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Effect of PH Changes on the Geotechnical Properties of Clay Liners in Landfill

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ABSTRACT:
Nowadays the proper sanitary disposal of waste is considered as one of the main options in waste management. The chemicals produced from landfills' leachate affects the structure and characteristics of clay layers, so based on the acidity/basicity state of leachate, the study of the geotechnical properties of clay layers under the influence of these materials is very important. Therefore, in this research, the effect of PH variation on the geotechnical parameters of the soil was investigated by conducting a series of Atterberg limits, permeability and consolidation experiments on kaolinite clay and kaolinite mixture with different percentages of bentonite. In these experiments, acetic acid and sodium hydroxide were used as chemical agents representing leachate. Permeability parameters were measured via falling head method. The results of experiments show that the presence of acid and base in the kaolinite clay and the kaolinite mixture with different percentages of bentonite increases the liquid limit, plastic limit and permeability of the soil, as well as increasing the level of settling and accelerating the consolidating process. Addition of 10% bentonite also enhances the liquid limit from 36 to 41 (13%), and the addition of further 10% bentonite enhances the liquid limit from 36 to 46 (27%) at pH=7. Soil settling increases 6% when exposed to acetic acid and 17% in light of exposure to sodium hydroxide in kaolinite Permeability index is enhanced 14% with the addition of acid and 25% with the addition of base in kaolinite. increasing of 10% in bentonite to the same sample of kaolinite soil reduces the permeability index from 21% and an addition of further 10% of bentonite, decreases the original permeability index from 1.42×10^{-7} to 0.61×10^{-7} at PH=7.

Key words: Geotechnical parameters, Leachate, Atterberg limits, Permeability, Consolidation.

ORIGINAL ARTICLE
Received 21 Jun. 2018
Accepted 14 Dec. 2018

1- Introduction

Leachate is a brown and smelly substance that leaks out of the waste material and includes soluble and floated materials. Most landfill sites are made through decomposition of organic and liquid matters, which may be related to external sources such as drainage of surface waters or rain and else, that is due to the underground resources involved. Leachates have a wide range of pH variations and also could have high concentrations of several contaminants simultaneously, which are hazardous even in low amounts and affect the geotechnical structure of the soil [1]. One of the most important contamination factors in the landfill site is the amount of leachate release, pH variations involved and the gas produced by the decomposition of organic waste [2]. Among soil, the presence of Special Surface Area (SSA), very low permeability and Cation Exchange Capacity (CEC) of clays altogether have caused these soils to be widely used in environmental geotechnical researches. Also, in the geo-environmental engineering, clay soils are considered as the best protective and absorbent layers of environmental pollutants [3].

The sanitary disposal of waste varies based on geographical location, groundwater level and the amount of available soil to cover the waste. In designing process of hygiene, engineered landfill, the separation of the contaminated environment from the leachate is carried out from the outside by the layers of seals. Usually the seals layer used in the hygiene landfill is made of compacted clay layers and in many cases due to presence of clay the permeability of the landfill reduces in order to prevent the spread of leachate liquid to the surrounding area [4],[5].

The advancement of technology and the ever growing population of people have made waste recycling as one of the most important challenges regarding environment and human related factors in different countries. Today, due to the importance of the environment and the rapid growth of science and technology in line with maintaining the environment, different solutions have been taken into consideration [6].

Large areas of land ecosystems are at risk due to human activities, so that, along with the development of the societies and their industrialization, comes the casualties; the mismanagement of the waste transfer from various industries in addition with the influx of pollutants and sewage into groundwater and soils, environmental health is threatened, so are the inhabitant creatures. Soil as the main part of the land ecosystem is not safe from this threat. Soil hosts the life once there'd be a balance between living and nonliving components. Organic elements control important soil attributes such as fertility, nutrient cycle, mineralization processes, availability of elements and soil stability [7].

