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EFFECTS OF WASTEWATER APPLICATION ON SOIL PROPERTIES

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Sakar Weli Ghafour AL-JAMMOOR

ABSTRACT

EFFECTS OF WASTEWATER APPLICATION ON SOIL PROPERTIES

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M.Sc. in Civil Engineering
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The aim of this study is to determine the effects of the wastewater application on some geotechnical properties of sand-clay mixtures. The wastewater used in this study was obtained at Gaziantep GASKI Plant (GGP). Standard compaction test, unconfined compressive strength (UCS), Atterberg limits and permeability test were carried out to the sand-clay mixtures. Sand particles were added to the clay at the ratio of 10%, 20%, 30%, 50% and 70% by dry weight. Firstly, the optimum moisture content (OMC) and maximum dry density (MDD) were found and other experiments were carried out by using these values. Suspended solid (SS), biological oxygen demand (BOD), power of hydrogen (pH) and chemical oxygen demand (COD) experiments were performed with sand-clay mixtures which saturated through wastewater. According to the results, as the sand ratio was increased, the productivity of cleaning wastewater was decreased and permeability of wastewater was increased.

Keywords: Wastewater, sand-clay mixtures.

ÖZET

ATIKSU UYGULAMALARININ ZEMIN ÖZELLİKLERİNE ETKİLERİ

Al-Jammoor, Sakar Weli Ghafour
Yüksek Lisans Tezi, Inşaat Mühendisliği Bölümü
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Bu çalışmanın amacı atıksu uygulamasının kum-kil karışımlarının bazı geoteknik özellikleri üzerine etkilerini belirlemektir. Bu çalışmada kullanılan atıksu Gaziantep GASKI Fabrikasından (GGF) alinmistir. Standart kompaksiyon, Serbest Basınç Dayanımı (SBD), kivam limitleri ve geçirgenlik testleri kum-kil karışımlarına uygulandı. Kum taneleri killi zeminin icine kuru ağırlıkca %10, %20, %30, %50 ve %70 oranında ilave edildi. İlk olarak optimum su içeriği (OSI) ve en maksimum kuru yoğunluk (MKY) bulundu ve diğer deneyler bu değerler kullanılarak gerçekleştirilmiştir. Atıksu ile doyurulmuş kum-kil karışımları ile askıda katı madde (KM), biyolojik oksijen ihtiyacı (BOI), hidrojen gücü (HG) ve kimyasal oksijen ihtiyacı (KOI) deneyleri gerçekleştirildi. Elde edilen sonuçlara göre, kum oranı arttıkça, atıksuyun temizlenmesinin verimliliği azalmış ve atıksuyun geçirgenlik arttırıldı.

Anahtar Kelimeler: Atıksu, kum-kil karışımlar.

To my lovely husband, children, family, teachers and those who had helped me in my life, even with a word.

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LIST OF SYMBOLS ABREVIATIONS

GGP	Gaziantep GASKI Plant
WHO	World Health Organization
AMD	Acid Mine Drainage
CEC	Cation Exchange Capacity
ESP	Exchange Sodium Percent
CEPT	Common Enhanced Primary Treatment
ASTM	American Standard for Testing and Materials
MDD	Maximum Dry Density (g/cm^3)
OMC	Optimum Moisture Content (%)
UCS	Unconfined Compression Strength (kN/m^2)
C	Clay
S	Sand
LL	Liquid Limit (%)
PL	Plastic Limit (%)
PI	Plasticity Index (%)
SS	Suspended Solid (mg/L)
COD	Chemical Oxygen Demand (mg/L)
pH	Power of Hydrogen
BOD	Biological Oxygen Demand (mg/L)

CHAPTER 1

INTRODUCTION

1.1. General

In general, the permeability is one of the most important geotechnical parameters, (Bear, 1972) defined the permeability as a property of rock; it is not relying on the fluid properties. Permeability is also a measure of alleviate when the water passes through the volume of the soil.

The physical which was based equation, related permeability to porosity and the specific surface area or the pore size equivalent between the uniform pore size and homogeneous rock (Kozney, 1927). Hence, according to Darcy's low the coefficient of permeability is unconstrained of the hydraulic gradient which mainly right in sandy soil. Moreover, permeability relies on the hydraulic pressure.

The coefficient permeability of infiltrated soil could be explained as a function of void ratio, but for non-filtrated soil can explained as function of the rate of filtration. While, the degree of filtration of specimen is hard and difficult to control, measure and predict (Fredlund and Rahardjo, 1993). The coefficient of permeability of non-filtrated soil could be defined as a function of known stress state. There are two types of techniques have been engaged for steady state method. The first one controls the hydraulic head and the other one controls the discharge throughout the specimen. To measure the coefficient of permeability some methods were developed. Therefore, another technique has been developed to measure the coefficient of permeability.

