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Effects of biological soil improvement method on leakage of waste leachate from engineering landfill liners

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Abstract

Biological soil stabilization is a new and environment friendly method of soil improvement. In this method the urease activity of a bacteria cause the precipitation of the calcium carbonate in the soil medium. This method has been performed by injection of solutions to the soil which are contained the needed materials for initiating the process. Besides the soil properties such as soil grading, porosity, etc., the cementation solution properties affects the obtained results of this method. The latter properties include injection method, solution concentration and PH. As a result, this process causes the bounding of the soil grains. Another important result of the mentioned method is decreasing the permeability of the soil. In the present paper, an engineering landfill liner is modeled by SEEP/W software to evaluate the effect of the biological soil improvement method on controlling the leakage of the waste liquids around these landfills.

Keywords: Soil improvement, biological method, permeability, cementation solution, landfill liner.

1. INTRODUCTION

When wet wastes are dumped in a waste disposal, a viscous liquid is leached as time is lapsed. This liquid which consists of numerous and usually toxic elements is called leachate [1,2]. Leachate flows through the wastes and gather at the bottom of the landfill. Therefore huge amount of this dangerous liquid will be in contact with the soil layer beneath the landfill. This accumulated leachate is penetrated through the beneath soil layers by different mechanisms and eventually enters the aquifer. Increase of the concentration of these materials may exceeds the available standards, hence the aquifer become toxic. To prevent the mentioned process in landfills, different engineered layers are constructed [3,4]. CCL liners are usually used as the leachate barrier system in the solid waste disposal facilities because of their low permeability and adequate compactibility and strength. However, shrinkage cracks may appear in the clayey liners and cause the seepage of the leachate and therefore decreasing the efficiency of the landfills through their lifetime [5]. Hence, in this paper the clayey landfill is replaced by a biologically improved soil system to evaluate the efficiency of the proposed system as leachate barrier system against the advection mechanism.

2. BIOLOGICAL SOIL IMPROVEMENT:

A new grouting material, biogrout, has been developed in recent years [6,7,8]. Biogrout has low viscosity in solution and thus can penetrate better than cement or chemical grouts. The other advantages of biogrout over dissolved organic grouts are lower cost and lower toxicity [7]. Bioclogging is a process of filling the pores in soil with minerals and other substances that are generated microbially to reduce the soil permeability. Biocementation is a process to bind soil particles together with minerals and other substances to increase the compressive strength of soil. A common process for bioclogging and biocementation is microbially induced carbonate precipitation (MICP). As bioclogging and biocementation take place simultaneously most of the time, the two terms are used to refer to mainly the purposes of applications rather than the processes in practice. MICP can be either a natural or engineered process that is controlled by different factors and through different mechanisms [9]. One of them is the production of calcite in the porous soil by ureaseproducing bacteria (UPB) in the presence of urea, calcium ions, and either pure or enrichment cultures[7]. This process is performed as follows:

$$CO(NH_2)_2 + 2H_2O + Ca^{2+} + UPB \rightarrow CaCO_4 + 2NH_4^+ + UPB \quad (1)$$

The MICP process can be used for numerous applications in geotechnical and environmental engineering such as reduction in soil permeability through bioclogging [7]. It has been demonstrated in the laboratory that the MICP process can significantly reduce the permeability of sand [10]. In this paper the latter application of MICP is used to replace a clay liner of an engineering landfill to evaluate its applicability to prevent the pollution transmission by advection process.

3. ENGINEERING SANITARY LANDFILLS

Nowadays, engineering sanitary landfills are used in the most of the developed countries around the world [11]. These landfills consist of different engineering layers to manage the leachate. Fig. 1 depicts a schematic view of a non-engineering landfill. This figure shows a conventional landfill that has no engineering layer, i.e. liner and drainage layer. Fig. 2 shows a landfill with an engineering layer comprise of a clayey liner that works as a leachate barrier system. The main disadvantage of these clayey liners is the cracks which are caused by shrinkage of the layer and therefore questioned the efficiency of the layer in the long time.

