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Landfill Liner: A Review of Materials and Enhancement Potential

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Liner is the most known name in the field of landfill innovation and has gotten enormous consideration from various research groups. Being an interdisciplinary zone of research, there have been testing different materials to find the best liners material. This review unveils the improvement of liners from their origin, the significant achievements in the materials utilised and as well as incredible varieties. Beginning from the traditional single layer (clay), multilayer layer utilisation of materials mixes are discussed. Endeavours have been made to reveal insight into the selection of alternate materials depending on changes in thickness. This is capable of noticing how much the soil will only be reasonable for the development of the liner depending on its acquired hydraulic conductivity, despite the financial benefits decided by using the combinations of treated soil-various materials, the utilisation of this industrial result rather than removal will help in enhancing related environmental problems. During this review paper, a thorough study on research by scientists on the utility of various materials as liners for landfills is completed by experimenting to find appropriate material.

Keywords: *Liners; Landfills; Solid Waste*

1. Introduction

Modern landfills are highly engineered containment structures, intended to reduce the effect of solid waste releases (trash, garbage, and refuse) on the ecosystem and public safety. In present landfill sites, the waste is enclosed by a liner system. The main aim of the liner system is to separate the landfill materials from the ground water and, thus, to shield the soil and ground water from pollutants occurring in the landfill. The biggest risk to ground water released by traditional landfill is leachate. Landfill liners are designed to stop uncontrolled leachate leakage into the ground water (Hughes et al., 2005).

As municipal solid waste is accumulated in landfills due to drought or underflow of groundwater, it is subjected to water leaching. Since water absorbs a variety of inorganic and organic components through the waste, such contaminated water is called as "leachate." Leachate may contain a wide range of materials based on landfill composition, age, waste depth and many other factors; ultimately, the leachate compounds are considered to be hazardous. (Adeolu et al., 2011). Leachate may contain heavy metals and can be divided into two groups. The first group is zinc, copper, nickel, and chromium that are phytotoxic and can affect crop growth. The second is lead, cadmium, mercury, and molybdenum that are usually not toxic to plants but may be harmful to animals that ingest the treated crops (Jasim & Ibrahim, 2020).

Landfill base liner systems usually consist of several components including protective layers, liquid accumulation and separation mechanisms, resistive surface sheets, and absorption amplification layers.

A variety of processes, including absorption, resistance, capacitance, and sometimes adsorption and reaction, are commonly used. Occasionally extractive lower barriers are also inserted as remediation systems for polluted areas.(US. Council, 2007)

During this review paper a thorough study on research by scientists on the utility of various materials as liners for landfills is completed by experimenting to find appropriate material.

2. Previous studies on various materials as liners in landfills:

In recent years, considerable focus has been paid to addressing technical and material barriers in order to produce commercially feasible liner materials in landfills with comparable cost-efficiency similar to clay. The purpose of this review is to demonstrate that concern in liners materials is not a new occurrence. Significant experimental research has been published in the past. This paper provides a review of certain previous research (1996-2019).

In 1996, Stewart and Mollins evaluated the use of bentonite-improved soils for waste containment, using one-dimensional swelling experiments and hydraulic conductivity measures. Bentonite powder swells to enter a final state represented by a single straight line on a graph of void ratio against the vertical effective stress logarithm, irrespective of the preparation methods. Swelling of sand / bentonite blends described in terms of clay void ratio indicates a divergence from bentonite behaviour over a tension that depends on the quality of bentonite. For bentonite and sand/bentonite mixtures, hydraulic conductivity results show a roughly linear relationship between the void ratio logarithm and the hydraulic conductivity logarithm (Stewart & Mollins, 1996).