With the advancement of technology and population growth, the spread of pollution has risen dramatically in different parts of the world, especially in industrial and agricultural areas. Soil, a source which has one of the longest reproducibility cycles, has played an important role in the organic and non-organic elemental cycle, and as a dynamic environment, affords life of the creatures. Soil pollution holds increasing dangers for health of mankind and of the environment [8].

Each year thousand tons of ingredients which are resulted of urban, industrial and agricultural activities invade the soil. The studies of various compatriot researchers show that the increase of industrial activities of the country on one hand, and failure to execute environmental protocols and standards by the owners of industries on the other hand, have led to environmental pollution crisis in some areas [9].

Geo and Wang also emphasized the effects of high pH variation range on the geotechnical behavior of clays, discussed this behavior and concluded that pH changes can reduce some parameters' rate such as wet weight and dry weight [10].

Kebria et al., in their research measured chemical and biological parameters of leachate and studied their effect on acidity potential and basicity amount of the soil. The results indicate that the decomposition of organic matters of leachate in the soil produces compounds of weak organic acids and carbon dioxide that can modulate pH amount of the soil [11].

Mohebbi et al., explained the essays published regarding the effects of leachate on the behavior of clay, therefore providing with a general view about the nature of leachate and its effects on clay behavior and ultimately concluded that by taking in consideration of these results they are able to design and execute optimal landfill sites. In addition, the acidic and basic chemicals in the vicinity of the clay increase liquid limit and plasticity index of the soil, 'though its plastic limit remains almost unchanged. Also the time period in which chemicals remain adjacent to clay liner is effective on their impact on clay permeability. Therefore, it could be resulted that the permeability of clay liner on landfill sites increases with passing of the time and the increasing duration of time that they are exposed to the leachate [are in its adjacency] [12].

Maleki et al. generally reviewed a number of laboratory-based studies. Basically, the results have proved that a growth in percentage of soil contamination leads to variations in the soil's permeability rate, Atterberg limits and simply its strength parameters [13].

In another study, Badv examined the effects of concentration amount of synthetic leachate on clay. It was found out that 1000-mg/l-calcium containing leachate results in a 13-percent-reduction of the soil's permeability rate, it could be due to the deduction of porosity which in its own way is affected by consolidation [14].

Owhadi et al. developed a thesis in which the variation manners of plastic and permeability behaviors of bentonite in the presence of organic pollutants and heavy metals were compared. In that study, the Atterberg limits and consolidation tests and experiments on the bentonite samples contaminated with heavy metals were compared.This ultimately revealed that by increasing the concentration in the presence of an organic pollutant, the plasticity index is reduced while the hydraulic conductivity coefficient of bentonite is grown [15].
Ghadak et al. in their paper entitled 'the effect of pH variation on the strength properties of clay' also found out that the type of chemicals which are combined with clay, as well as the constituents [ingredients] of the clay are of the major points regarding strength properties changes [16].
These surveys show that investigating the effect of pH variation on geotechnical properties is essential for sealing landfill clay liner. The goal of this research is determining the relationship between pH changes (pH:4-10) and Atterberg limits, permeability and consolidation .

2- Materials and methods

The soil types used in this research, kaolinite and bentonite are extracted from the mines located in the city of Mashhad in Iran. The chemical compound of kaolinite and bentonite is depicted in table1 and 2.

Table1: The chemical compound of kaolinite

K_2o	Loi	Na_2o	Mgo	Al_2o_3	Fe_2o_3	Cao	Sio_2
0.25	10.98	0.12	n. d	27.05	0.91	0.44	55.25

Table 2: The chemical compound of bentonite

Loi	Na_2o	Mgo	Al_2o_3	Cao	Sio_2
10%	2-4%	2-4%	8-15.1%	1.5-4%	50-55.2%

Three types of soils including, pure kaolinite, kaolinite with 10% and kaolinite with 20% bentoniteis investigating research. Table 3 shows the compounds of the clay used in this project. Considering the constituents of the soil, the potential reactions with chemical substances that were used, are put into discussion.