4. NUMERICAL SIMULATION

To model the seepage of the leachate through a landfill the SEEP/W program from the Geostudio package is used. In all models the advection is considered as the dominant mechanism. The first model is considered a 2D landfill like the one depicted in fig. 2 with the width of 30 m and height of 10 m. clayey liner has the

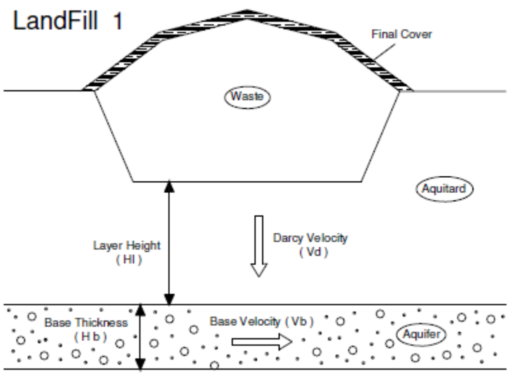

Figure 1. Schematic view of a non-engineering landfill

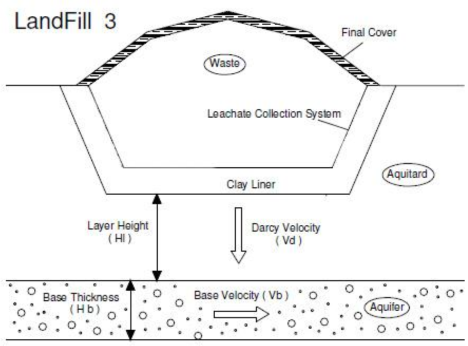

Figure 2. Schematic view of an engineering landfill with a clayey liner

thickness of 1 m and saturated hydraulic conductivity of $1*10^{-9}$ m/s. The underlain soil is unsaturated and considered as the underlain soil of the Urmia Nazlou sanitary landfill with saturated hydraulic conductivity of $4.7*10^{-2}$ m/s [12]. The function of the hydraulic conductivity versus matric suction is considered as fig. 3 based on the Van Genuchten estimation. The ground water is at 20m below the bottom of the landfill. Fig. 4 illustrates the geometry of the problem and thickness of the different layers.

In the second model, the clayey liner is replaced by a biologically improved sandy layer with a drain system. The improved sandy layer characteristics are defined in the software based on the obtained results of the tests performed in the geotechnical laboratory of Sahand University of Technology. The sand used is categorized as SP based on the unified standard [13]. Improvement process is performed by the *Sporosarcina Pasteurii* based on the percolation method [14-20]. Then matric suction of the specimens is evaluated by filter paper based on ASTM 5298. The graph which shows the matric suction versus volumetric water content is obtained based on the calibration diagrams of the mentioned standard. At the end function of the hydraulic conductivity versus matric suction is drawn based on Van Genuchten estimation using the SEEP/W software (fig. 5). Drainage system consist of pipes with intervals of 2m is implemented at the bottom of the landfill (fig. 6).

