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Reduction of methane emission from landfill using biocover as a biomitigation system: A review

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Methane (CH_4) emission from landfills ranks as the third major source of anthropogenic emission. It has been observed that atmospheric CH_4 concentration is more than doubled in last 150 years.CH_4 has 23 times more global warming potential (GWP) than that of carbon dioxide (CO_2). Therefore, the growth and field application of cost-effective techniques are essential for decreasing the rate of CH_4 emissions from landfills to minimize the associated risk of global warming and human health. Microbial oxidation of CH_4 has been universally observed in a variety of biomitigation system. The present paper attempts to describe the key issues linked with CH_4 oxidation process in landfill biocover and the underlying kinetics of CH_4 oxidation. Influence of several controlling parameters, such as CH_4 and oxygen concentration, properties of the cover material, temperature, moisture, pH on CH_4 oxidation in landfill biocover system is also discussed.

Keywords: CH_4 emission, CH_4 reduction, Global warming, Microbial oxidation

Methane (CH_4) and carbon dioxide (CO_2) are produced when organic solid waste gets degraded. These gases originated deep in municipal solid waste (MSW) landfill, and it can readily travel to the surface and then migrate into the atmosphere. Even after the closure of the landfill site, the biochemical reaction might continue to produce landfill gas (LFG) emissions[1] and both these gases i.e. CO_2 and CH_4 are highly responsible for global warming[2]. CH_4 is identified as a third significant greenhouse gas (GHG) after water vapour and it has 23 times more global warming potential (GWP) than that of CO_2[3]. There are numerous scenarios under which modern LFG extraction systems are insufficient to capture whole CH_4 emissions, and loss of CH_4 from such landfill sites is also huge. Older MSW landfill sites are not capable of capturing CH_4 due to insufficient gas collection system. The cost required for LFG extraction is high and it is not possible to adopt such system at all MSW landfills[4]. According to the expected growth in World global landfill CH_4 emissions, it is necessary to adopt and promote cost-effective technologies immediately to mitigate anthropogenic CH_4 emissions from the atmosphere[2].

Conventional LFG extraction systems are reported to collect only 50 to 90 % of total CH_4 emissions[5,6]. Various technological inputs have played vital role in reducing the associated environmental impacts from landfills. However, it still requires attention with respect to minimizing CH_4 emissions[2].

Microbial CH_4 oxidation is attributed to a group of microorganisms called methanotrophs, which have been found in a variety of ecosystems and climatic conditions. Several researchers concluded that CH_4 oxidation process in landfill biocover is an efficient and effective technique for mitigation of CH_4 emissions from MSW landfills[7-10]. The principle of biocover technology is the use of methane-oxidizing bacteria to oxidize CH_4 into water, CO_2 and biomass. Methanotrophs possess CH_4 mono-oxygenase enzyme that allows them to consume CH_4 as a source of energy as well as carbon.

Biocovers are suitable either for larger engineered MSW landfill sites or for smaller MSW landfills where CH_4 emissions are comparatively low[11]. The present review focused on the use of biocover on landfill for CH_4 mitigation and associated influencing parameters for CH_4 oxidations, such as pH, temperature, CH_4 and oxygen concentration, soil texture, properties of biocover material, moisture, etc.

Biocovers

First attempt to quantify CH_4 oxidation in landfill cover was carried out by Whalen *et al*.[12]. Since then,

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several landfill sites and biocovers have been tested for their CH_4 oxidation potential in various laboratory and field trials[12-14].

Kinetics of CH_4 oxidation in Biocover

Biocovers are landfill covers designed to optimize CH_4 oxidation. It consists of two layers; one, the gas dispersion layer; and the other CH_4 oxidation layer where actual oxidation takes place[8]. Gas dispersion layer is also called as the permeable layer made up of gravel, broken glasses or sand. A naturally occurring microbial CH_4 oxidation in landfill upper covers stops a fraction of CH_4 produced in deposited waste being released to the outer atmosphere[15]. For reduction of CH_4 emissions using microbial CH_4 oxidation process in landfill biocover, both CH_4 and oxygen (O_2) are required to be present. Biocover layer on landfill functions as a CH_4 oxidation enhancer to convert CH_4 into CO_2, water and biomass. Fig. 1 shows the kinetics of CH_4 oxidation in the biocover layer.