Table 3: The original samples of clay in the research

Samples compound	Abbreviation
Pure Kaolinite	K
Kaolinite + 10% bentonite	Kb10
Kaolinite + 20% bentonite	Kb20

The kaolinite particle size distribution is carried out using hydrometric method in accordance with ASTM D422-63 standard. Which is presented in Figure. 1.

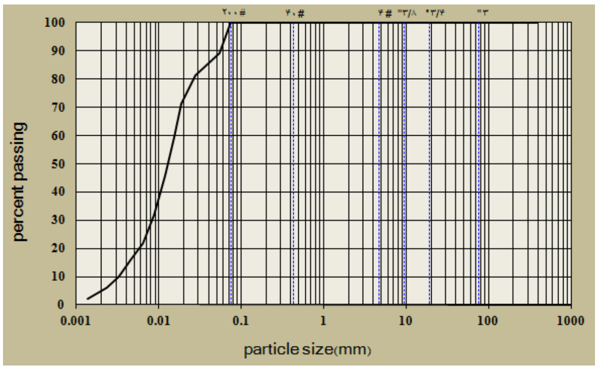

Fig.1. Particle size distribution

In order to determine the liquid limit and plastic limit, experiments were conducted according to ASTM No. D4318 standard, and then these experiments were confirmed as plastic limit, liquid limit and plasticity index the experiment was repeated twice to determine the liquid limit and the plastic limit, the results of which are shown in Table 2.According to the united soil classification system, these experimental soil could be classified as low plastic clay (CL). The classification and Atterberg limits of soils PH=7 is shown in table 4.

Table 4: The Atterberg limits and classification of examined soils at PH=7

PI	PL	LL	USCS	sample
10	26	36	CL	**k**
17	24	41	CL	**Kb10**
25	21	46	CL	**Kb20**

The main and major factor related to the influence of leachate on the soil is PH variations, of a range which differs over time. Therefore, in order to simulate the effect of acidification and basification of leachate on the soil, artificial leachate is utilized. The artificial leachate used in this project is acetic acid and sodium hydroxide. The PH value of acetic acid and sodium hydroxide was chosen from 4 to 10.

In consolidation, after providing the samples, the amount of water required to saturate the samples was determined with PH value of 4, 6, 7, 8, and 10 and then was placed in the consolidation machine/equipment. After the saturation phase of the samples, loading phase were executed in five steps and respectively with values of 50, 100, 200, 400, 800 kPa.

The duration of each loading step and the recording of soil settlement results would go on to continue for up to 24 hours later. During the period, the deformation value of the sample indicated by the machine's pointer were read at times included; 0.1, 0.25, 0.5, 1, 2, 4, 6, 8,15 and 30 minutes and 1. 2. 4. 8 and 24 hours.

To investigate the effect of PH on the soil permeability parameter, a permeability test was carried out through falling head method using a permeability mold rigid wall according to ASTM D 5856-95. These tests were conducted at PH values of 4, 6, 8, and 10. In order to add the required moisture content, drying the soil in the oven was avoided, because this action causes the molecular evaporation of the clay and changes its properties. To prevent such a problem, before each experiment, the soil moisture content was measured and as much water needed was added to reach optimum moisture content.

After saturation and before the start of the experiment, the air bubbles formed in the sample (due to acidic or basic chemical reactions with/to the soil) were carefully removed from the tubes, so that no errors would harm the results.

3- Results

3.1. Effects of PH changes on LL, PL, PI

As shown in Figures 2 to 5, soil PH variation due to the addition of acid or base, increases the liquid limit, while leaving the plastic limit significantly unchanged. As a result, the plasticity index of the soil increases. On the other hand, by adding bentonite to the soil, the susceptibility to chemicals is increased and by doing so; the variation range of the liquid limit and plasticity index enhances due to variation of PH.

By the addition of 10% bentonite to pure kaolinite value of plasticity index increases from 10 to 17 and Furthermore, the addition of 20% bentonite to pure kaolinite increases the value of plasticity index from 10 to 25 at PH=7.liquid limit index increases 13% when exposed to acetic acid and 27% in light of exposure to sodium hydroxide in kaolinite at PH=7.