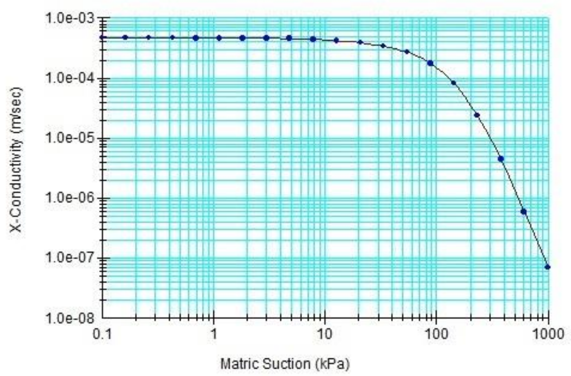

Figure 3. Matric suction versus conductivity for natural soil

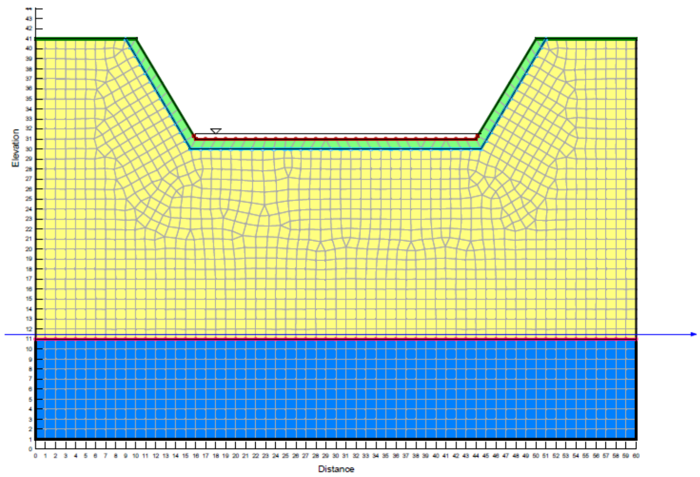

Figure 4. Landfill geometry and thickness of the different layers

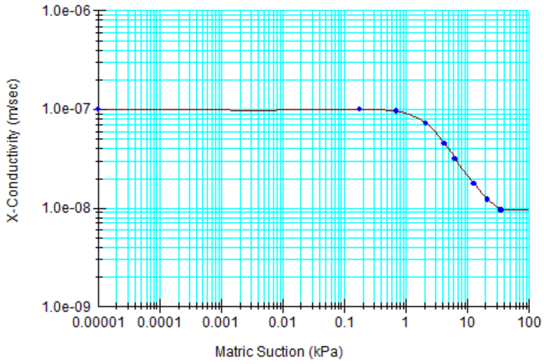

Figure 5. Matric suction versus conductivity for improved soil

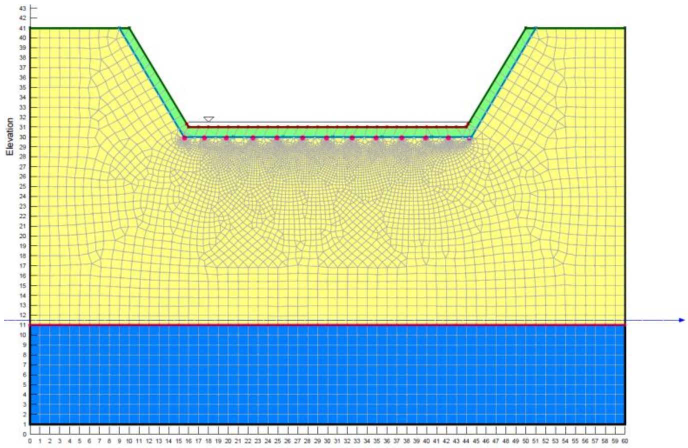

Figure 6. Landfill geometry and mesh formation for improved soil with drainage system implementation

The leachate flux to aquifer is calculated for the improved sand layer and compared to the results of the clayey system (fig. 7). As could be seen in fig. 7 the improved sand with drainage system shows adequate performance against the leachate flux to the aquifer. The reduction in the leachate flux could be seen, even more than the clayey liner, in the middle points in the graph (where the drainage system is implemented). Although biologically improved soil can’t perform like the clayey liner by itself to decrease the contamination transport flux (because of the difference in permeability). However, using a drainage system with the improved soil liner can be considered as a clayey liner and even better. The main advantage of the mentioned hybrid system is the overcome to the probable shrinkage cracks and the huge amount of leachate leakage through them.

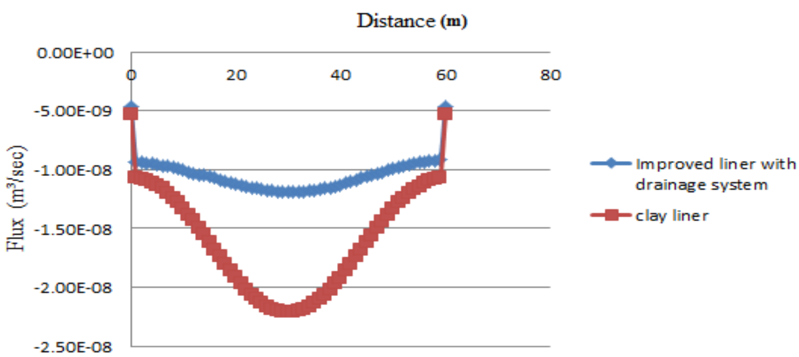

Figure 7. Contamination flux change at the aquifer level

5. CONCLUSION

Clayey liners are among the engineering sanitary landfill elements. These liners prevent the transportation of the leachate to the natural soil layers and eventually aquifer. However, the mentioned layers could suffer from the shrinkage cracks and lost their efficiency. Therefore, substitute the clayey liner with other systems looks rational. Since in MICP, permeability is reduced greatly because of bioclogging mechanism, so in this paper the clayey liner is substituted by the biologically improved liner. The flux of the leachate at the level of the aquifer is compared for both clayey and improved liner systems. The obtained results show that the proposed system has an adequate efficiency to control the contamination flux into the ground water. It is concluded that the use of the biologically improved liner with drainage system can perform like the clayey liner and even better.

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