The microbial CH_4 oxidation process is carried out by a group of the methanotrophic bacteria present in the soil biocover[16]. Numbers of evidence proved that the presence of methanotrophic bacteria in landfill biocover is responsible for CH_4 oxidation process[7,10,17-19]. Methanotrophs are aerobes having special ability to oxidize CH_4 under favorable conditions and to convert into CO_2, water (H_2O) and microbial biomass.

$$CH_4 + 2O_2 \longrightarrow CO_2 + H_2O + \text{microbial biomass}$$

At different CH_4 concentration, methanotrohphic bacteria have broad categories with respect to their respond to CH_4 concentrations[6,20].

Review of experimental work

In last several years, the establishment of a number of biocovers (Biomitigation systems) for reduction of CH_4 emissions has been reported at various MSW landfills worldwide. Biomitigation systems imply both pilot and full-scale biocovers for landfill CH_4 reduction. Full-scale biocover systems are handling whole landfill CH_4 emissions and pilot-scale biocovers are treating only part of CH_4 emissions from MSW landfills.

Laboratory studies

Rachor *et al.*[21] carried out a laboratory experiment in a column on four mineral biocover soil samples and in single sediment soil sample which was having higher organic matter and having very fine particles. All the soil samples were subjected to compaction like compaction of the actual field in the waste dumpsite. Mineral soil columns have shown higher CH_4 oxidation rate as compared to sediment sample. It is concluded that surface area, finer particles and organic matter are influencing factors for effective CH_4 oxidation process[21].

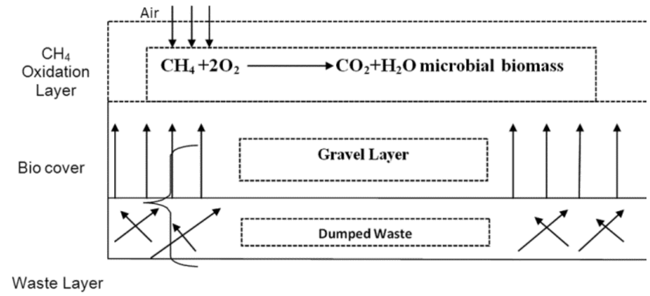

Fig 1 — Kinetics of Microbial CH4 Oxidation on Landfill.

He *et al.*[22] collected the cover soil from MSW landfill site in China and studied the interaction effects of several influencing parameter impacting microbial CH_4 oxidation process, such as pH, temperature, moisture content and O_2 concentration. This study concluded that the microbial CH_4 oxidation process is highly sensitive to the moisture content in the substrate and it gets affected by O_2 concentrations. Further, it also has considerable influence on the distribution of Type II methanotrophs[22].

Gebert *et al.*[23] conducted a study on the effect of compaction on the portion of pores available for gaseous transportation through the soil biocover. In a laboratory experiment, three soil columns were filled with a 17 cm gas distribution layer which is made up of gravel having soil thickness of about 80 cm, which was compacted at 3 levels (75, 85 and 95 %) of its proctor density value. All the soils samples were adjusted for moisture content close to the field capacity. The study concluded that there is a strong correlation between the diffusion of oxygen through the soil biocover and the existing share of pores. It revealed that the soil biocover material at 75% proctor density can fully oxidize CH_4 influx of about 3.5 g $CH_4/m^2/day$[23,24].

