A COMPREHENSIVE REVIEW ON LANDFILL LINER

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Abstract - A landfill site is a site for the disposal of waste materials by burial. It is the oldest form of waste treatment. Leachate is the fluid that leaches from a landfill. Its composition varies with respect to the age of the landfill and the kinds of waste it contains. A landfill liner is intended to be a low permeable barrier which is laid down under engineered landfill sites. Until the point when it break down, the liner hinders movement of leachate and its poisonous constituents into underlying aquifers or close-by streams. The aim of the study is to develop an amended soil liner mix with laterite soil and zeolite. Different trial mixes are developed on the basis of plasticity index and grain size distribution. The final mix is then determined based on the hydraulic conductivity and shear strength of the liner material. Leachate compatibility of the liner mix developed will be studied by permeating the material with leachate to determine its effects on the performance of the material. Leachate can be prepared using municipal solid wastes

Key Words: Plasticity Index, Shear Strength, Grain Size Distribution, Hydraulic Conductivity

1. INTRODUCTION

Waste disposal has become one of the most serious modern environmental problems in developed and developing countries all over the world. The open dumps create several environmental pollutions. One of the preferred methods of dealing with this kind of environmental problem is to dispose off the waste in sanitary landfills. Landfills are highly engineered waste containment facilities, designed to minimize the impact of solid waste on the environment and human health. Landfills are the most popular and important method for disposing solid waste due to their simplicity, low exploitation and low capital costs.

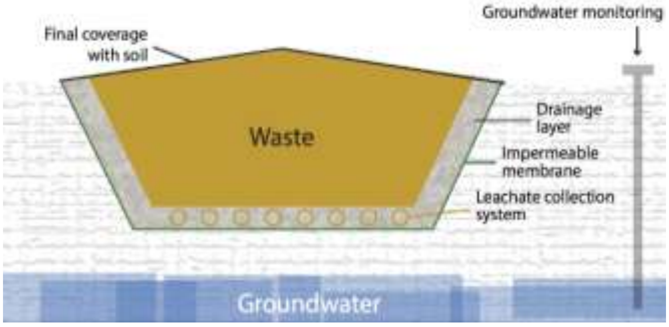

Fig-1: Schematic representation of a landfill

The waste will generate leachate. Leachate is the fluid that leaches from a landfill. Its composition varies with respect to the age of the landfill and the type of waste it contains. In landfills, waste is encapsulated by liner system at bottom and cover system at the top. The cover system and liner system are designed to prevent the migration of leachate and gas from the landfill. The liner system and barrier system consist of a very low permeable layer with sufficient strength, called barrier layer. The barrier layers are normally constructed with compacted clay or very low permeable clay with local soil or along with geomembranes. The liners designed with a mixture of very low permeable clay and local soil is called amended soil liners. The properties of liner get altered when it comes to contact with the leachate.

Landfills are often the most cost-efficient way to dispose waste, especially in countries with large open spaces. Both resource recovery and incineration requires extensive investments in infrastructure and material recovery also requires extensive manpower to maintain. On the other hand landfills have little fixed or ongoing costs, allowing them to compete favourably. In addition, landfill gas can be upgraded to natural gas which is a potential revenue stream. Another advantage is that a specific location is available for waste disposal where it can be monitored and processes to remove all recyclable materials before tipping. Landfills can be considered as an abundant source of materials and energy. In the developing world, trash collectors often scavenge for still usable materials. In a commercial context, landfill sites are being discovered by companies, and many have even begun harvesting materials and energy. Gas recovery facility is a well-known example. Other commercial facilities include waste incinerators with built-in material recovery system. This material recovery is done using filters.
In this paper, landfill liners made using different materials, the effect of leachate on the liner material and generation of energy from landfills are studied.

1.1 Types of Landfill

There are mainly three types of landfills

1. Municipal Solid Waste Landfills

A municipal solid waste landfill (MSWLF) is a landfill designed to receive household waste. A MSWLF may receive other types of nonhazardous wastes as well, such as incinerators with built-in material recovery system. This material recovery is done using filters.