In 1999, Hettiaratchi examined how fly ash-based materials can be used to create landfill liners to pollutant migration at polluted areas. Lime-fly ash, fly ash, polyvinyl alcohol, bentonite-fly ash, and polymer-lime-fly ash are the tested components. Built on research findings, polyvinyl alcohol-lime-fly ash has been ideally suited for the construction of both low-permeability, versatile landfill bottom liners contaminant migration barriers at polluted areas. In addition, mixtures of fly ash bentonite are more suitable for bottom liners than to vertical barriers. (Hettiaratchi et al., 1999)

In 2000, Sivapullaiah examined the effect of bentonite content in decreasing liner hydraulic conductivity. The analysis shows the role the coarser fraction size plays in regulating the clay liner's hydraulic conductivity. It has been shown that the hydraulic conductivity of the liner differs with low bentonite content, reliant on the size of the coarser portion aside from the amount of clay. The hydraulic conductivity increases at a given clay material, with a rise in the size of the coarser portion. But when the content of clay is more than what can be accommodated within the voids of the coarser portions, the hydraulic conductivity is regulated primarily by the content of clay itself. (Sivapullaiah et al., 2000)

In 2003, Sivapullaiah and Lakshmi conducted an investigation of Indian red earth combined with 20 percent of bentonite coated with either 1 percent lime or cement. Indian red earth mainly contains of the minerals quartz and kaolinite. Although holding soil hydraulic conductivity low, it increases the potential for swelling and shrinking, and increases the reduction in strength due to reduced cohesion. The addition of lime or cement improves the mixture volume stability. Lime has a greater role in reducing soil compressibility than cement. Based on the overall evaluation, it was concluded that 20 percent red earth stabilised bentonite mixture with 1 percent lime or cement can be used as a liner construction material. (Sivapullaiah et al., 2003)

In 2004, Cokca and Yilmaz completed a set of laboratory experiments on fly ash added from rubber and bentonite. The experiments aimed to determine the possibility of using rubber, bentonite and fly ash as a low hydraulic conductivity liner material. Use of fly ash in a liner process in areas near to the power plant may be economically attractive. The use of fly ash in this way even has the benefit of recycling a by-product of industrial waste without negatively impacting the landscape or future land use. Overall results evaluation indicated the fly ash applied to rubber and bentonite show a significant success and good choice for liner construction. (Cokca & Yilmaz, 2004)

In 2005, Mohamedzein investigated the possibility of smashed shales as liner for landfill. Two types of shales have been examined: Al-Fulaij shales and Fanja shales. The study showed that Shales of Al-Fulaij have extra clay content, greater plasticity, larger activity, higher optimum moisture content, low maximum dry unit weight, lower permeability, high compressibility and lower shear strength than shales of Fanja. That is accurate with the quantity of clay-portion particles in each shale. The study concluded that the smashed shales reach the core properties of clay liners (e.g., percent of clay and grain size(Mohamedzein. 2005).

In 2005, Afolayan and Nwaiwu established and compared statistical properties of laterite soil characteristics with those of soil filled liner soil. The distribution forms for related soil characteristics were used to perform a reliability-based evaluation of the feasibility of laterite soils as a hydraulic barrier in waste containment structures employing known hydraulic conductivity models produced from field and laboratory results taking into account soil parameter variations. Changes in compactive effort and preliminary degree of saturation were found to have the greatest impact on the reliability of hydraulic conductivity of soil liner depending on the laboratory model. Using a first order reliability method, an external evaluation of the applicability of lateritic soils to be used as compact liners and covers in landfill sites had also been made. (Afolayan & Nwaiwu, 2005)

In 2006, Kalkan examined the effect of red mud on hydraulic conductivity, swelling and unconfined compressive strength ratio of clay liners as a hydraulic shield (red mud is an industrial waste produced by the aluminium industry commonly used to generate alumina from bauxite).Test results indicate that compacted clay products contain red mud and cement red mud compounds have a good compressive strength and lower hydraulic conductivity and swelling rate relative to normal clay. (Kalkan, 2006)

In 2006, Bozbey and Guler studied the potential use of the excavated soil as landfill liner material after a highway project. While the soil gained in terms of strength from lime treatment, the values of hydraulic conductivity were adversely impacted. This conclusion was established using both lab and field experiments. Elevated compactive efforts resulted in increased dry unit weights in lab tests and reduced hydraulic conductivity but never in field tests. This has been attributed to intrinsic variations in the compaction system used. There is no known technique for direct comparison of the forces used in the field with those of the techniques of impact applied in the lab. (Bozbey & Guler, 2006)