Eun-Hee *et al.*[25] have studied the depth profiles of CH_4 oxidation potentials and methanotrophic community for soil mixture at a lab-scale biocover. Three soil samples were collected for characterization from top, middle and bottom layer. The size of these layers varies from 0-10, 10-40 and 40-50 cm, respectively. Results obtained shows that CH_4 oxidation rate was observed more at the top most layer of biocover due to more O_2 consumption. The rate of CH_4 oxidation for middle and bottom layer was 85 and 71%, respectively as compared to the top layer. It was also observed that methanotrophs are equally present in the middle and bottom layer than those present in the top layer. Microbial analysis has shown that the methanotrophs of type I & II are equally present in the top layer and type II methanotrophs are more abundant in a middle and bottom layer of biocover. This difference in the community structure of methanotrophs mainly depends on CH_4 and O_2 concentrations. It has been suggested the deeper layer of biocover serves as a sustainable reservoir for CH_4 reduction[25].

Zhang *et al*.[26] have studied the effect of NH_4^+ on microbial CH_4 oxidation in landfill cover soil. Effect of ammonium addition on methanotrophic activity in soil biocover has been studied using series of NH_4+ concentrations (100, 300, 600 and 1200 mg kg^{-1}). The results has shown that addition of 100-300 mg kg^{-1} of NH_4^+ in soil biocover stimulates the rate of CH_4 oxidation. Addition of ammonium up to 600 mg kg^{-1} inhibits the rate of CH_4 oxidation. During the last stage, it has been observed that rate of CH_4 oxidation decreases due to limitation caused by the presence of nitrogen[26].

Changgen *et al*.[27] have carried out a study for the performance of green waste biocovers for enhancing CH_4 oxidation. In this study, green waste aged 2 and 24 months, named "fresh" and "aged" green waste, respectively, were placed in biocover test cells and evaluated for their capability to oxidize CH_4 under high LFG loading over a 15-month testing period. It was observed that rate of CH_4 oxidation is relatively higher during the initial period which was 140 and 200 g/m^2/day for aged and fresh green waste, respectively. The rate of CH_4 oxidation was decreased during the winter season with significant generation of CH_4 in 60-80 cm thick biocovers. It is suggested that green waste may not be a workable biocover material for several climates and landfills due to difficulties in preventing undesired CH_4 generation[27].

It has been also observed that the biocovers for landfill CH_4 reduction can also act as a sink for atmospheric CH_4 even when it has not combined with LFG extraction system. Several studies on soil biocover reported negative gas fluxes in biocovers but not in the conventional biocovers[10,28]. When LFG extraction system is combined with the biocover, it generates a negative pressure that draws air into landfill through the biocover, where atmospheric CH_4 could be oxidized. Even when LFG extraction system is not installed, some portion of air can be drawn into a highly active landfill biocover. This phenomenon occurs when more moles of CH_4 and O_2 are consumed in CH_4 oxidation process than their production.

Field-scale studies

Chanton *et al*.[29,30] studied flat and sloped landfill sites. Effect of CH_4 concentration on the rate of CH_4 oxidation was investigated for both, the flat and sloped landfills. Inventory for CH_4 emissions from the flat and sloped landfill sites was also carried out. Another study was carried out in the summer season when the rate of CH_4 oxidation is very high. It has been concluded that CH_4 concentration should be controlled for higher CH_4 oxidation in landfill biocovers[29,30].

Chiemchaisri *et al*.[31] carried out a study for the utilization of stabilized wastes for reducing CH_4 emission from the municipal solid waste disposal site. In this study, a stabilized solid waste was used as a biocover layer for CH_4 oxidation on MSW landfill. Stabilized solid waste containing plastic wastes has loosened its texture and facilitated the supply of oxygen from the soil surface whereas the fine organic fraction of stabilized solid waste had excellent water holding capacity and nutrients to increase the rate of CH_4 oxidation. Results obtained have shown that the microbial CH_4 oxidation potential of the stabilized solid waste layer was up to 34.1 g/m^3d. Test carried out for microbial activity discovered that the rate of methanotrophic activities of the plastic and organic fraction of wastes was observed at a similar level. The mixture of plastic and fine degraded organic waste matrix proved to be sufficient for oxygen transfer and it has support for the growth of methanotrophs throughout 0.8 m depth of stabilized solid waste cover layer[31].