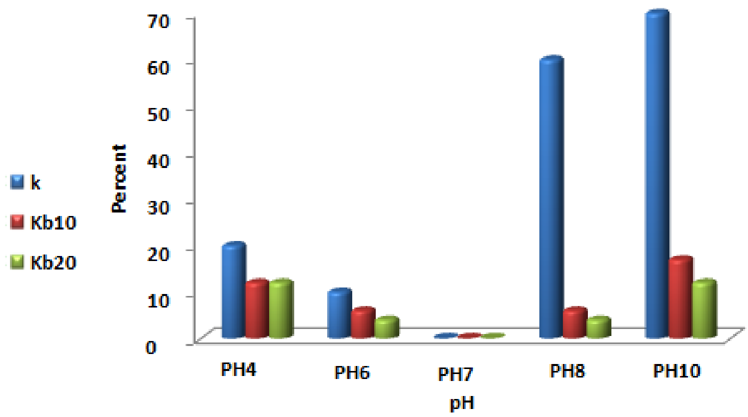

Fig.2. Percentage plasticity index variation range versus pH variations for examined soils.

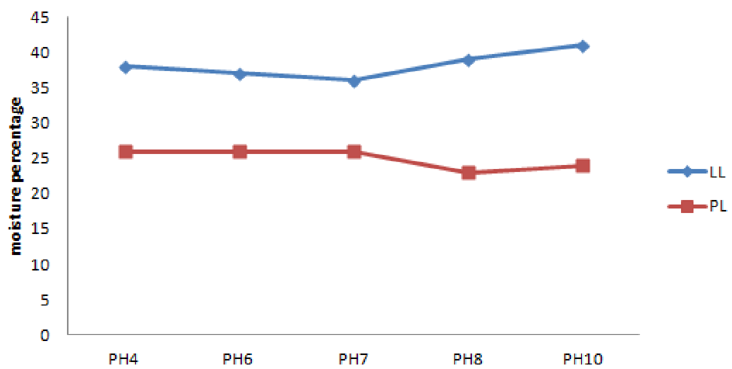

Fig.3. Atterberg limits variation range versus PH variations for k.

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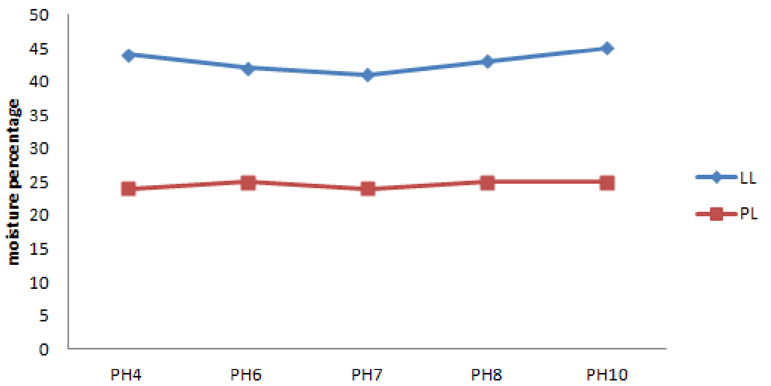

Fig.4. Atterberg limits variation range versus PH variations for kb10.

