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Effect of MSW Leachate on Soil Consistency under Influence of Electrochemical Forces Induced by Soil Particles

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Investigations on the effect of leachate from municipal solid waste on the soils in landfill sites usually focus on the effect of leachate compounds on the engineering properties of the soil. Leachate chemical composition and its effect on the consistency of soil are important factors for designing liner systems. Soil samples from the bottom of the Esfahan, Iran, landfill were collected. Leachate samples were collected within the a landfill and a composting factory leachate lagoon. Effects the leachates on cation exchange capacity, electrical conductivity, pH, and consistency of the soil samples were investigated. The chemical property of leachate showed that leachate from the compost factory was contaminated by higher concentrations of heavy metals (Cu, Zn, Pb, Cd, Ni, and Hg); higher concentrations of Na^+,Ca^{+2}, Mg^{+2}, and K^+; and higher EC; and were more acidic than the landfill leachate. Liquid limits and plastic limits of the soil were higher from the effect of the compost factory leachate in comparison with the values for landfill leachate.

Keywords: Consistency, landfills, leachate

1. INTRODUCTION

Accumulated municipal solid wastes (MSW) in landfills decompose by a combination of physical, chemical, and biological processes. Leachate is generated when water percolates through the waste in the landfill. The water can be from all forms of water that fall from the air or flow from the surrounding land into the landfill or from the waste itself. While the liquid moves into the landfill, many organic and inorganic materials are transported in the MSW leachate. As a result, various organic and inorganic compounds leach out from the solid waste [1]. Environmental or Adsorbed waters are under the influence of electrochemical forces induced by the colloid particles [2].

A compost factory in a landfill site is a good idea to compost out some portion of MSW to organic fertilizer, although it would produce compost leachate in the process [3].

Study of soil sensitivity to leachate in landfill site is important for designing a liner system. This study focused on the effect of leachate originating from the landfill and the compost factory on the consistency of the landfill soil.

2. MATERIALS AND METHODS

Soil samples were collected from the bottom of MSW landfill site, Isfahan, Iran for the laboratory research and prepared in accordance with BSI (British Standard Institution) 1377-1:1990 [4]. The physical properties of the natural soil used in the tests, such as particle density and Atterberg limits were determined in accordance with BSI 1377-2:1990.The soil also was characterized chemically and mineralogically.

Leachates from the municipal landfill and the compost factory lagoon were used in the tests conducted in this study. The major inorganic chemical components (Ca^{+2}, Mg^{+2}, Na^+, K^+, NH_4^+, Cl^-, SO_4^{2-}, and NO_3^-) were analyzed using the standard methods [5]. and heavy metals (Cu, Zn, Pb, Cd, Ni, and Hg) were measured by an Inductively Coupled Plasma Mass Spectrometer (ICPMS).

Initially, the samples were treated with 30% H_2O_2 solution and organic matters contained in the samples were completely decomposed. Then, the sample was prepared for $pH<2$ using HNO_3 [6]. The total hardness (Ca^{+2} and Mg^{+2}) was determined by titration with 0.02 N EDTA using black eriochrome-T as the indicator. The Ca^{+2} was titrated with 0.02 N EDTA using Calcon^{TM} as the indicator and the Mg^{+2} content was obtained by the difference between the total hardness and the Ca^{+2} content. The Na^+ and K^+ concentrations were determined using flame photometry. The Cl^- content was obtained by argentometric titration using $AgNO_3$ 0.1 N and K_2CrO_4 as the indicator, and SO_4^{-2} was obtained by gravimetry using $BaCl_2$. The NO_3^- concentration was measured using a potentiometric method [7].

The soil specimens were saturated with various leachate concentration ratios in distilled water ranging from 20 to 100% with 15 days curing time. Atterberg limits were determined in accordance with BSI 1377-2:1990. Cation exchange capacity (CEC) of the samples was measured at pH 7 with ammonium acetate [8]. Determination of pH and EC were carried out by the electrometric method, which gives a direct reading of the pH and EC values of a soil suspension in water.

3. RESULTS AND DISCUSSION

The soil was silty clayey sand (SC-SM) texture as defined by the Unified Soil Classification System. The physical and chemical results are given in Table 1. The soil sample contained 20% clay size fraction. Mineralogical analysis of the soil showed the presence of calcite, quartz, and montmorillonite.

The contents of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, SO_4^{-2}, Zn, Pb, Cd, Ni, and the electric conductivity (EC) in the leachate of the compost factory were higher in comparison with the contents of the leachate from the landfill (Table 2). The leachate from the compost factory was acidic (pH 4.5), while the landfill leachate pH was 7.14. High EC values indicated the presence of dissolved inorganic materials in the samples [9].

The CEC value of the soil increased with increase in volume leachate concentration in distilled water (Figure 1).