Scheutz *et al*.[32] conducted a study for mitigation of CH_4 emission from an old unlined landfill in Klintholm, Denmark using a passive biocover system. In this study, gas collection trenches are constructed along the slope of the landfill site. Local compost material was used as a biocover material for CH_4 oxidation. Use of trenches for gas collection along with biocover system was proved successful with an average CH_4 reduction efficiency of approximately 80%. In this case, use of compost material plays significant role for CH_4 oxidation. It was observed that biocover system has great efficiency for CH_4 reduction even in the period of cold winter due to the self-heating capacity of compost material. Cost-benefit analysis of this biocover system along with gas collection trenches proved to be competitive as compared to other GHG mitigation system[32].

Bomin *et al*.[33] carried out a study for mitigation using a pilot-scale engineered biocover at a Landfill in South Korea. A study was carried out in a pilot-scale biocover of size (10×5×1 m in length/ width/depth) which was constructed at a landfill, Gwangyang in South Korea. Results obtained have shown that rate of CH_4 reduction through microbial oxidation in soil biocover were ranging from 21-72% during the period of February to May. In this study, packaging material used for biocover layer were analyzed for CH_4 degradation rate at a different depth of intervals 0-15, 15-30, and 30-50 cm, respectively. It was observed that rate of CH_4 oxidation was optimum in the 15-30 cm depth[33].

Scheutz*et al*.[34] conducted a study for mitigation of CH_4 emissions in a pilot-scale biocover system at the AV Miljo Landfill, Denmark. The semi-passive biocover system was constructed at the AV Miljo Landfill of Denmark. The semi-passive biocover system was used for CH_4 oxidation from landfills. An innovative gas distribution system was used to overcome the often observed uneven gas distribution to the active CH_4 oxidation layer resulting in overloaded areas causing CH_4 emission hot spot areas on the biocover surface. It was observed that efficiency of CH_4 varied between 81 and 100% and the pilot plant biocover system was very efficient in oxidizing the landfill CH_4[34]. Some of the laboratory and field-scale studies established in the area of biocover for CH_4 reduction are presented in Table 1[35-43].

Factors affecting CH_4 oxidation process

Influence of several controlling parameters in the process of microbial CH_4 oxidation, such as pH, moisture content, temperature, the texture of the soil, organic content, CH_4 and oxygen concentration, properties of the cover material are discussed in this section.

Soil texture

Soil texture affects the rate of CH_4 oxidation in soil biocover. Studies carried out by Gebert *et al*.[23,24] suggested that use of coarse-textured soils has better efficiency of CH_4 oxidation in soil biocover. Soil texture of biocover influences the rate of CH_4 oxidation. Soil texture determines the porosity of biocover layer that influences CH_4 diffusion from gravel layer to CH_4 oxidation layer. Analysis of CH_4 oxidation rate at different soil textures has ban carried out by Pawłowska & Stępniewski[44] concluded that the size of coarse sand had an influence on CH_4 oxidation rate. It was observed that coarse sand of 0.5-1 mm size has greater potential to oxidize CH_4 as compared to other soil profiles.

Organic content

CH_4 oxidation rate increases with the increase in the organic content of biocover[45]. Christophersen *et al*.[46] has concluded that the biocovers with higher organic matter more effectively oxidize CH_4 from MSW landfills. Materials with higher organic contents, such as manure or compost, are widely used at MSW landfills as a biocover layer to enhance the rate of CH_4 oxidation[18,45-47]. Soil with higher organic content, high nutrient levels and porosity has been proven to have a greater CH_4 oxidation potential[5]. A study carried out by De Vischer *et al*.[14] observed that addition of compost materials on landfill results into an increased rate of CH_4 oxidation.