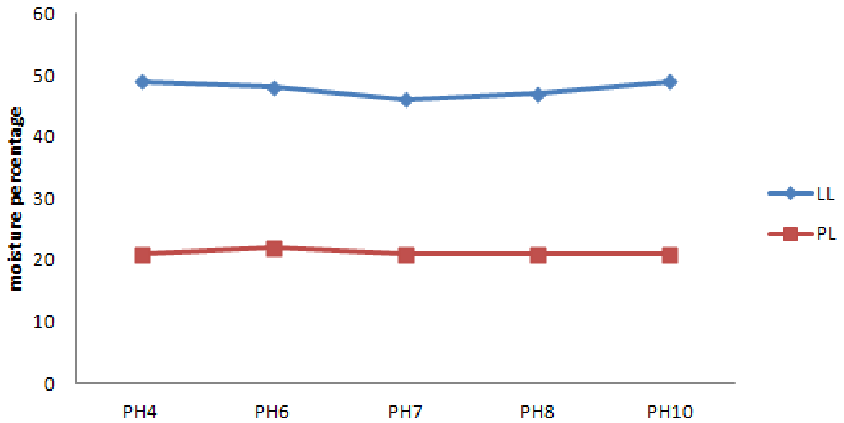

Fig.5. Atterberg limits variation range versus pH variations for kb20.

3.2. Effects of PH on consolidation

Figure 6 displays variation of the compression index of kaolinite clay and also the mixtures of kaolinite and bentonite against PH variation. According to the chart, when acid content increases, the compression index value rises on the average up to 6% and when the base content increases, the same value rises averagely 17% compared to original kaolinite at PH=7. Also, the compression index averagely increases up to 17% compared to the pure kaolinite soil when 10% bentonite is added at PH=7.futher more addition of 20% bentonite in increases 35% compression index compared to pure kaolinite at PH=7.

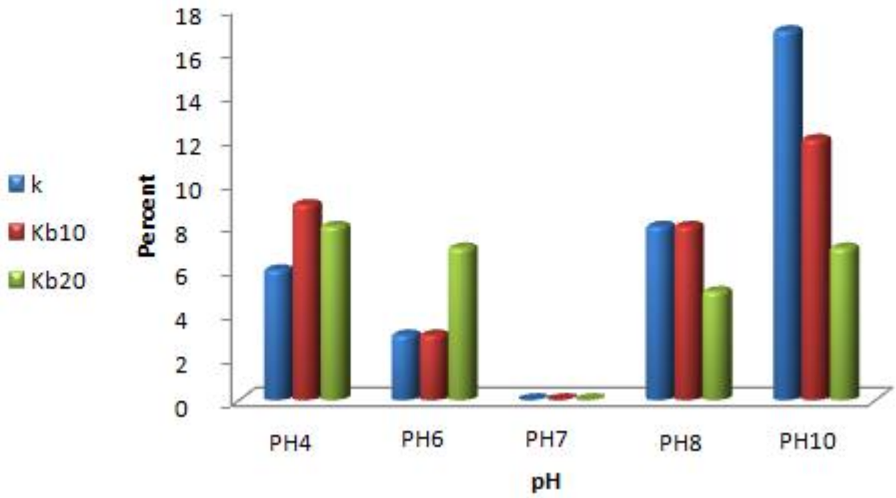

Fig.6. Percentage Compression index variation based on PH changes.

Figure 7 shows the variation of swelling potential of kaolinite clay and also the mixtures of kaolinite and bentonite with pH values altered. According to this chart, the increase in acid content leads to an average amount of 7% rise compared to the original kaolinite at PH=7. Increase in base content leads to 14% rise compared to the original kaolinite soil. By addition of 10% bentonite to pure kaolinite value of swelling index increases 14%,and furthermore, the addition of 20% bentonite increases this value to 28% at PH=7.