In 2008, Andrejkovičová conducted a study to check the possible mixture of various calcium bentonites in geosynthetic clay liners before activation and utilisation. Soda ash processing of mixtures of an Al-rich bentonite of rich smectite content and a Fe-rich bentonite of low smectite content creates materials with attractive geotechnical properties (coefficient of permeability, free swelling, water adsorption and liquid limit) for geosynthetic clay liner use. As a correction constituent, Al-rich bentonite increases the swelling and sealing characteristics of the mixes with the less costly Fe-rich bentonites. (Andrejkovičová et al., 2008)

In 2008, Katsumi investigated the applicability of two improved bentonite compounds, dense-prehydrated geosynthetic clay liner and multi-swellable bentonite, saturated with electrolytic chemical solutions to waste containment facilities. Based on long-term testing results of the hydraulic conductivity, all multi-swellable bentonite and dense-prehydrated clay liner show exceptional resistance and swelling to chemical agents. Hence, each have capacity in terms of hydraulic conductivity as barrier materials at waste containment sites. (Katsumi et al., 2008)

In 2008, Roberts and Shimaoka Studied the using bentonite-coated gravel as waste landfill liner material in which each particle aggregate is coated with the clay material. They conducted laboratory tests to determine controlled and unregulated factors for liner materials. Results revealed that hydraulic conductivities are low and could be done through the correct application of compactive forces. With this material, compressibility is low even at low compactify forces. The findings also suggested how better compactify action would decrease bentonite-coated gravel permeability (Roberts & Shimaoka, 2008).

In 2008, LU and Hai jun examined the adsorption ability for Cr(VI) batch testing of landfill liners containing acid activated bentonite or granular activated carbon. The findings indicated that both granular activated carbon and activated bentonite should be used in landfill liners as sorption modifications for confining Cr(VI). The sorption of Cr(VI) to granular activated carbon and activated bentonite is higher than the sorption of clay by Cr(VI). With increasing temperature, the adsorption ability of Cr(VI) on all soils rises; soil-solid concentration also greatly influences the adsorption capacity. When the soil-solid concentration was increased adsorption efficiency will first logarithmically decrease, then stabilise, after a critical value of soil-solid concentration (400 gram / Liter). (LU et al., 2008)

In 2009, Chalermyanont assessed laterite soil and marine clay ability, typically of those located in warm and humid climate zones to be used as liner material for landfill. A variety of experiments were calculated to evaluate the heavy metal sorption ability, hydraulic conductivity chemistry compatibility, and soil transport parameters. Experimental tests showed that the marine clay had greater potential for adsorption than the laterite clay, and that its hydraulic conductivity was a lower order of magnitude. In general, the marine clay's properties clearly show that it has huge benefits over lateritic soil as material for landfill liner. (Chalermyanont et al., 2009)

In 2013, Osinubi and Eberemu examined the impact of bagasse ash content on hydraulic conductivity for the different compactive efforts at the OMC showed a decrease with increase in bagasse ash content up to 8% treatment before increasing at 12% treatment. The maximum variance in hydraulic conductivity with improved bagasse ash treatment was approximately two orders of magnitude for all compactify activity to the optimum. (Osinubi & Eberemu, 2013)

In 2014, Qiang conducted research to improve the characteristics of straw-fibre with clay that may be used in landfill liners structures to improve the efficiency of the anti-seepage capability and durability of landfill liners. Results from shear tests and unconfined compression tests showed that the shear strength and unconfined compressive strength first heightened but then decreased with the rise in fibre material (Qiang et al., 2014).

In 2015, Umar examined the feasibility of using metakaolin to enhance the characteristics of compacted laterite soil for municipal solid waste containment barrier structures. The soil has been replaced by zero, five percent, ten percent, fifteen percent and twenty percent metakaolin. The findings of this analysis indicated a general enhancement in the soil samples' unconfined compressive strength, with a rise in the proportion of metakaolin substitution. Results of the analysis also indicated that the hydraulic conductivity values of the samples saturated with leachate are higher than those of the hydraulic conductivity results obtained when de-ionized water was used as the saturated fluid (Umar et al., 2015).