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1. Municipal Solid Waste Landfills

A municipal solid waste landfill (MSWLF) is a landfill designed to receive household waste. A MSWLF may receive other types of nonhazardous wastes as well, such as commercial solid waste, nonhazardous sludge, conditionally exempt small quantity generator waste, and industrial nonhazardous solid waste. Disposal of some waste materials are forbidden in MSWLFs, including common household items like paints, cleaners/chemicals, motor oil, batteries and pesticides which can be dangerous to one's health and the environment if mishandled.

2. Construction and Demolition Landfills

A C&D landfill receives construction and demolition debris, which typically consists of roadwork material, excavated material, demolition waste, construction/renovation waste, and site clearance waste. Hazardous waste or industrial solid waste are not dumped into C&D landfills unless they meet certain standards and are permitted to receive such wastes.

3. Industrial Landfills

Landfills that accept specified industrial wastes are industrial landfills. Industrial waste means solid waste generated by manufacturing or industrial processes. It includes waste resulting from manufacturing processes such as electric power generation, fertilizer and agricultural chemicals, food and related products and by-products, inorganic chemicals, iron and steel manufacturing, leather and leather products, nonferrous metals manufacturing and foundries, organic chemicals, plastics and resin manufacturing, pulp and paper industry, rubber and miscellaneous plastic products, stone, glass, clay and concrete products, textile manufacturing, transportation equipment and water treatment. Mining waste or oil and gas waste are not industrial waste. In most cases industrial waste landfills are monofills associated with a specific industry or facility.

2. COMPONENETS OF A LANDFILL

Landfills are facilities used for the disposal of solid waste on the surface of the earth. The term engineered landfill refers to a landfill designed and operated to minimise environmental impact. The components of a landfill are:

- Bottom liner system
- Cells
- Leachate collection system
- Storm water drainage
- Methane collection system
- Cover

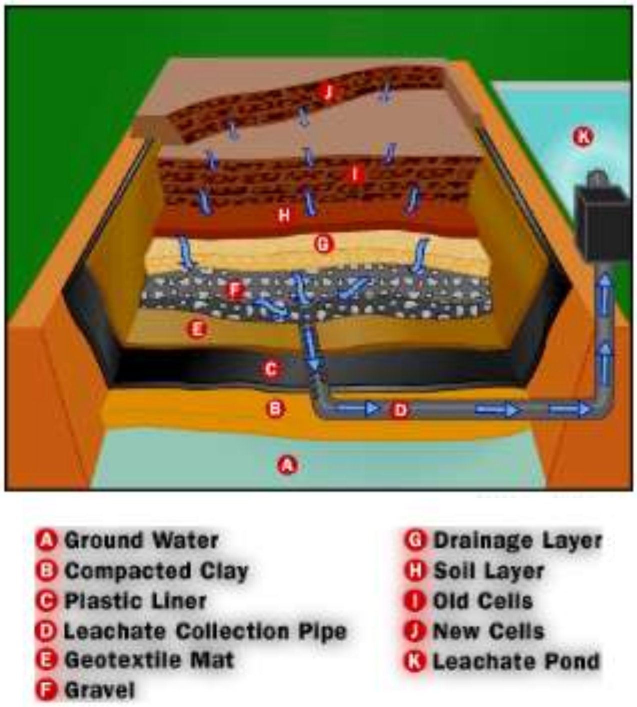

Fig-2 : Cross Section of a Municipal Solid Waste Landfill

2.1 Bottom Liner System

The main purpose of a landfill is to contain the trash so that it doesn't cause any problem in the environment. The bottom liner ensures that the trash doesn't comes in contact with the outside soil, particularly the groundwater. The liner used in MSW landfills is usually some type of durable, puncture-resistant synthetic plastic. The plastic liners are sometimes accompanied with compacted clay soils as an additional liner. Surrounding the plastic liner on either side with a fabric mat will help to keep the plastic liner from tearing or puncturing from the adjacent rock and gravel layers.

