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Effect of Urban Wastewater on Chemical, Physical and Mechanical Properties of Soil (Case Study: Central Area of Mashhad)

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Abstract

Chemical changes in the soil have a significant effect on its physical and mechanical properties and the rate of settlement. In this research, the effect of urban wastewater on chemical properties and soil engineering characteristics such as Atterberg limits, uniaxial compressive strength and consolidation parameters in central areas of Mashhad have been investigated. Based on the results, some chemical parameters such as Ca, Mg, Al and K decreased after the soil samples has been saturated by wastewater. Also, changing the chemical properties of the soil has changed its physical and mechanical parameters. For example, the consolidation parameters of the selected soil indicate that the (Cc) has increased over time with changes in the concentration of input wastewater. Also, the (Cs) has decreased over time and the rate of change in high concentrations is less. In addition, the results show that low concentrations of wastewater in short time have the greatest effect on reducing the uniaxial strength of soil. An examination of the electron microscope images shows that when the soil sample is saturated with wastewater, a layer of salt is accumulated around the soil particles, which expands the size and surface of the particles and also tends its structure towards the grain pattern. Therefore, simultaneously, the two factors of time and the change in concentration of wastewater affect the physical and mechanical parameters of the soil, and the effect of concentration on the time is more indicative.

***Key words**: Wastewater leakage, Physical properties, Mechanical properties, Chemical composition, Soil pollution, Central of Mashhad*

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Extended Abstract:

1. Introduction

Soil Pollutions by Wastewater in urban areas is a common and growing phenomenon which was a subjects of many studies in the past decades especially from environmental impacts aspects(Beigi & Bani Talibi, 1392; Khodadadi & colleagues,1394; Kharat Sadeghi & Karbasi, 2007; Delijani et al., 2009; Tamasi & Cini, 2004; Singh et al., 2002; Harikumar & Jisha, 2010).) In addition to environmental effects, changing the geotechnical properties of polluted soil such as soil strength are the other important subjects in the urban area. Reduce of soil strength less than of the accepted design values will be resulted to non-allowable foundation subsidence and structure damages (Oahadi et al., 2012. Today it is known that contamination of soil will be affected some of the engineering properties of soil such as permeability, internal friction angle and Atterberg range (Estabragh et al., 2011, 2015.) The study area is the central part of Mashhad metropolis in northeastern Iran. Geologically, Mashhad is located at the eastern end of Mashhad plain between two basins of Kopet-Dagh in the north and Binalud in the south. Mashhad Plain is a tectonically subsidence area filled with young alluvial deposits originated from the north, south and south-west mountains. Soil texture in the study area in the central part of Mashhad city is mainly clayey silt along with the silty sand horizons. The study area has a high construction density and many important structures such as city center, two subway lines, many hotels, and various important commercial buildings and especially holly shrine of Emam Reza(a.s) one of holiest places in Muslim (exclusively Shia) world are located in this area.

Seepage of wastewater in the urban aquifer in recent years are consequences to rising of the groundwater table and contamination of soil foundation of engineering structures and increased the potential of structural subsidence and damages(Fig.1)

Fig. 1. An example of rising water level (wastewater) in the projects of the city center of Mashhad (Ghahremani et al., 2017)

2. Soil and wastewater samples

The required soil sample and wastewater were obtained from a deep trench (16 m high) located in the Mashhad downtown(Shohda squire). Different concentrations of wastewater samples are produced with mix of drinking water and wastewater. To simulate the natural soil conditions, 150 soil samples are reconstructed in PVC tubes with a diameter of 110 mm and insitu density. The soil samples were divided into four groups of A to D and each of the sample group are saturated by different wastewater concentrations (A, zero; B, 10%; C, 50%; 50, and D 100% concentration of effluent) for 4, 6, and 9 months duration. Table 1 shows the physical and chemical properties of wastewater and tables 2 and 3 show the physical properties and chemical analysis of the soil sample.