Moisture content

The rate of CH_4 oxidation gets altered by moisture content in soil biocover. It was observed that excessive moisture soil cover negatively affects the process of microbial CH_4 oxidation. Also on the other hand, it is reported that the inadequate level of moisture content reduces CH_4 oxidation capacity[4]. A higher level of moisture in biocover reduces O_2 penetration level, which is the main influencing factor in the process ofCH_4 oxidation and also low moisture content in biocover reduces the biological activity and results in a reduction of CH_4 oxidation capacity[48].

Temperature

The temperature has a great effect on the process of microbial CH_4 oxidation[4]. Microbial CH_4 oxidation in biocover is a completely biological process and the temperature is a most important factor which influences CH_4 oxidation process[10]. Mor *et al*.[49] have studied the relationship between compost material and

Table 1—Summary of laboratory and field-scale studies of biocover for CH_4 reduction

Location of study	Type of study	Medium for experiment	Cover material	Remarks
Nanjing, China	Lab-scale	Batch Experiment	Soil & Mineralized refuse	Mineralized refuse, excavated from MSW landfill was incubated in livestock waste water to accumulate CH_4 oxidizing bacteria into it and obtained material was applied on MSW landfill as a biocover[35].
Lafleche Landfill Site, Canada	Lab-scale	Column Experiment	Mature & Stabilized compost	Compost material used in this study can be a potential biocover application[36]. Influencing factors: Temperature, Moisture content
The University of Malaya, Kuala Lumpur, Malaysia	Lab-scale	Batch Experiment	Organic waste (sewage sludge, fine sawdust, spent yeast, black soil, empty fruit brunch, spent tea leaves) & Compost. (75% Grass clippings + 25% Cow manure)	A mixture of organic waste & compost as a biocover material will provide major potential for landfill CH_4 reduction[37].
Taman Medan Dumpsite, Malaysia	Lab-scale	PVC soil columns	Soil cover	Soil cover is essential for CH_4 reduction from Landfills[38]. Influencing factor: Moisture Content
Fitholt Landfill, Iceland	Field-scale	Stainless steel sampling probes	Crushed wood & Gravel sand	CH_4 Oxidation efficiency ranges 0-99% and reaches its optimum values at the cover depth of 30 and 60 cm[39].
Jeram Sanitary landfill, Malaysia	Lab-scale	Column reactor experiment	Mixture of soil & Ground coconut husk	At the lab-scale, 87.33% average CH_4 reduction was observed[40].
MSW Landfill at Bennington, USA	Field-scale	Evapo-transpiration Landfill cover	Soil cover with vegetation	CH_4 oxidation was observed highest during the summer season[41].
Haryana, India	Lab-scale	Packet Burman Design (PBD) & Box-Behnken Design (BBD)	Rice husk & Soil	This experiment shows that CH_4 oxidation can be improved by rice husk amended soil[42].
Northeast llinois Landfill, USA	Lab-scale in conjugation with Field Scale study	Soil columns	Bio-char and wood pellets	In column test mixed soil-biochar layer achieved better oxidation rate. A highly active methantrophs responsible for CH_4 oxidation was found abundant in the bio-char layer during the test[43]. Influencing factors: Moisture, Soil texture

temperature for CH_4 oxidation and it was concluded that the effect of temperature on microbial CH_4 oxidation is a time-dependent and optimum range of temperature varies in between 15 and 30°C. A study carried out by De Visscher *et al*.[14] has confirmed these results and reported that 35°C is an optimum temperature for microbial CH_4 oxidation process. It is also reported that there is interdependency between temperature and moisture content on CH_4 oxidation rate[6]. Castaldi and Fierro[50] concluded that rate of CH_4oxidation was maximum at lower moisture content when the temperature was very high.

pH

It has been observed that the microbial CH_4 oxidation can be seen in a broad range of pH. The optimal range of pH for methanotrophic bacterial growth is found between pH 6 and 8[51]. It is stated that the variation in the value of pH affects CH_4 oxidation process in biocover of the landfill. Saari *et al*.[52] have suggested optimum pH range from 4 to 7.5 for microbial CH_4 oxidation. Hanson and Hanson[53] has concluded that soil pH below 5 negatively affects the rate of CH_4 oxidation.