2.2 Cells

Cells are another component of landfills which ranges in size from a few acres to 20 acres or more depending upon the amount of waste the landfill receives each day. The larger cell contains smaller cells that are known as the daily workface. The incoming waste is prepared each day in the smaller cells. The waste is placed in layers, compacted and shredded by heavy landfill compaction machinery. Cells are arranged in rows and layers of adjoining cells (lifts).

2.3 Leachate Collection System

The water percolates through the cells and soil in the landfill. The water picks up contaminants while it percolates through the trash. This water with the dissolved contaminants is called leachate. Perforated pipes run throughout the landfill to collect the leachate. These pipes then drain into a leachate pipe, which carries leachate to a leachate collection pond. The leachate can then be tested and treated like any waste water.

2.4 Storm Water Drainage

The storm water drainage portion of the landfill is an engineered system that is designed to control water runoff when it rains. This is accomplished by directing the runoff through a series of ditches or berns into holding areas. Referred to as sed ponds, these holding areas slow down the water long enough to allow suspended soil particles to settle before the water is discharged.

2.5 Methane Collection System

Bacteria present in the landfill break down the trash in the absence of oxygen (anaerobic) because the landfill is airtight. A byproduct of this anaerobic breakdown is landfill gas, which contains approximately 50 percent methane and 50 percent carbon dioxide with small amounts of nitrogen and oxygen. This presents a hazard because the methane can explode and/or burn. Therefore the landfill gas must be removed and to do this, a series of pipes are embedded within the landfill to collect the gas. In some landfills, this gas is vented or burned. More recently, it has been recognized that this landfill gas represents a usable energy source. The methane can be extracted from the gas and used as fuel.

2.6 Cover

The cover or cap is compacted soil or some alternative material that is placed over the waste in a cell each day. This covering ensures that the compacted trash is sealed from the air and prevents pests such as birds, rats, mice, flying insects, etc. from getting into the trash. When a section of the landfill is finished, it is covered permanently with a polyethylene cap. The cap is then covered with a 2-foot layer of compacted soil which is then planted with vegetation to prevent erosion of the soil by rainfall and wind. Trees, shrubs or plants with deep penetrating roots are not used so that the plant roots do not contact the underlying trash and allow leachate out of the landfill.

3. LANDFILL LINER

A landfill liner or composite liner is a low permeable barrier, which is laid down under engineered landfill sites. Until it deteriorates, the liner prevents permeation of leachate and its toxic constituents into underlying aquifers or adjacent streams, causing spoliation of the local water. Modern landfills generally require a layer of compacted clay with a minimum required thickness and a maximum allowable hydraulic conductivity, overlaid by a high-density polyethylene geomembrane.

An effective liner in a landfill system controls water, in terms of movement and protects the environment. It regulates the flow away from the waste area and withhold the waste contents as it enters the actual landfill. Water moves through the landfill and downward through the composite liner. The final cover functions as a way to keep the water out of the contaminant and to control the runoff from entering the system. This helps prevent plants and animals from being harmed by the waste contaminated water leachate.

There are different types of liner systems depending on the harmfulness of trash in various disposal sites. The first type is single liner-systems. These systems usually used in landfills which mostly hold construction rubble. These landfills are not meant to hold the disposal of harmful liquid wastes such as paint, tar or any other type of liquid garbage that can easily seep through a single liner system. The second type is double-liner systems. These systems are usually found in municipal solid waste landfills as well all hazardous waste landfills. The first part is constructed to collect the leachate while the second layer is engineered to be a leak-detection system to ensure that no contaminates leak into the ground and contaminate everything.