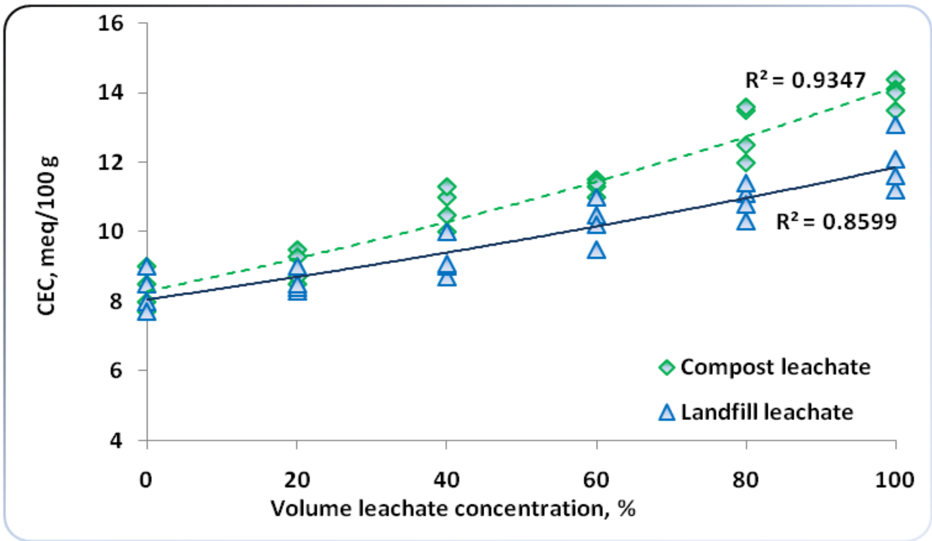

Figure 1. The soil CEC versus volume leachate concentration

The effect of landfill leachate in increasing the CEC of the soil was less than the effect of compost factory leachate. Increase in the soil organic matter could increase the CEC (Stevenson 1994). Although clay size fraction was 20%, a low content of Al_2O_3 (6.04%) and SC-SM texture suggests that the native soil CEC was not under influence of montmorillonite (Table 1). The levels of Na^{+}, K^{+}, Ca^{+2}, and Mg^{+2} present in the leachate of the compost factory were sufficiently high that they could effectively exchange some of the cations present in the native soil during advection and diffusion. This reaction could expand the native soil double layers [9-10-11-12-13-14-15-16]. The sensitivity of soil to environment is hinged not only to the local environment but is also influenced by naturally inherited mineral structure, initial CEC, and length of time.

The decrease in the soil pH caused by adding compost leachate was greater in comparison to that caused by adding landfill leachate (Figure 2). The pH is an important indicator of the leachate as a pure fluid of the soil. During the biological decomposition process and increase in the leachate age in the landfill, the production of acids decreased [9]. In essence, decreasing the soil pH can cause changes in the soil-water structure, the soil-water adsorption, and movement of the pore fluid. Low pH conditions favor the soil particles to aggregate and reduce the soil inter-particle repulsion [2].

A significant increase in EC of the soil by the compost factory leachate was observed (Figure 3). This result can be explained as an increase in EC of pore fluid because of an increase in leachate constituent acting as charge carrier [9]. Electrical potentials of the soil may also give rise to movement of leachate and may cause change in the soil porosity [2].

Table 1. Chemical and physical properties of the soil.

Property	The soil sample
Specific gravity	2.68
Liquid limit (%)	39
Plastic limit (%)	25
Plasticity index (%)	14
Unified Soil Classification	SC-SM
Clay size fraction (<2µm, %)	20
EC ds/m	5.1
pH	7.6
CEC meq/100 g	8.3
AL_2O_3 %	6.04
MgO %	1.25
CaO %	30.56
Fe_2O_3 %	1.30
TiO_2 %	0.22
SiO_2 %	23.71
Na_2O %	1.3
K_2O %	0.6
SO_3 %	0.2
P_2O_3 %	0.02
Loss on ignition %	34.80