It is necessary to look for a method to recycle the wastewater or a method to re-use it in industries. Wastewater could be defined as a community's spent water. Wastewater contains polluted materials, and through the use of humans the impurities increased. Here, also it could be mentioned the term "sewage" which is often referred to wastewater but is more properly applied to domestic wastewater (Judd and Jefferson, 2003).

The types of wastewater depend on its application. The occurrence of the large amounts of the toxic pollutants in wastewater has become very crucial issue in the environment. It will lead to environment degradation, if there is no control.

Consequently, wastewater is generally used as a part of figure with surface overflow as well as stream water. Nonetheless, the agriculturists used wastewater specifically from the channels and broke sewers without further preparation, especially in the dry season. Wastewater will be embraced to allude to every one of these origins of wastewater (Keraita and Drechsel, 2004).

The impacts of clay content on the engineering properties stated that when the soils were contented to loading, the clay content created an important role on the mechanical reaction of soils. Generally, by enlarging clay content, the plasticity and the coefficient is increased, while the permeability is decreased in friction angle (Kim et al., 2005).

The ways to solve the problem are expensive, time consuming and labor-intensive, it is associated with the garbage which is used by the populaces (Davies et al., 2007). Moreover, the application of wastewater sometimes restricted, because of the technological or the economic constraints (Pino et al., 2006).

Wastewater re-use may be used into two different ways, which are 'direct' or 'indirect'. The direct use of wastewater is usually located near large metropolitan area, which is employed in the most developed countries. It was only used a small percentage of wastewater which is generated. The second one is indirect use of wastewater which occurs when treated; nearly treated or untreated wastewater is dismissed to reservoirs, rivers and canals that provide irrigation water for agriculture. More than 10% of the total populace consumed water system with wastewater. The ratio will be significantly higher among populaces in low-income countries. Both treated and untreated wastewaters were used directly by implication in the developed and less developed countries. Generally, the developed populace will be the principle of the further demanding on water assets, and then the wastewaters increased (WHO, 2006).

The advancement in technology obliged the evolving of treatment processes that eliminates discontinued matter and noxious substances. Commonly, the advancement of scientific knowledge led to the reduction of the polluted prevention and recycling with the noble aim of discharge pollutants (Steven et al, 2008).

It is difficult to classify the soils into sand or clay in sand-clay mixture. It is contained in both properties of sand and clay. It was constituted by investigating the effect of clay content on the engineering properties of sandy soils; it has been carried out by many researchers in the past that used reconstituted sand-clay mixtures (Dimitrova and Yanful, 2012).

1.2. Objectives of the Study

The major objective in the study is to find and analyze the effects of wastewater application on soil properties. While the important points of this study is to find out and make the relationship between sand-clay mixtures and the environmental impacts of the wastewater from the sand clay mixtures. It is also to specify the various solutions of the permeability of sand-clay mixtures. The findings of the study are important to the academic fraternity as they will be added to the body of knowledge and form a basis for further research in this area.

1.3. Outline of the thesis

Chapter 1- Introduction: In this chapter the effects of wastewater application on soil properties were fully described and showed in the way that needs for this study.

Chapter 2- Literature review: This chapter describes wastewater, sand-clay mixture and the permeability of wastewater.

Chapter 3- Experimental Study: In this chapter, the materials which had been used in this study is mentioned, the description and the procedure of the experimental were used in this study.

Chapter 4- Results and Discussion: Evaluation and the arguments were discussed in this study are described.

Chapter 5- Conclusions: Conclusions of the thesis are given.

Chapter 6- Recommendations

CHAPTER 2

LITERATURE REVIEW

2.1. General

This chapter describes the effects of wastewater application on soil properties. It also presents the inclusive characteristics of the soil as well as the detailed of the reported research that carried out by other researchers on the permeability of wastewater on sand-clay mixtures. This chapter will finally give the detailed observations and the importance of the study.

2.2. Behavior of Sand-Clay mixtures: Factors and Mechanisms

2.2.1. Pore Fluid

In this study, soils were contained on sand and clay. The increasing in the pore electrolyte compacted, decreases the swelling, compressibility and plasticity of soil characteristics. In the case of the sodium, increasing the amount of electrolyte (Sodium chloride) compacting from 5×10^9 to 1×10^{11} N, the void ratio that is reduced from 11.18 to 5.40 for effective of consolidation pressure of 0.05 Kg/cm^2. In the case of calcium which increases in the amount of electrolyte (Calcium chloride) compacting from 1×10^3 to 1.0 N which has resulted into the void ratio decreasing from 2.18 to 1.84 only at a pressure of 0.05kg/cm^2 (Mesri and Oslon, 1971).