4. LINER MATERIALS

4.1 Amended Liners

Lei et al. (2016) studied the feasibility of using shale and clay mixtures as an improved landfill liner material. Relevant laboratory tests were performed to examine basic geotechnical properties, compaction, hydraulic conductivity, batch adsorption, and transport parameters. The test results showed that the dry weight percentage of shale in shale-clay mixtures should be maintained below 32%, 48% and 23% under the standard, modified, and reduced Proctor compaction tests, respectively, to meet the minimum requirement of landfill liners for hydraulic conductivity (i.e., $\leq 1 \times 10^{-7}$ cm/s). A numerical model was constructed to simulate a typically sized landfill liner consisting of shale-clay mixtures on the basis of laboratory tests. The modelling results showed that the mixture in right proportions can be used as a landfill liner.

Qiang et al. (2013) studied the behaviour of bentonite amended compacted clay membrane. Bentonite is already proven to be an excellent additive that improves the membrane behaviour of clay and the hydraulic conductivity. Membrane behaviours of a locally available clay, amended with different amounts of dry bentonite (5%, 10%, 15%, and 20%) is studies. Furthermore, the mechanisms that influence the membrane behaviour were discussed from the viewpoints of the diffuse-double layer and the interparticle pore size. It was seen that increasing the bentonite content from 5% to 20% slightly improved the membrane properties.

Shyla et al. (2017) conducted a study on amended landfill liner using bentonite and zeolite mixtures. The study focused on improving the locally available dump yard site soil using bentonite and zeolite mixtures. The variation of properties such as permeability, dry density, OMC, consistency limits etc. were studied. The mix containing 40% dump yard site soil, 35% bentonite and 25% zeolite had the least permeability. From the results it was evident that the geotechnical properties make bentonite and zeolite mix an innovative material for liners in landfills.

Nisha et al. (2018) designed an amended landfill liner using nano silica. In this, a mixture of site soil, nano silica and bentonite were studied as a potential liner. Tests were conducted to determine the variation in properties such as hydraulic conductivity, dry density, OMC, Atterberg's limits etc. while mixing Nano silica and bentonite with site soil in various percentages. It was seen that with the increase in Nano silica and bentonite content the OMC increases and dry density decreases. Therefore the property of mixes shows that it can be used as a liner in the landfill.

Oluwapelumi et al. (2017) conducted a study on the strength and hydraulic conductivity characteristics of sand-bentonite mixtures designed as a landfill liner. Igbokoda sand mixed with bentonite at varying percentages of 0%, 2%, 4%, 6%, 8% and 10% by weight of sand was used for the study. Strength tests, such as compaction test, California Bearing Ratio (CBR) test and direct shear test, were performed on various sand-bentonite mixtures using standard methods. Hydraulic conductivity tests were also performed on various sand-bentonite mixtures in order to ensure their suitability as a landfill liner. Results showed that 8% of bentonite with sand mixture had a hydraulic conductivity below 1×10-7 cm/s, a cohesion value of 250 kN/m3 and a reasonable strength (CBR) value of 54.07%, hence being the safest of the selected varying percentages for the design of a landfill liner.

Yucel et al. (2014) conducted a study on utilization of sepiolite materials as a bottom liner material in solid waste landfills. The study focused on the feasibility of using natural clay rich in kaolinite, sepiolite, zeolite, and their mixtures as a bottom liner material. Laboratory tests such as unconfined compression tests, swell tests, hydraulic conductivity tests, batch and column adsorption tests were performed on each type of soil and sepiolite–zeolite mixtures. It was evident from the results that an increase in sepiolite content in the sepiolite–zeolite mixtures improved the strength, swelling potential and metal adsorption capacities of the soil mixtures. The increase in sepiolite content also decreased the hydraulic conductivity of the mixtures. Using sepiolite–zeolite materials as a bottom liner material even allowed for thinner liners which help in bringing down the construction costs compared to use of a kaolinite-rich clay.
Yahia et al. (2005) assessed the possibility of using crushed shales as compacted landfill liners. Two types of shales were studied by performing the following laboratory tests: hydraulic conductivity, compaction, swelling, consolidation, X-ray diffraction (XRD), scanning electron microscope (SEM) and chemical analysis. For both compacted shales, the hydraulic conductivity was in order of 1x10-7 cm/s or less which satisfies the specifications for landfill liners. The shear strength of the compacted shales was found to be within the range expected for earthen liners. The crushed shales also satisfied the other criteria related to Atterberg limits and grain size. Thus it was seen that crushed shales can be used as compacted landfill liners.

