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Phyto cover for Sanitary Landfill Sites: A brief review

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ABSTRACT
Landfill gases (LFG) are produced due to biodegradation of organic fraction of municipal solid waste (MSW) when water comes in contact with buried wastes. The conventional clay cover is still practiced to mitigate the percolation of water in landfills in India. Gas extraction systems in landfill for gas collection are used but are much expensive. Thus, "Phytocapping" technique can be one of the alternatives to mitigate landfill gases and to minimize percolation of water into the landfill. Indian plants with locally available soil and municipal solid waste can be tested for the purpose of methane mitigation, heavy metals remediation from leachate. Methane oxidation due to vegetation can be observed compared to non-vegetated landfill. Root zone methane concentrations can be monitored for the plant species.
Keywords: *Phytocap, methane, MSW, landfill gases.*

I. INTRODUCTION

Due to rapid Industrialization, urbanization, increase in population, and economic growth, the generation rate of municipal solid waste is increasing significantly. Over 377 million urban people are living in 7,935 towns/cities. India is a huge country divided into 29 States and 7 Union Territories (UTs). There are three mega metropolis-Greater Mumbai, Delhi, and Kolkata-having more than 10 million population, 53 cities have more than 1 million population, and 415 cities having population 100,000 or more (Census, 2011) [26]. Municipal solid waste (MSW), commonly known as trash or garbage, refuse or rubbish, is a waste consisting of everyday items that are discarded by the public. In India, it is estimated that the rate of increase of solid waste generation is 1 to 1.5 % annually [24]. As per information by Pollution Control Boards 1,27,486 TPD (Tons per day) municipal solid waste was generated in the Country during 2011-12. Due to the enormous increase in solid waste generation, cumulative requirement of land for solid waste disposal is about 1400 km^2 by 2047 in India [24].

The generated waste consists of biodegradable, non-biodegradable and inert waste. They attribute to air pollution in the atmosphere in the form of inorganic Figure 1: Percentage composition of municipal solid waste (Source: CPHEEO Manual on MSW, 2005) particles and foul odour. In India, MSW is disposed off in landfill without processing the waste. Therefore, MSW management (MSWM) is one of the major environmental problems of Indian cities. MSWM consists of generation, storage, collection, transfer and transport, processing and disposal of solid wastes. However, in most of the Indian cities, MSWM system comprised of only four activities, *i.e.*, waste generation, collection, transportation, and disposal. Figure 1 shows the composition of municipal solid waste, which comprises of more of food and garden waste and refuse (paper waste), that are highly organic in nature. Among all available options for MSWM, landfill disposal is the most commonly employed waste management option in India. Conventionally, the landfill is designed to contain or store the wastes so that the exposure to human and the environment could be minimized. There are many shortcomings in existing practices. This is due to inadequate manpower, financial resources and machinery required for efficient activities of MSWM. In most cities segregation is not carried out. Waste is directly dumped even without compaction. The amount of waste quantity is not measured and is usually assessed by number of trips by transportation vehicles. India produces around 70 million tons of MSW annually, of which only 5% of waste is processed scientifically (Planning Commission of India, 2011).

The survey conducted by FICCI reveals MSW disposal at dumpsite varies from 16 to 100%, like in Kozhikode (Kerala) it is 16%. Ludhiana (Punjab) and Greater Mumbai (Maharashtra) have 100% waste disposal and in Delhi and Surat (Gujarat) around 95% of MSW reached to landfill sites, and in the rest of the cities/town less than 90% waste disposed to dumpsites (CPCB, 2013; FICCI, 2009) .

A. Landfill Leachate

The liquid containing innumerable organic and inorganic compounds is called "Leachate". This leachate is accumulated at the bottom of the landfill and percolates through soil and reaches in the groundwater. Leachate from a landfill varies widely in composition depending on the lifetime of the landfill and the type of waste that is dumped on that corresponding landfill. It can usually contain both dissolved and suspended material. The generation of leachate is caused basically by precipitation of water percolating through waste dumped in a landfill. Due to the contact with solid waste, the percolating water becomes polluted and then it flows out of the waste matter that is termed leachate. The main issue with leachate is that it contaminates the nearby groundwater by percolating through ground and surface water by runoff.