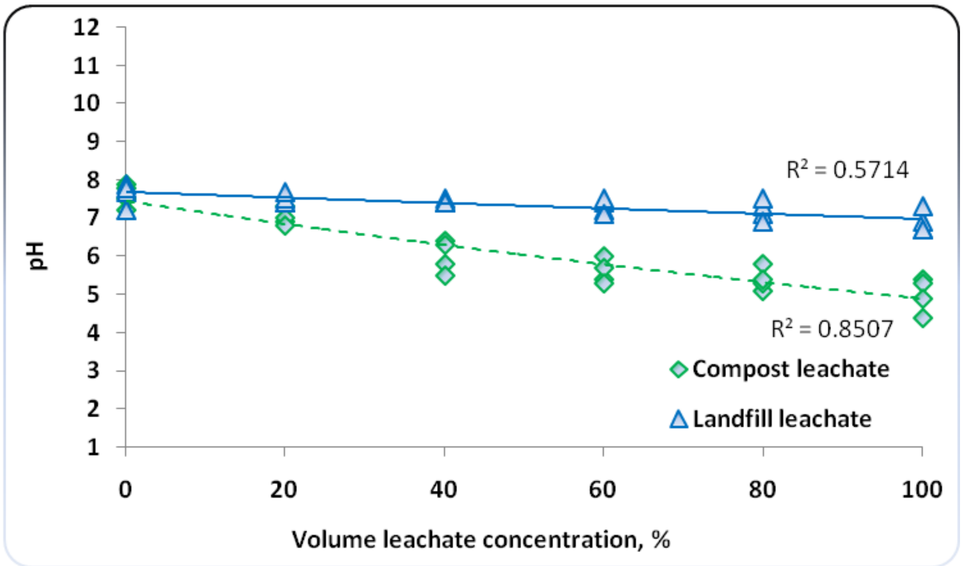

Figure 2. The soil pH versus volume leachate concentration

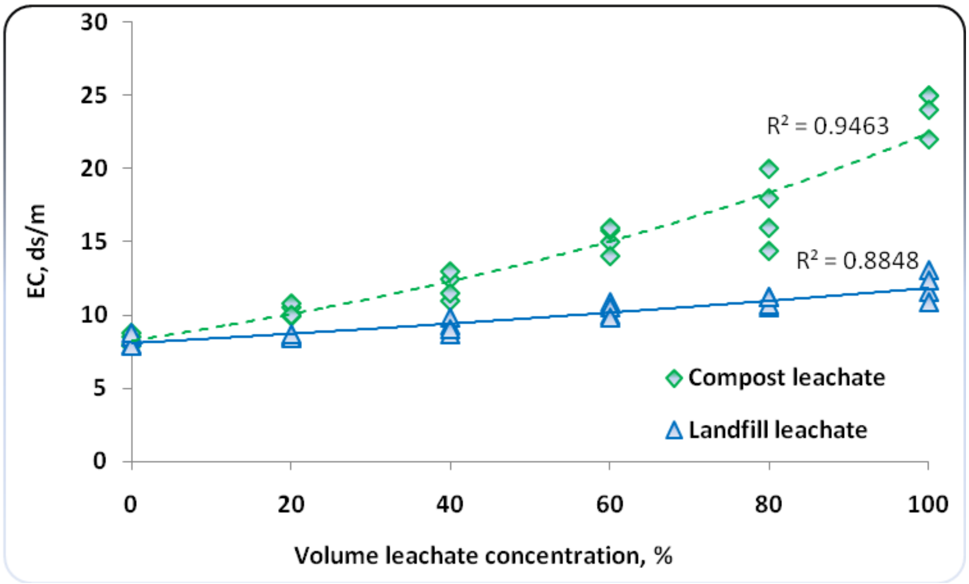

Figure 3. The soil electrical conductivity versus volume leachate concentration

Table 2. Chemical composition of the landfill and compost leachate

Parameters	Landfill leachate	Compost leachate
pH	7.14	4.50
E.C (ds/m)	15.74	34.2
Na^+ (mg/l)	800	4200
Ca^{+2} (mg/l)	1800	7820
Mg^{+2} (mg/l)	39	890
K^+ (mg/l)	185	4100
Cl^- (mg/l)	3400	4100
SO_4^{-2} (mg/l)	150	650
NO_3^- (mg/l)	39	150
Cu (mg/l)	10	12
Zn (mg/l)	120	181
Pb (mg/l)	5	6.8
Cd (mg/l)	0.9	1
Ni (mg/l)	1	1.42
Hg (mg/l)	0.7	0.9
TDS (mg/L)	17065	23558

There were significant increases in LL and PL when 20% leachate was added (Figure 4). Furthermore, the effect of leachate from the compost factory on LL and PL is higher than that of leachate from the landfill.