Musso et al. (2010) assessed the possibility of using smectite-rich claystones from Northpatagonia as liner materials in landfills. Two types of Northpatagonic claystones were considered as potential materials for landfill liners. To analyse the suitability of the claystones, physical (hydraulic conductivity, compaction, consolidation, and swelling), chemical (cation exchange capacity and bulk chemical analysis) and mineralogical analysis (X-ray diffraction and scanning electron microscope) were performed. It was seen that the high compressibility of the claystones makes it unsuitable to use them directly as liner materials. These materials satisfy the requirements for compacted clay liners in municipal waste disposal repositories when combined with well graded sand. In this way, a new applicability for clay materials of regional provenance was found.

Tanit et al. (2009) studied the potential use of lateritic and marine clay soils as landfill liners to retain heavy metals. A series of tests such as physical and chemical, batch adsorption, column, hydraulic conductivity, etc., were conducted to evaluate the heavy metal sorption capacity, chemical compatibility of hydraulic conductivity, and transport parameters of the soils. It was clear from the results that the marine clay had better adsorption capacity than that of the lateritic soil. In addition, the hydraulic conductivities of both soils when permeated with low concentration heavy metal solutions were found to be below 1 x 10-7 cm/s. In general, it was seen that the properties of the marine clay had significant advantages over the lateritic soil as landfill liner material.

Sezer et al. (2003) investigated the mineralogical and sorption characteristics of ankara clay as a landfill liner. This clay is Pliocene in age and was deposited in a fluvial environment. Mineralogically it consists mainly of illite, smectite, chlorite and kaolinite minerals. The non- clay minerals, quartz, feldspars, calcite and Fe–Ti oxides were detected. The characteristics determined together with its known engineering properties, suggest that Ankara Clay can be utilized as a component of a barrier system.

Kamil (1997) investigated certain features of a novel material proposed to serve as an impervious liner in sanitary landfills. The natural zeolites and the commercial powdered bentonite were used in various experiments, such as compaction, hydraulic conductivity, and strength. Various ratios of bentonites and zeolites (B/Z) compacted at the optimum water content (Wopt) were tested to determine the strength parameters. The laboratory samples compacted under Wopt and slightly higher water contents were tested for hydraulic conductivity. A B/Z ratio of 0.05-0.10 was found to be an ideal landfill liner material regarding its low hydraulic conductivity and high cation exchange capacity. The use of B/Z mixtures as an alternative to clay liners would significantly reduce the thickness of base liner for sanitary landfills.

Nithi et al. (2017) studied the use of lateritic soil amended with bentonite as landfill liner. Various proportions of lateritic soil blended with bentonite have been tested to suggest a suitable liner. In the mixture, bentonite content was varied as 0%, 10%, 20% and 30% to the dry weight of lateritic soil. Of all the blend 80%-20% laterite-bentonite blend was found to be best suited for the use as a landfill liner

4.2 Alternate Materials

Martisa et al. (2016) investigated the possibility of using spilite valorization, a mining waste produced during the exploitation of nickeliferous laterites, as an alternative material for the construction of compacted landfill liners. Different types of mixtures were tested with bentonite content up to 3% weight. The evaluation of the produced spilitic sand-bentonite mixtures was carried out on the basis of the liquid limit (WL), the plasticity index (PI), the organic matter content, the proctor compaction and the hydraulic conductivity. The results showed that the hydraulic conductivity of the mixture with bentonite was satisfying the requirements for landfill liner materials.