B. Landfill Gases

The landfill gases such as methane, carbon dioxides, nitrous oxides, sulphur oxides are formed due to anaerobic decomposition of municipal waste on sanitary landfill sites. The formation of this gases leads to fire in the dumped waste and thereby causing odour problems too. Gas extraction systems are used for extraction of methane gas, but are expensive. India ranks fifth in aggregate greenhouse gas (GHG) emissions in the world (MoEF, 2010) [10].

C. Problems With Landfilling

Landfill is a vacated land area onto or into which waste is disposed. Landfilling of the segregated MSW is emerged as the most suitable mode of disposal of MSW. Landfill gas (LFG), generated by anaerobic decomposition of organic fractions in buried waste consists 55-60 % methane (CH_4) and 40-45 % carbon-dioxide (CO_2).

CH_4 is one of the most important GHGs. As a result of human activities, CH_4 emission concentrations in the atmosphere have increased from 715 ppb during the pre-industrial age to 1,732 ppb in the early 1990s and 1,774 ppb in 2005 (IPCC, 2007). Although the CH_4 concentration in the atmosphere is much lower than that of CO_2, its global warming potential is 21 times greater than CO_2 (IPCC, 2007). Adverse Effects of Landfill are as follows.

- Ground water contamination by the leachate generated by the waste dump;
- Surface water contamination by the run-off from the waste disposed;
- Bad odour, flies, rodent and wind-blown litter in and around the waste dump;
- Fires within the waste dump;
- Erosion and stability problems relating to slopes of the waste dump;
- Acidity to surrounding soil; and
- Release of GHGs, such as Methane (CH_4), Nitrous oxide (N_2O), Carbon dioxide (CO_2).

D. Health Effects Due To Solid Waste

Continuous increase in solid waste generation due to increase in population, change in lifestyle, poor public attitude and mismanagement, composition of generated waste is changed continuously. Thus People are directly exposed to health danger. In developing countries, the bad attitude of waste generators has made the situation annoying. The waste is commonly thrown on the roads, which is further scattered by rag pickers in search of recyclables and animals looking for food. Hence waste generated clogs the drains, creating stagnant water condition which is favorable for insects and mosquitoes breeding responsible for malaria, lymphatic filariasis and other diseases [12]. Thus causing risk to human health. The landfills generally creates health problem particularly cancer, reproductive outcomes and mortality is inadequate. The landfill workers are more susceptible to tissue damage and cardiovascular diseases due to activation of leukocyte and platelets as well as airway inflammation [12].

II. LITERATURE REVIEW

A. Scenario of municipal waste

Solid waste generation is the derivative of the urbanization, rapid industrialization and population growth. It is usually considered as an urban issue. On one hand more generation of solid waste indicate the economic growth but on the other it increases environmental stresses. India ranks fifth in aggregate GHG emissions. Solid waste contributes 3% of overall greenhouse gases emission globally, which are causes of global warming and climate change [42]. Massive amount of solid waste generation and their incorrect management worsen the air quality in the cities which in the long run affect the human health significantly. The average collection efficiency of MSW ranges from 22-60% [10]. The problem of municipal solid waste management is a much more acute environmental problems in mega towns like Delhi where land available for landfill sites is inadequate.. Agricultural land of Delhi has been grabbed by way of the unauthorized private colonizers and builders by means of converting the land use overnight. Delhi is the adobe of 14 million people out of which approximately half of the population (52%) population lives in slums and 1400 unauthorized colonies [42]. Municipal solid waste management activities in Cuddalore Municipality at the capital city of Chennai, Tamil Nadu were found to be poor as no processing of waste was done and directly dumped on the landfills. The two main landfills were Kammiyampettai from 1985 and Pachankuppam for