In 2016, Slim explored the addition of polymers to a combination of paper grinding and fly ash to optimise a model that would be appropriate as a landfill liner component. He demonstrated the ability to improve the material's attractive engineering characteristics. Initial research reveals that polymer A has the maximum unit weight at one percent. This will turn into a tighter structure of packed soil and will have a low hydraulic conductivity. The material demonstrated the most consistent increase in friction angle, stability and shear strength with the addition of polymer B, rendering this combination the most appropriate for production (Slim et al., 2016).

In 2016, Maritsa conducted an investigation into the viability of spilite, a mining waste material-product from the extraction of nickeliferous laterites, as an alternative base liner material in MSW landfills. Based on the findings of chemical and mineralogical analysis, it is a silicon-rich substance and is distinguished by the large proportion of sodium feldspar. Six major phases where chlorite and muscovite may lead to a reduction in the final hydraulic conductivity were found. The higher albite content, along with the existence of chlorite, is characteristic of greenschist rocks. (Maritsa et al., 2016)

In 2017, Hui and Qingbo reported study results on the usage of the coal gangue as material for landfill liner. The batch sorption analysis revealed that the gangue of coal demonstrated impressive sorption potential for the heavy metals Zn2 and Pb2 tested. Additionally, the concentrations of heavy metals in the coal gangue leachate were all smaller than the acceptable limit. Such attractive characteristics indicated the use of the coal gangue as landfill liner products, in combination with other materials or alone to preserve clay resources as well as recycle industrial solid wastes (Wu et al., 2017).

In 2017, Parastar enhanced the performance of geotextile clay liner structures. By modifying certain structural factors such as texture, geotextile density, type of clay, clay density, geotextile thickness, and punching needle density, a series of geotextile clay liner samples were manufactured. Sample self-healing properties were tested, and the findings were explained using an analytical model. It has been concluded that greater Montmorillonite composition of clay, overload pressure, needle punching density and density of clay have good self-healing characteristics and less hydraulic conductivity, while, hydraulic conductivity increases with rising water pressure (Parastar et al., 2017).

In 2018, J. N. Chen conducted experiments to evaluate two geosynthetic clay liners leachate hydraulic conductivity to coal combustion product. All geosynthetic clay liners contained granular sodium bentonite and had between needle-punched geotextiles. The results of this study are generally consistent with the existing body of information regarding the effect of chemical solutions on geosynthetic clay liners hydraulic conductivity. Nevertheless, the basic findings are peculiar to coal combustion product leachates. It is possible to achieve lower hydraulic conductivity to coal combustion product leachate by placing high effective stress prior to leachate permeation or by permeating the geosynthetic clay liners with deionized water prior to permeation, particularly for leachates with higher ionic strength (J. N. Chen et al., 2018).

In 2019, G. Chen studied the adsorption ability of Pb2 by the laterite-bentonite combination for use as waste landfill liner. The test results demonstrated that the absorption of Pb2 by laterite-bentonite combination increases with an increase in contact time and bentonite amount and eventually reaches a concentration of equilibrium. The greater the bentonite component of the mixture, the less the equilibrium time. Although of the much higher adsorption potential of bentonite than laterite, the Pb2 adsorption rate of pure bentonite is around eight times that of laterite. (Y. G. Chen et al., 2019)

3. **CONCLUSION**:

The science of liners and bases, as can be seen from the above review, is not a finite study field. It is an emerging situation that needs scientists to remain attuned to the ever-changing science. It is eligible to take account that the soil alone would be sufficient to build a liner based on its acquired hydraulic properties. However, notwithstanding the financial advantages determined utilising the treated soil–various materials blend, the utilisation of this industrial result rather than removal will help in enhancing related environmental problems. The parameters governing the performance of liners include soil hydraulic properties, initial water content, liners thickness, and site specific weather conditions. The performance of liners is influenced by those factors. This review has addressed the significant issues about how the materials of liners effects liner performance, and suggested that coefficients are needed to improve liner performance. The determination of coefficients is complicated.

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