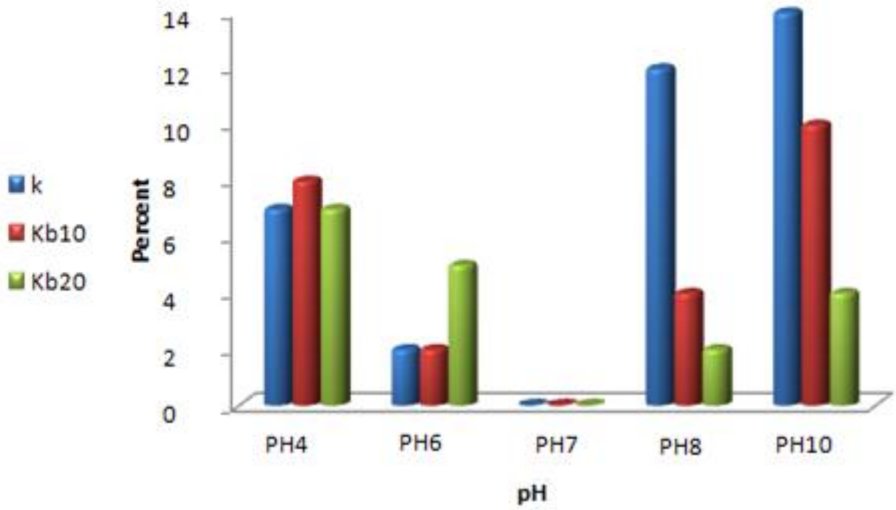

Fig.7. Percentage swelling index variation based on PH changes.

3.3. Effects of PH on permeability

Figure 8 show that kaolinite has a lower permeability by itself than the other compound hydroxide in kaolinite Permeability index is enhanced 14% with the addition of acid and 25% with the addition of base in kaolinite. Increasing of 10% in bentonite to the same sample of kaolinite soil reduces the permeability index from 1.42×10^{-7} to 0.74×10^{-7} (21%) and an addition of 20% bentonite, decreases the original permeability index from 1.42×10^{-7} to 0.61×10^{-7} at PH=7.

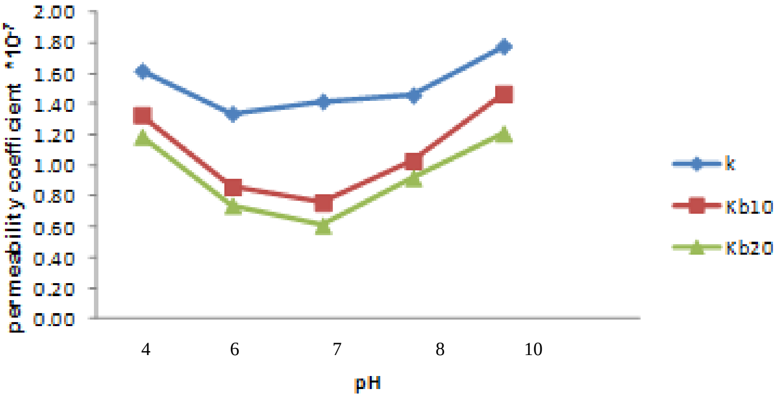

Fig. 8. Permeability variations based on PH change.

4- Conclusion

Based on conducting a series of laboratory experiments such as Atterberg limits, permeability, consolidation of the clay, combined with kaolinite and also the mixture with bentonite in the presence of acetic acid and sodium hydroxide, the following results were observed:

1- Adding 10% bentonite increases the liquid limit from 36 to 41 by 13%, and the plasticity index from 10 to 17, adding 20% bentonite to kaolinite, increases the liquid limit from 36 to 46 by 27% and the plasticity index from 10 to 25. When acetic acid and sodium hydroxide are in the vicinity of kaolinite clay and the mixtures with bentonite, the liquid limit and the plasticity index are increased, but liquid limit remains significantly unchained. The reasons behind these findings are the growth of soil activity or dynamic and increased ability to absorb and maintain water by bentonite.

2- Adding acetic acid or sodium hydroxide to kaolinite soil swelling increases the compression index as well as the swelling value. The further is the pH degree of the water from the value; 7, the more dramatic growth is observed in terms of compression index due to the interactions of clay minerals.

3. According to the results of the permeability test via falling head method, increasing of 10% in bentonite to the same sample of kaolinite soil reduces the permeability index from 1.42×10^{-7} to 0.74×10^{-7} and an addition of 20% bentonite, decreases the original permeability index from 1.42×10^{-7} to 0.61×10^{-7} at PH=7. Furthermore, sodium hydroxide proved to have a greater impact on the permeability value of the soil in comparison with acetic acid.

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