Nutrients

A study carried out by Albanna *et al*.[17] explained that moisture content and the addition of nutrients had a combined effect on CH_4 oxidation capacity and reported that external addition of nutrients in bio-cover doubles CH_4 oxidation capacity. On the other hand, it is also reported that the adding external nutrients with low moisture content (approximately 15%) to biocover have negative effects on CH_4 oxidation capacity.

Lee *et al*.[54] found that rate of CH_4 oxidation of sandy biocover improved by 60 % with the addition of 100 mg-N NH_4 per kg of soil. Vegetation on biocover might affect the growth and activities of methanatophic bacteria in different ways. Bohn and Jager[55] observed that the rate of CH_4 oxidation could be increased by 50% through vegetation growth on landfill biocover. A vegetation root assists the process of transporting $O_2$from the atmosphere into deeper soil layers. Also, supportive nutrient materials for the growth of methanotrophic bacteria are released to root zone which increases the microbial CH_4 oxidation process[55]. Vegetation on biocover might compete with the methanotrophs for water and nutrients, which might result in an overall decrease in the rate and capacity of CH_4 oxidation[2]. In engineered biological treatment system at landfill sites, Phosphorous and Nitrogen are added in the form of NH_4+ and orthophosphate. Addition of NH_4^+ on landfill biocover reduces CH_4 oxidation capacity due to the inhibition of NH_4^+ on the growth of methanotrophic bacteria[20].

Oxygen concentration

Presence of O_2 is a major influencing factor behind CH_4 oxidation process in landfill biocovers. All types of methanotrophic bacteria i.e. methane-oxidizing bacteria are aerobic in nature and always prefer O_2 concentrations lower than that of atmospheric level for oxidation of CH_4[4]. The O_2 concentration in biocover varies along with the depth of biocover layer and it gets influenced by different parameters, such as metrological conditions, texture of the soil, biocover thickness, moisture content and CH_4 oxidation rate. Several studies reported that CH_4 oxidation could be observed under an anaerobic condition at the bottom layer of biocover[6]. Humer and Lechner[18] also explained about the porosity of bio-cover material which controls the depth of O_2 penetration in soil layer.

CH_4concentration

Several researchers through various laboratory experiments reported that the rate of CH_4 oxidation increases with the increase in CH_4 concentration. A study carried out by Pawlowska and Stepniewski[44] observed an influence of CH_4 concentration on CH_4 oxidation potential with the Bio-filter assay. It is also observed that increase in CH_4 concentration results in the increased capacity of CH_4 oxidation by a factor of 1.1 to 1.5.

Design of gas dispersion layer for biocover

The gas dispersion layer of biocover should have properties favorable for CH_4 oxidation and for the interaction between CH_4, oxygen and microbes. The significant influencing factors required to be considered for the gas dispersion layers include porosity, water-holding capacity, and suitable nutrient concentration[10,18,56]. Gas dispersion layer of biocover should be porous in nature and it should have a fine surface[10,18]. The content of organic matter present in the medium should be biologically stable in nature so that process of oxygen consumption due to heterotrophic microorganisms does not distract oxygen away from methanotrophs[16,19]. Mature compost materials have special characteristics for CH_4 oxidation. Organic waste products like compost are also used in gravel layer because of their ecological sustainability and special ability for CH_4 oxidation[57]. Table 2[2,10,11,15,16] presents design parameters and characteristics of the support medium required for the biocover design on landfills.