more than 15 years [6]. About 70-80% of MSW is collected and rest remains unattended on streets or in small open dumps. In India about 90% of municipality's total budget is spent on collection of waste, yet collection efficiency is poor about 70-72% [12], and More than 90% of MSW in India is directly disposed of on the land in an unsatisfactory manner [34]. Material recovery and composting is the more environmentally preferable option for solid waste management. Open burning/incineration is not suitable option for solid waste management from environmental point of view as it has highest toxic effect due to nitrogen oxide [24]. Some measures that can be taken for proper management of solid waste system are: Tax should be levied on SWM, awareness programs about the importance of segregation at generation point should be carried out, inert and recyclable material should be segregated for proper waste management, viable decentralized composting plants should be installed to reduce the loads on urban local bodies for collection and transportation of MSW due to which there will be reduction of the pressure exerted on the landfills, characterization of waste at collection and disposal should be made available in public domain, waste should be treated as raw material, polyethylene must be banned, waste to energy and gas recovery must be practiced at landfill sites, and steps for protection of groundwater contamination from leachate percolation from open dumping sites should identified [26]. Waste management is a problem in both urban and rural areas. Many areas, particularly in developing countries, still have inadequate waste management; poorly controlled open dumps and illegal roadside dumping remain a problem. To minimize the solid waste generation, the policy of 4R's is to be adapted. i.e. Refuse, Reuse, Recycle and Reduce [27]. During segregation of MSW, the collection of organic waste, which comprises 60% wt. of MSW, for either composting or anaerobic digestion should be encouraged [29]. Cities in India have many shortcomings in existing MSWM practices.

B. Impact of municipal solid waste

There are potential risks to environment and health from improper handling of solid wastes. The workers in this field are mainly affected as they are directly in contact with the waste, and it is most important that they are protected. There are also specific risks in handling wastes from hospitals and clinics. For the general public, the main risks to health are indirect and arise from the breeding of disease vectors, primarily flies and rats. A major environmental concern is gas release by decomposing garbage. Methane is a by-product of the cellular respiration of bacteria that does not use oxygen, and these bacteria develop in landfills having high amounts of moisture. Methane concentrations can reach up to 50% of the composition of landfill gas at maximum anaerobic decomposition [43]. A second problem with these gasses is their contribution to the enhanced greenhouse gas effect and climate change [43].Leachate management varies throughout the landfills. Leachate creates problem to local surface and ground water systems. The use of dense clay deposits at the bottom of landfill sites, incorporated with plastic sheets type liners to prevent infiltration of leachate into the surrounding soil, is generally regarded as the optimum strategy to contain excess liquid. In this way, waste is encouraged to evaporate rather than infiltrate [43]. The impact on environment included; increase day-time temperature, global warming, increase incidences of crop absorption and subsequent reduction in yield and productivity [8]. As a result of the high levels of chemical and bacteriological contamination of water from the boreholes, health problems as typhoid fever, worm infestation are impending when such water is consumed in its without any treatment. Presence of *E-Coli* and total coliform bacteria indicated microbial pollution of the groundwater by anthropogenic activities [8]. Water hardness was higher due to the leaching of both Ca and Mg into the groundwater table. Presence of Fe, Pb and Cr in detectable quantities can be an indication of toxicity level in the groundwater and therefore poses serious environmental risk. Some landfills are operational for many years and had contaminated ground due to heavy concentration of heavy metals and other hazardous chemicals formed by the reaction of percolated water with the waste in the disposal sites. Delhi and Greater Mumbai in India emits the major amount of emissions, 2232Gg and 1928Gg of CO_2 equivalents when compared with other cities [39]. Ahmedabad, Gujarat contributes to 7.17% GHG footprint [39]. This showed that waste sector accounts for considerable amount of green house gas emissions when city level studies are carried out [39]. The short term suggestions that can be practised to mitigate the LFG and leachate issues are: stop open burning inside landfills, improvement of access road, constructing basic structures like weighing bridge, infrastructure and fencing, raising awareness, construction of leachate collection and gas venting facility [19].