Hui et al. (2017) conducted a feasibility study on the application of coal gangue as landfill liner material. Coal gangue is one of the largest industrial solid waste all over the world. In this study, the feasibility of using coal gangue as landfill liner material was studied through a series of laboratory tests in terms of hydraulic conductivity, sorption characteristics and leaching behavior. The results indicated that the hydraulic conductivity of coal gangue could be smaller than the regulatory requirement 1×10^{-7} cm/s. The desirable characteristics indicated that the coal gangue has potential to be used as landfill liner materials.

Anel et al. (2008) conducted an analytical study on the suitability of using bentonite coated gravel (BCG) as a landfill liner material. The concept of BCG is that each aggregate particle has been covered with the clayey material. Laboratory tests conducted included X-ray diffraction, methylene blue absorption, compaction, free swelling, permeability, 1D consolidation, triaxial compression and cone penetration. It was seen from the results that even though aggregate content represents 70% of the weight of the material, hydraulic conductivities as low as 6×10^{-10} cm/s can be achieved when proper compactive efforts are used. Results demonsatrated that moderate compactive efforts, are recommended for constructing a BCG barrier. Using moderate compactive efforts, very low hydraulic conductivities, good workability and good trafficability are easily attainable.

Ilknur et al. (2006) investigated the feasibility of using a silty soil excavated in highway construction as landfill liner material. The tests were conducted both at laboratory and in situ scales, and the soil was tested in pure and lime treated forms. Different levels of compaction energy were used. For the field study, a test pad was constructed and in situ hydraulic conductivity experiments were conducted by sealed double ring infiltrometers (SDRI). Laboratory testing revealed that while lime treatment improved the shear strength, it resulted in higher hydraulic conductivity values compared to pure soil. It was observed that leachate permeation did not change the hydraulic conductivity of the pure and lime treated samples. Undisturbed samples collected from the test pad were not representative of field hydraulic conductivities. Contrary to laboratory findings, higher compaction efforts did not result in lower hydraulic conductivities in field scales. The study verified the importance of in situ hydraulic conductivity testing in compacted liners. The results showed that further research should be conducted to determine the utilization of excavated soil as liner material.

4.3 Geosynthetic Clay Liners

Fatemeh et al. (2017) conducted a study on hydraulic conductivity and self-healing properties of geotextile clay liners used in landfills. Geotextile clay liner (GCL) that has a sandwich structure with two fibrous sheets and a clay core can be considered as an engineered solution to prevent hazardous pollutants from entering into groundwater. Water pressure, type of cover soil and overburden pressure were the environmental variables, while the response variables were hydraulic conductivity and self-healing rate of GCL. It was found that higher Montmorillonite content of clay, overburden pressure, needle punching density and areal density of clay poses better self-healing properties and less hydraulic conductivity, meanwhile, an increase in water pressure increases the hydraulic conductivity.

Jiannan et al. (2018) studied the hydraulic conductivity of geosynthetic clay liners with sodium bentonite to coal combustion product leachates. Experiments were conducted to evaluate the hydraulic conductivity of geosynthetic clay liners (GCLs) containing granular sodium bentonite that were permeated with coal combustion product (CCP) leachates. Hydraulic conductivity tests were conducted on non-prehydrated and subgrade hydrated (by compacted soil for 60 days) GCL specimens at effective stresses ranging from 20 to 450 kPa. At 20 kPa, GCLs permeated directly had high hydraulic conductivity ($>10^{-6}$ m/s) to trona leachate and moderate to high hydraulic conductivity (10^{-10} to 10^{-7} m/s) to the other CCP leachates. Hydraulic conductivity was strongly related to the ionic strength of the leachate and inversely related to the swell index of the bentonite when hydrated in leachate. Increasing the effective stress from 20 to 450 kPa caused the hydraulic conductivity to decrease up to three orders of magnitude. Hydration on a subgrade prior to permeation has only modest impact on the hydraulic conductivity to CCP leachate. Hydration by permeation with deionized (DI) water prior to permeation with trona leachate resulted in hydraulic conductivity up to three orders of magnitude lower than obtained by direct permeation, suggesting that deliberate prehydration strategies may provide chemical resistance to CCP leachates.