3. Tests results

Atterberg limits are performed according to the standard method (ASTM D 4318-10), and the results are presented in Figs 2 and 3 for samples keep saturated for 4, 6 and 9 months. The liquid and plastic limits of the original sample(reference sample) were 19.7 and 15.6, respectively. The results are normalized in terms of the reference sample(A). As can be seen, changes in the liquid limits in the four-month period low and the slope of curve variation became greater over the time for six and nine months which indicating the direct effect of exposure to the effluent. Therefore the results show that as the concentration of wastewater increases, the soil becomes more sticky over time. The increase in the liquid limit is due to the reduction in the size of the soil particles, which increases the special surface of the soil (Karkush and Abdul Kareem, 2016). The decrease of the plastic index in the samples is also due to the entry of the salt into the soil structure, which in practice changes the interstitial fluid, and directly affects the behavior of the clay (Cyrus et al., 2010). The presence of bipolar molecules of water between the soil particle is the main factor of the plasticity. However, when the clay particles are surrounded by wastewater, this property will be decreased (Kermani and Ebadi (2012); Elisha, 2012) Karkush et al., (2014); Akinwumi et al., (2014)). Abdullah et al., (1999) concluded that in the presence of organic matter less than 15 percent, soil structure is colloidal, but by the rise in organic matter soil particles tend to be detached and the soil specific surface will be increased. The increase in the specific surface and organic matter cause of improvement in the soil plasticity. In the presence of organic matter content less than 10%, the plasticity index gradually increases but more increasing in the organic matter content, result to decrease of plasticity index(Fig. 5).

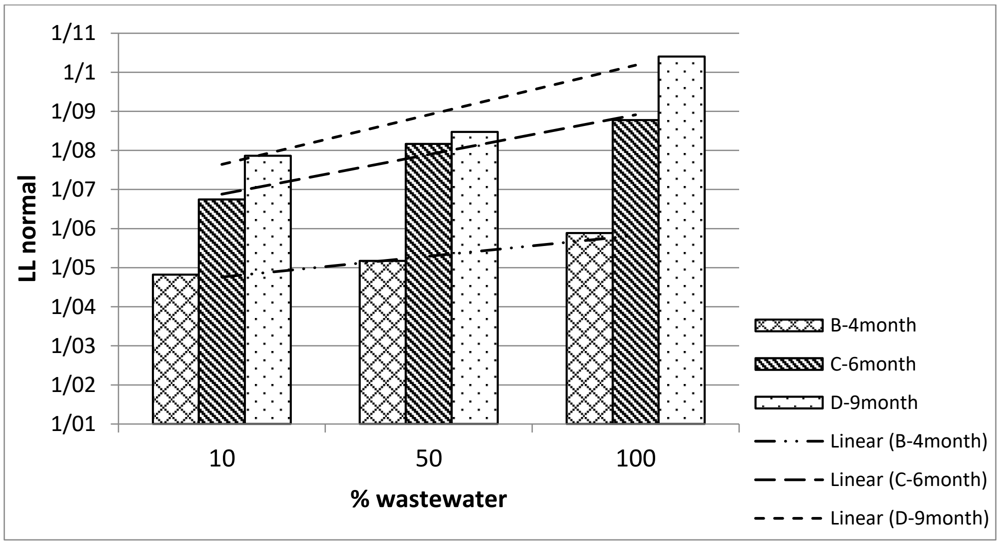

Fig. 5. Change in the liquid limit with time and infflient concentration (the Liquid limit of the samples is normalized to the initial value)