CH_4 oxidation in landfills includes biocovers, biowindows, biofilters, and biotarps. Biomitigation applications are depending upon controlling the significant environmental parameters for the activity

Table 2—Design parameters for gas dispersion layer of biocover[11]

Type of layer	Importance	Site studies
Material of support medium	It enables suitable conditions for the growth of methanotrophs, and also for gas flow and O_2 diffusion. Influencing factors are porosity, size, nutrients level, moisture content etc[10,16].	Yard solid waste compost[10] Sludge compost[16]
Compaction of oxidation layer	Affects the air-filled pore volume and gas dispersion[15].	Compaction is not suggested for compost layer[15]
Thickness of oxidation layer	Oxidation layer thickness affects CH_4 oxidation capacity. The rate of CH_4 oxidation gets increases with increase inthickness[16].	Recommended: 120 cm[16]
Gas distribution layer or system	To maintain CH_4 concentration in biocover layer[2,10].	Landfills with no impervious layer: Gas dispersion[2,10]

Table 3—CH_4 reduction efficiency obtained by use of biocover layer

Location & Type of the study	CH_4 Reduction Efficiency
Unlined Landfill, Klintholm, Denmark[32]. Field-scale	80%
Fitholt Landfill, Iceland[39]. Field-scale	0-99%
University of Technology MARA, Malaysia[40]. Lab-scale	87.33%
Gwangyang Landfill, Korea[33]. Field-scale	21-72%
Gwangyang Landfill, Korea[58]. Field-scale	3.6-100%
AV MiljA, Landfill, Denmark[34]. Field-scale	81 and 100%
EwhaWomans University, Korea[59]. Lab-scale	66.6±12.8%
KasetsartUniversity, Bangkok, Thailand[60]. Lab-scale	86%

of methanotrophs for CH_4 oxidation. Biocovers established at different locations and their CH_4 reduction efficiency are presented in Table 3[32-34,39,58-60].

Biocovers provide huge surface area and higher volume of gas dispersion layer, which increases the rate of CH_4 oxidation[61]. Microbial CH_4 oxidation in landfill biocovers could be improved by selection of gravel layer (gas dispersion layer) having favourable conditions for microbial CH_4 oxidation. Moreover, along with CH_4 few other LFG emissions were reported in Indian MSW landfill context. Mostly in India, waste without any segregation is deposited into open dumping sites. Through these sites, there is uncontrolled emission of CH_4 and landfill gas. The LFG has tremendous potential in terms of converting and using them as source of energy. The emission of LFG mainly depends on types of wastes, its biodegradability, its CH_4 potential and segregation. In order to quantify the LFG emission, there are a range of US EPA recommended models are available. One of them is LandGem[62]. A specific model designed for measuring rate of CH_4 generation form MSW landfill by Kumar *et al*.[63] specifically for Indian climatic conditions and the landfill's waste characteristics described CH_4, carbon dioxide (CO_2), oxygen (O_2) and temperature are considered as the prime factors.

Summary and Recommendations

Varieties of organic materials are explored for their use as a biocover layer on MSW landfills. Many laboratory and field-scale experiments have been carried out to establish the bio-cover technology but still some field studies are required to stimulate the concept of microbial CH_4 oxidation on MSW landfills. Steps are required to be taken for efficient biocover layers that can reduce CH_4 emissions from MSW landfills and encourage the re-use and recycling of waste materials. Microbial CH_4 oxidation can be a promising way to mitigate CH_4 emission from MSW landfills. Biocover might be an economically feasible option for controlling CH_4 emissions from landfill. The microbial CH_4 oxidation can be enhanced by appropriate control measures and operations. The rate of CH_4 oxidation has been found to be affected by various environmental parameters, such as pH, the texture of the soil, moisture content, temperature organic content, CH_4 concentration, oxygen concentration, and properties of the cover material. Special attention should be given to these environmental parameters for validation of biocover technology in a different geographical region, and its application for effective CH_4 emission reduction from the landfill. This extensive survey based on scenarios and review should be taken up for experimental and field studies.

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