5. EFFECT OF LEACHATE ON LINER

Melissa et al. (2017) studied the effect of ammonium on hydraulic conductivity of geosynthetic clay liners. Hydraulic conductivity and swell index tests were conducted on a conventional geosynthetic clay liner (GCL) containing sodium-bentonite (Na-B) using 5, 50, 100, 500, and 1000 mm ammonium acetate (NH_4OAc) solutions to investigate how NH_4^+ accumulation in leachates in bioreactor and recirculation landfills may affect GCLs. Control tests were conducted with deionized (DI) water. Hydraulic conductivity of this GCL specimen decreased from 5.9×10^{-6} m/s to 2.9×10^{-11} m/s during permeation with DI water, indicating that "NH_4-bentonite" can swell and have low hydraulic conductivity, and that the impact of more concentrated NH_4^+ solutions on swelling and hydraulic conductivity is reversible.

Qiang et al. (2014) assessed the effects of leachate concentration on the integrity of solidified clay liners. The results indicated that the unconfined compressive strength of the solidified clay decreased significantly, while the hydraulic conductivity increased with the leachate concentration. The large pore proportion in the solidified clay increased and the sum of medium and micro pore proportions decreased, demonstrating that the effect on the solidified clay was evident after the degradation caused by exposure to landfill leachate. The unconfined compressive strength of the solidified clay decreased with increasing leachate concentration as the leachate changed the compact structure of the solidified clay, which are prone to deformation and fracture. The hydraulic conductivity and the large pore proportion of the solidified clay increased with the increase in leachate concentration. In contrast, the sum of medium and micro pore proportions showed an opposite trend in relation to leachate concentration, because the leachate gradually caused the medium and micro pores to form larger pores. Notably, higher leachate concentrations resulted in a much more distinctive variation in pore proportions. The hydraulic conductivity of the solidified clay was closely related to the size, distribution, and connection of pores. The proportion of the large pores showed a positive correlation with the increase of hydraulic conductivity, while the sum of the proportions of medium and micro pores showed a negative correlation.

Sheela et al. (2015) investigated the effect of acetic acid on amended clay liner designed using thonnakal clay. The main mineral content of the clay is kaolinite. It is low expansive clay with very small percentage of fine sand. The liner consists of bentonite, Thonakkal clay and fine sand. The effect of 0.1 M, 0.5M, 1M, and 2M concentration of acetic acid solution on geotechnical properties of the liner were found out. For this liners the consistency limits reduces with the increases in concentration of acetic acid solution. The liquid limit decreased with time for certain period. The free swell was decreased as the concentration of acetic acid increased above 0.5 M and then no swelling was observed. As the concentration of the acetic acid increased the liner strength also reduced but it was found that the failure was in gradual manner and the sample could take more strain. The permeability of all the liner was found to decrease with increase in concentration and time.

Qiang et al. (2018) studied the impact of biological clogging on the barrier performance of landfill liners. The durability of landfill mainly relies on the anti-seepage characteristic of liner system. The accumulation of microbial biomass is effective in reducing the hydraulic conductivity of soils. This study aimed at evaluating the impact of the microorganism on the barrier performance of landfill liners. According to the results, Escherichia coli produced huge amounts of extracellular polymeric substances and coalesced to form a confluent plugging biofilm. This microorganism eventually resulted in the decrease of soil permeability by 81%–95%. Decreasing the hydraulic conductivity from 1×10^{-8}m/ s to 1×10^{-10}m/s resulted in the increase of the breakthrough time by 345.2%. This indicates that a low hydraulic conductivity was essential for the liner systems to achieve desirable barrier performance.