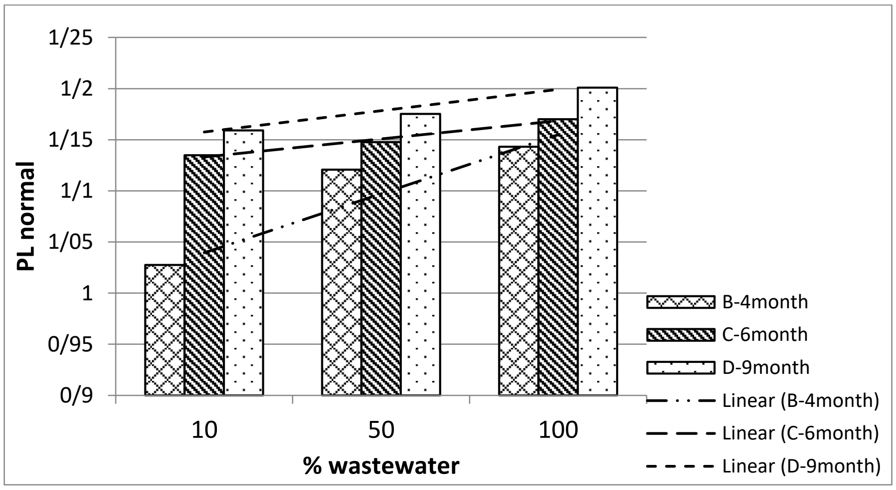

Fig. 3. Plastic limit changes with concentration and time (the plastic limit of the samples is normalized to the initial value)

Consolidation Test:

The test was performed according to ASTM D 2435 -11 and soil consolidation parameters including compression index (Cc) and swelling index (Cs) before and after exposure to wastewater were measured (Fig. 4). The results are normalized to the original values of Cc equal of 0.665 and Cs equal to 1.166.

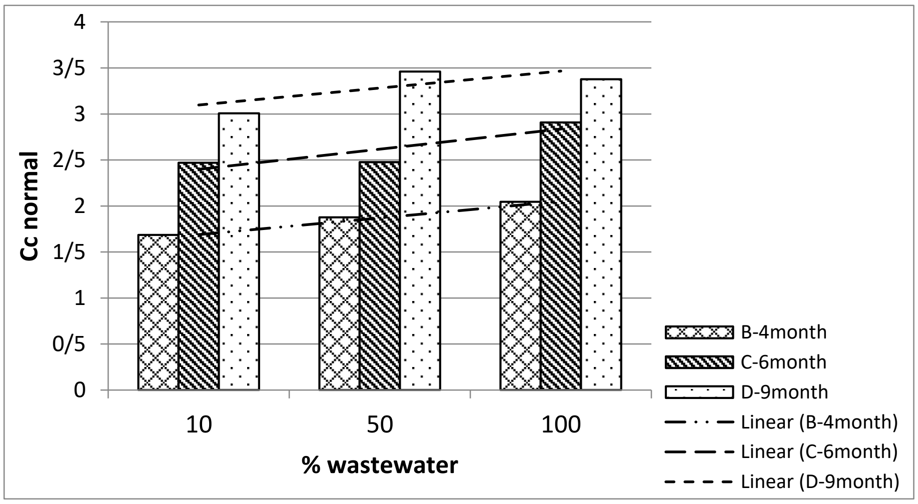

Fig. 4. Modifications of the compression parameters (compression index) with time and time (Cc samples are normalized to the initial value)