C. Phytocapps as an enhanced biocovers

Phyto techniques are the new emerging attractive technique that has emerged. 'Phytocapping' has been considered as an effective, economical and environment friendly technique for landfill recovery. In this technique, trees are established/planted on a layer of soil cap placed over the refuse. Soil cover acts as a 'storage' and trees act as 'bio-pump and filters' show that the planted trees can remove more water than that received via rainfall and rainfall

interception can reduce up to 20% of the rain reaching the soil in a 1.5 year old plantation, and the plants show no nutrient toxicity or deficiency symptoms [13]. Functions of phytocaps are to control percolation of water into waste, promotes surface runoff, minimise erosion, control odour and land fill gases oxidation [38]. Avoiding percolation of water into refuse is the key function of landfill covers. This technique offers excellent perspectives for the development of plants with potential for cleaning metal contaminated soils [1]. Plant root penetration has impact on integrity of clay barriers [37]. Overall phycapping can reduce 80% of methane emissions from landfill compared to un-vegetated fields. Thick cover of soil has better water carrying capacity than thin cover [13]. Biocovers while offering the advantages of covering an entire landfill while also simultaneously providing good water holding capacity and porosity for vegetation and evapotranspiration. Factors affecting methane oxidation are soil texture, soil moisture content, temperature, pH, nutrients, oxygen concentration, and methane concentration [20]. Other advantages of phytocaps are their lower cost, utilizing available resources, high ecological site improvement and GHG emission reduction, phytocaps require less technical skills and engineered infrastructure to construct and maintain [37].

D. Plant selection

Phytoremediation using plants has benefits in restoring a balance in stressed environment. It is an emerging low cost technology, non-intrusive, and aesthetically pleasing using the ability of plants to metabolize various elements and toxic matter from the environment in their tissues. Because all natural hyperaccumulater species are small in size, genetic modification can be used to introduce this technology to other species or to increase the biomass of the natural hyperaccumulater in order to create effective phytoremediators. Brassica Juncea (Indian mustard) can survive in adverse condition so can be used as phytoaccumulator [4]. Cymbopogon Winterianus (Lemon grass) and Ocimum Basilicum (Tulsi) are ecologically viable and can sustain on the polluted sites and accumulate heavy metals [2]. Sunflower and Brassica Juncea (Indian mustard) can accumulate the heavy metals in their roots [7]. Brassica Juncea (Indian mustard) was one of the best metal accumulating species for both soil and water. The metals are accumulated in roots and shoot. Mustards can effectively remove lead, chromium, cadmium, nickel, zinc, copper and other metals from soil [9]. Lead concentration is not toxic for Indian mustard [17]. Copper extraction by Sunflower was also high. Indian mustard, sunflower and hyacinth plants are tolerant of heavymetals and have a high capacity for the uptake of metals like Pb, Ni, Co, Cr, Cd. [32]. Different plants according to weather condition of the region can be used.

III. METHODOLOGY

A. Phytocapping

Phytocap functionality depends on the intrinsic properties and communication between the local climate, the substrate (soil) and the established plant community. Typical phytocap system is shown in figure 2.

The landfill caps can be used to:

- Minimize exposure on the surface of the waste facility,
- To prevent vertical infiltration of water into landfill that creates leachate,
- Contains waste while treatment is being applied,
- Control gaseous emissions from underlying waste,
- Create a land surface that can support vegetation.

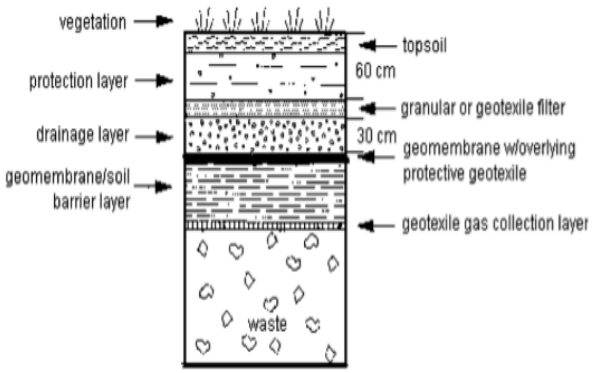

Figure 2: *Typical landfill cap system*
(Source: Platinum International, Inc. 2002, Nagendra R. et al. 2006)

IV. FUTURE SCOPE

- The phyto covers can be applied to the closed landfills to mitigate the methane gas emission and leachate formation.
- The phytocaps do not require any skilled supervision so it is cost saving.
- Still more plant species are to be identified which can survive in toxic condition and can be applied on the landfill sites.

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