6. ENERGY GENERATION FROM LANDFILLS

Ivan et al. (2018) conducted a study on the combined use of biogas from sanitary landfill and wastewater treatment plants for distributed energy generation in Brazil. Biogas is a fuel which has a high potential energy and it is produced from the anaerobic degradation of organic material. It can be used for many applications such as heat and electrical generation and fueling vehicles. Given that anaerobic reactors and landfills are the main forms for treating domestic solid waste in Brazil, this current article presents a five scenario analysis on the energy potential and economic viability of the combined use of biogas produced in these structures for generating electricity in the city of Itajubá, Brazil. From the energy point of view, the best case scenario is the combined use of biogas from sanitary landfill and sewage treatment station. This scenario resulted in an installed power of 685 kW, with an annual energy production capable of supplying approximately 10% of the city's energy. Concerning the economic aspect, the best option is the use of biogas from sanitary landfill in an isolated manner, due to the shorter distance of the transport of the gas, in comparison with other scenarios. The results demonstrate the potential and possibility of economic viability for the use of biogas in urban structures for these microregions in Brazil, indicating that the development of biogas use in small cities can be accomplished within the resolutions of distributed microgeneration. Such potential tends to increase as basic sanitation grows throughout the country.

Nazli et al. (2016) investigated heat management strategies for MSW landfills. Heat is a primary byproduct of landfilling of municipal solid waste. Long-term elevated temperatures have been reported for MSW landfills under different operational conditions and climatic regions around the world. A conceptual framework is presented for management of the heat generated in MSW landfills. Three main strategies are outlined: extraction, regulation, and supplementation. Heat extraction allows for beneficial use of the excess landfill heat as an alternative energy source. Two approaches are provided for the extraction strategy: extracting all of the excess heat above baseline equilibrium conditions in a landfill and extracting only a part of the excess heat above equilibrium conditions to obtain target optimum waste temperatures for maximum gas generation. Heat regulation allows for controlling the waste temperatures to achieve uniform distribution at target levels at a landfill facility. Two approaches are provided for the regulation strategy: redistributing the excess heat across a landfill to obtain uniform target optimum waste temperatures for maximum gas generation and redistributing the excess heat across a landfill to obtain specific target temperatures. Heat supplementation allows for controlling heat generation using external thermal energy sources to achieve target waste temperatures. Two approaches are provided for the supplementation strategy: adding heat to the waste mass using an external energy source to increase waste temperatures and cooling the waste mass using an external energy source to decrease waste temperatures. For all strategies, available landfill heat energy is determined based on the difference between the waste temperatures and the target temperatures. Example analyses using data from landfill facilities with relatively low and high heat generation indicated thermal energy in the range of 48.4 to 72.4 MJ/m3 available for heat management. Further modeling and experimental analyses are needed to verify the effectiveness and feasibility of design, installation, and operation of heat management systems in MSW landfills.

7. CONCLUSION

Landfill liners are constructed with very low permeability clay. Local soils are mixed with medium to high plasticity clays like bentonite or similar products to form amended soil liners. The requirements include the most extensive retardation potential possible for all contaminants and efficacy over long periods of time which can be measured by the degradation, conversion and consolidation processes in the waste body. Any maintenance and repair of a basal liner is practically excluded since, if feasible at all it would be highly labour and cost intensive. One highly problematic aspect particular to the field of landfill technology is the exceptionally long time spans over which the liner elements are required to function effectively. This problem of time scale has most certainly not been laid to rest yet, especially in the case of capping systems where, over a period of fifty years or more is required and in the absence of any after -care, woodland will eventually establish itself.

Under normal conditions the geomembrane is almost certainly the crucial liner component, while the mineral component guarantees failure tolerance and redundancy. An integrated research programme has suggested alternative solutions such as a geomembrane with a geosynthetic clay liner, a geomembrane with a leakage detection system and a geomembrane with a capillary barrier. However, if such systems were used, the monitoring and assessment and, possibly, repair of the liner components would represent an almost endless after-care programme. Thus the design of suitable liner materials is the need of hour as the ground water pollution is increasing day by day.

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