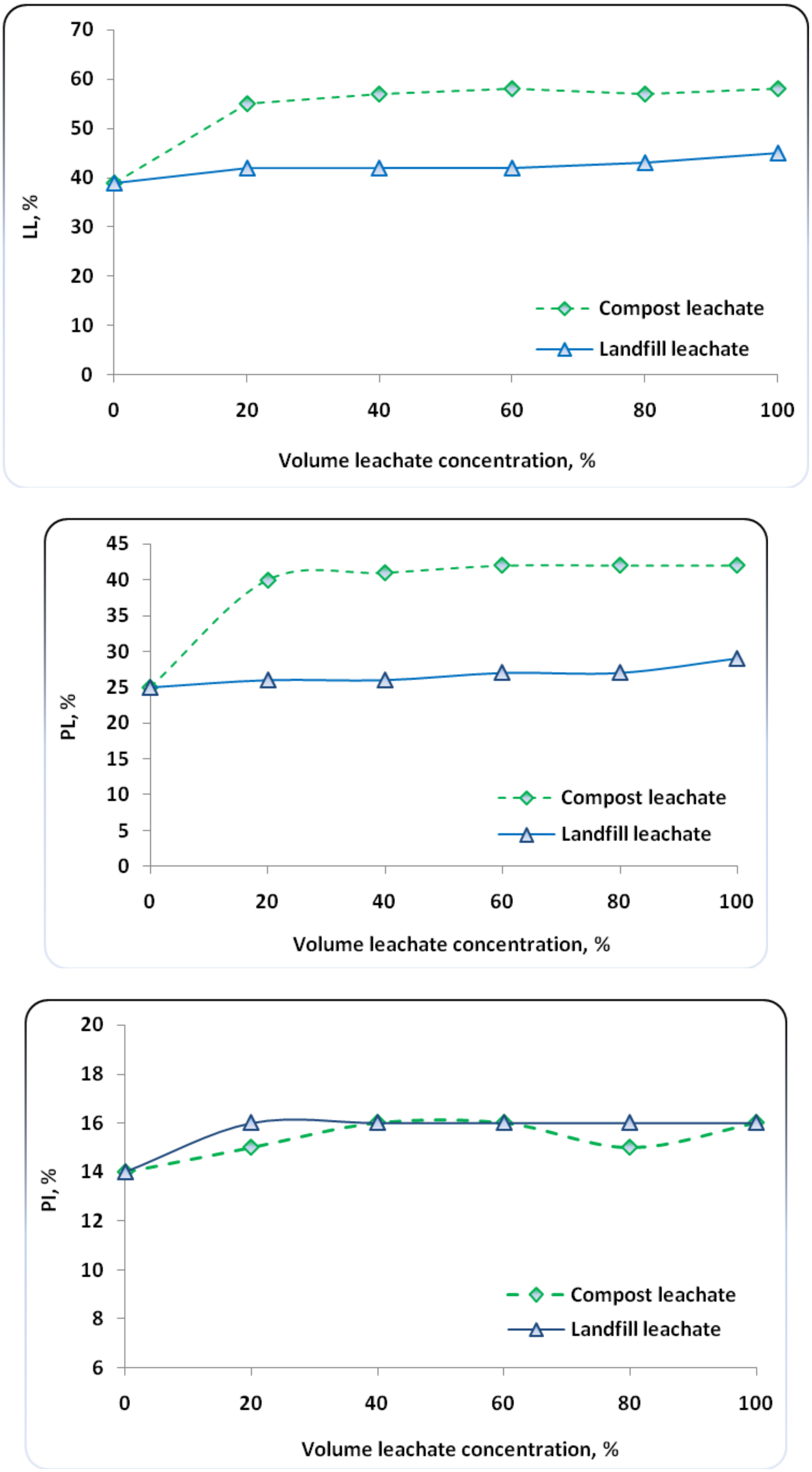

Figure 4. Effect of leachate concentration on the (a) soil liquid limit, (b) soil plastic limit, (c) soil plasticity index

The relationship between fine grain fraction and the engineering behavior of the soil depends not only on its quantity and the physical-chemical properties but also on the relative amounts and characteristics of the leachate as a pure fluid in landfill site. The compost factory leachate was more acidic and rich in divalent cations in comparison with the landfill leachate. Therefore, the compost factory leachate could cause more changes in the soil-water structure and water holding capacity. Tests showed additional extreme concentration of leachate did not cause a correspondingly high change in the plasticity index (Figure 4c).

A good understanding of the clay colloid as the most chemically active fraction of the soils could make clear the underlying reasons for the significant differences[17-18]. The clay micelle includes the solid clay particle itself as well as its sphere of influence in the surrounding water or aqueous solution. Within this sphere of influence, exchangeable ions are in a state of dynamic equilibrium. These ions are attracted to the net negative surface charge of the particle, but they also seek to diffuse away under their own inherent kinetic energy[19-20]. Environmental or Adsorbed waters are under the influence of electrochemical forces induced by the clay particles and have been affected by different leachates, resulting changes in soil consistency.

4.CONCLUSIONS

The compost factory leachate was more acidic, had higher electric conductivity, and was richer in cations in comparison with the landfill leachate. The study showed that the soil properties have been changed by electrochemical forces induced by clay particles. The effect of landfill leachate in increasing the CEC of the soil was less than the effect of compost factory leachate. The effect of leachate from the compost factory on LL and PL is higher than that of leachate from the landfill.

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