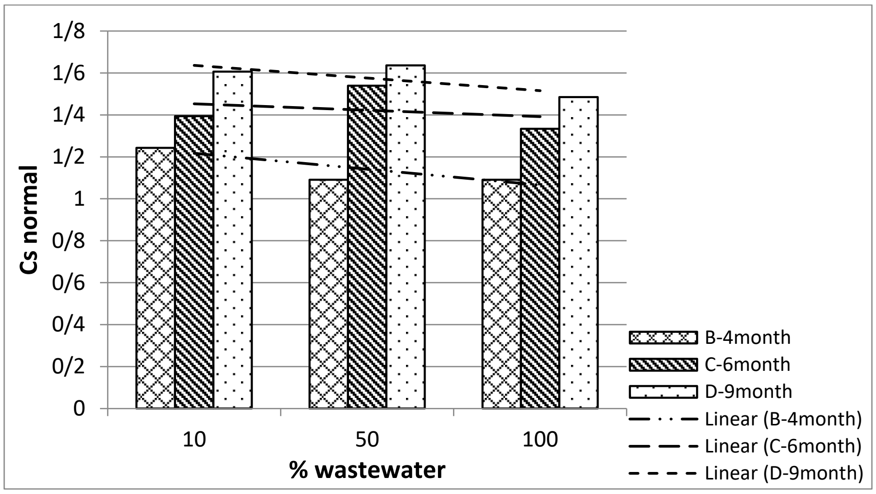

Fig. 5. Changes in consolidation parameters (inflation index) with concentration and time (Cs of samples are normalized to the initial value

Uniaxial Strength Test

These tests were performed according to the ASTM D2166-13 before and after saturated the soil with effluent. Fig.6 show the results of these tests.

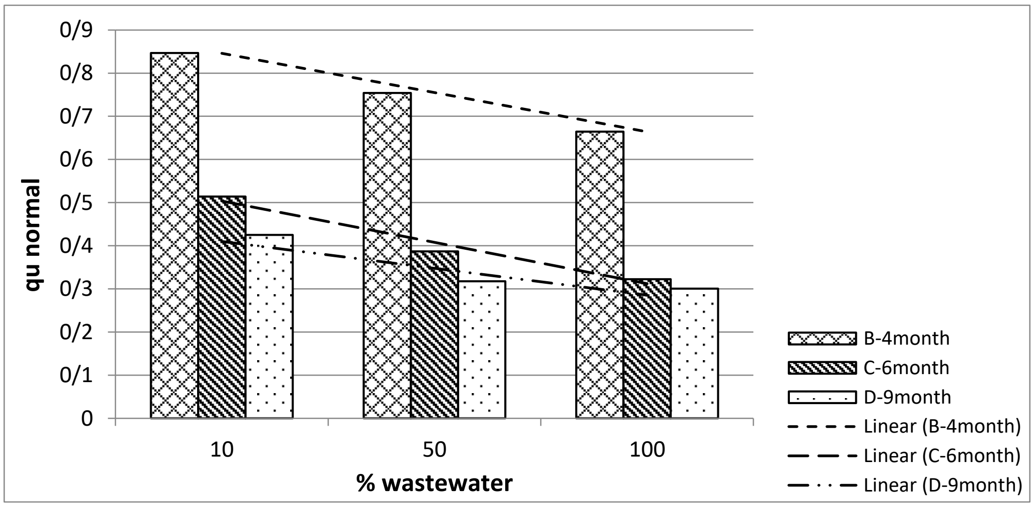

Fig. 6. Uniaxis strength variations with concentration and time, results are ronrmalized by uniaxial copmersion strength of original sample(qu=0.95 kg/cm2).

4. Conclusion

In this research, the effect of urban wastewater on the characteristics of fine-grained soil in the central area of Mashhad (Shohada Square) has been studied. The results showed during the different saturation times of 4, 6 and 9 months, the liquid limits of the samples 5.88, 8.77 and 4.1 percent increased, respectively. Also, the compression index (Cc) has increased over the saturation time as the concentration of wastewater rises, which can be indicative of the presence of more vacant spaces in the soil structure. At the same time, the swelling index (Cs) has decreased over time. The reason for this can be attributed to the growth of bacteria and fungi on the soil surface, which leads to clogging of soil, resulting in more compaction of soil structure. The uniaxial compression strength of soil also decreases with increasing the concentration of effluent and saturation time. However, the low concentration of wastewater in a short time has a greater effect on resistance reduction. The reason for this can be attributed to the changes made to the soil structure. The SEM images of samples show that the soil structure after the flushing with wastewater tends toward the grain pattern. Therefore, in the long run, chemical changes due to the proximity and mixing of effluent with fine-grained soil have altered its mechanical properties and could reduce the soil strength and can be leed to the ground subsidence.