monitoring boreholes for landfill gas should be located next to landfill boundaries as well as pumping boreholes on landfill site for the protection of agricultural resources, land uses' facilities and public health from landfill emissions' associated hazards and risks i.e. explosions, fires, odors, air quality to nearby outdoors – indoors spaces from landfill boundaries, volatile organic carbons (V.O.C's) etc. In this way are protected the food safety; particular agricultural resources; land uses; other anthropogenic activities; buildings that exist; public health; water resources; environmental resources that could exist next to landfill boundaries.

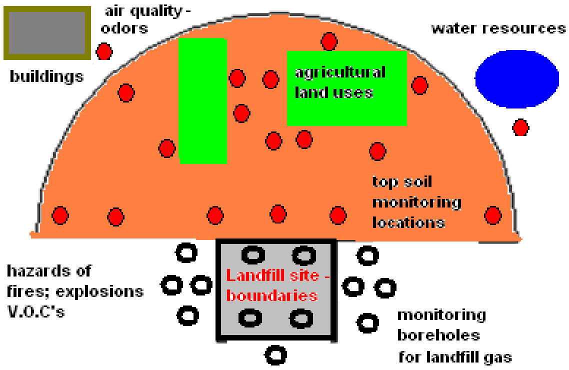


Fig. 2.4. Sanitary drawing for the right monitoring locations of soil, environmental resources from landfill gas migration for agricultural land uses next to landfill boundaries.

However, the experimental element of the MACH project, is a test bed for a shallow landfill bioreactor and its control as an enhanced degradation system. A target of this project is to show that shallow landfill of municipal solid waste is feasible in terms of establishing and maintaining a suitable environment for methanogenic degradation to occur at significant rates. It is possible to control and enhance landfill gas production and flush potential pollutants from the waste mass, by manipulating the whole process of landfill. Shallow landfill concept can be used as a sequential batch bioreactor which could be an economic solution for developing countries.

The treated landfill emissions can be used properly to support agricultural development works or other recreational activities for community health, public health protection i.e. greenhouse heating; electricity produced by landfill gas for pumping machines in irrigation – drainage systems; treated leachates for irrigation projects supporting phytoremediation projects for landfill leachates, planting activities etc.

Careful design and engineering of the cells is considered to be important, so that an effective design to be arrived at without excessive construction costs. Shallow landfill is particularly sensitive in this respect due to the higher plan area / volume ratio.

A comprehensive predictive model of landfill gas production in sanitary landfills must include simulation of temperature variations, because of the strong effect of temperature on the fermentation of any ecosystem. Such geo-information tool could be the use of SIMGASRISK tool (SIMulation of GAS RISK) focused on the modelling of landfill gas production and heat generation versus waste biodegradation based on the field data of MACH site [45].

Risk assessment tools of probable migrated landfill gas quantities next to landfill boundaries, like SIMGASRISK, should take into account several risk factors in the calculations. Soil porosity should be taken into account in the calculations [43,45]. Based on the numerical results should take place monitoring schemes of landfill emissions for public health protection from long term toxic chemical hazards to working staff and associated environmental receptors from the risk sources and pathways (figure 2, 3).

The development of a landfill risk assessment tool, like SIMGASRISK one, and efficient technology not only will control and manage better the environmental impacts due to the increase of the waste generation rate but also will promote environmental protection and sustainable development of our society. Integrated landfill gas simulation models are necessary for the building capacity of manufactures - right equipment selection in clean technologies; lining of machines for biogas pumping; efficient designs in sanitary engineering and construction materials in reclamation works of landfill emissions; risk assessment environmental resources – public health protection and project management of equipment, machines of landfill gas exploitation to electricity and greenhouse heating.

3. CONCLUSIONS

According to the MACH's landfill management results and the presented literature review is clear that anaerobic design under favourable landfill's chemical, physical and biological conditions assists the site's stabilization in short time period; pH environment to take neutral values in short time period as well as chemical toxic concentrations were decreased in short time. Hydrogeochemical characteristics should be taken into account for the transport of chemical pollutants in soil. Passive ventilation design on top soil of landfills could establish aerobic conditions accelerating the waste mass biodegradation, avoiding long term chemical concentrations to associated environmental resources.

Soil cover material should be more than one-meter in depth protecting heat biomass balances; landfill biodegradation. Proper drainage material design should be taken into account on top soil cover systems so as to avoid flood events on landfill areas in extreme weather conditions. In this way there is protection of public health and agricultural resources at nearby areas next to landfill site's boundaries from toxic and hazardous chemical concentrations. Also phytoremediation projects can be used for treatment of leachate concentrations that exist on top soil areas at areas next to landfill sites i.e. leakage of leachates, other reasons. All these should be taken into account for agricultural resources and public health protection.

Risk assessment software geo-information utilities for simulation of landfill emissions are necessary not only for the protection of agricultural land uses next to landfill boundaries; food protection; public health protection but also for monitoring schemes protecting associated equipment, machines for agricultural resources; landfill operational management and taking the right measures in emergency cases like fires or other natural disasters.

ACKNOWLEDGMENTS

The authors acknowledge the UK Energy Technology Support Unit (ETSU, UK), Department of Trade and Industry (DTI) and UK Environmental Agency (EA) for their support of the Mid Auchencarroch experiment project. The conclusions expressed herein represent the findings of the authors and are based on their expertise and experience in this area and their findings in their professional literature. It does not necessarily represent the views of EA or other stakeholders.

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