2.2.2. Soil Structure

The properties of soil structure include the characteristics on the soil properties, consolidation and consistency. The fabric plays a critical role in addition to the inter-particle repulsive and attractive powers. The term fabric can be defined as the arrangement of particle groups, particles and pore spaces in the soil (Van Orphan, 1963; Young and Warkentin, 1966; and Mitchel, 1976).

2.3. Sources of Soil Pollution

Shaylor et al. (2009) studied the soil pollution as a complex process which is usually seen in the soil pH of the pore fluid and temperature of the ionic characteristics of the solution. The major sources which cause soil pollution;

i. Nuclear waste
ii. Animal waste
iii. Harmful tanks
iv. Acid rain
v. Disposal well
vi. Sea water intrusion and the salt solution
vii. Disposal of the oil fields brines
viii. Dangerous chemical waste
ix. Petroleum development and exploration
x. Solid wastes
xi. Spills hazardous materials

2.4. Consequences of Soil Pollution

Friedland (1990) stated that categorizes of pollutant have either direct or indirect effects on the soil characteristics, due to the interaction between the organic and inorganic pollutants that is generated because of the imposed environmental conditions. The interaction between the pollutants and the soil, changes the behavior of the soil. Modification of the various soil characteristics resulted in various geotechnical engineering problems such as ground subsidence, landslides, erosion, corrosion and the durability of the foundation problems.

2.5. Some Parameters for Soil Classification

Fang (1997) found that soils were the most sensitive environmental factors than any other construction materials. Although loading may also affect the characteristics of the soil, it is not the only aspect to be taken in to consideration. Fang (1997) also suggested that controlling parameters such as pH in the pore fluid, specific surface, dielectric constant, adsorption, and the percentages which passing through the sieves. Furthermore to present the controlling parameters for soil classification such as soil consistency, grain size distribution, and the index properties to be evaluated for the soil classification.

2.6. Characterization, Identification and Classification of the Pollutant Soils

2.6.1. Characterization

Fang (1997) recommended that the properties of polluted soil were based on sorption properties of soil, dielectric constant and the specific surface of the soil.

2.6.2. Identification

Fang (1993) proposed that, it is important to make visual identification of all polluted soils, emphasized on observing some special items such as the characteristics of the water, the soil properties, characteristics of the site, cracking pattern of the ground soil and the color of the ground water. The characterization and identification of the ground soil is one of the requisites for a complete understanding of the sand-clay mixtures with the pollutants interactions in the environment.

2.6.3. Classification

Fang (1997) stated the main concepts of the classification for polluted soil. It depends on the particle size soil which is the interaction between sand-clay mixtures and the pore fluid which depends on physico-chemical and chemical composition properties of the particle surfaces. The environments influenced by the inherited mineral structure which includes the ionic exchange capacity, and the bonding characteristics of the soil. It also depends on the local environment. It is also affected by the naturally inherited mineral structure of the sand-clay mixture, the bonding properties of the higher ion-exchange capacity and the particles and the higher sensitivity of the sand-clay to the environment. Wastewater can be classified as a slow process, medium and high. From the pollution sensitivity index, it can be found that the sand-clay mixture content increases, as the pollution sensitivity increases significantly.

2.7. Soil-Water Interaction

Pakbaz et al. (2008) stated that the pore wastewater affected the soil behavior into two ways;

i. The method in which sand-clay mixture particles join together so as to form a mineral frame that is the chemical interaction.
ii. Impacts of the large forces that transmit through the mineral frame that is the physical interaction.

Another characteristic of wastewater, which evidently influences the behavior, is surface tension. Wastewater has a high surface tension when compared to of other liquids. Surface tension defined the way that wastewater moves and retained in the soil, it may change sand clay mixture properties (Judd and Jefferson, 2003)

Al-Othman (2009) discussed that soil-water interaction and the soil behavior need the integral evolution from physical to abnormal state to be clarified. The variations in the properties of soils are mainly qualified to the transformation steps in the unfiltered and swamped step.

2.8. Effects of Wastewater Application on Soil Properties

Do Monte et al. (1989) stated that commercial manures could replace and take the same role by the engineering wastewater.

Russell et al. (1988) stated that wastewater irrigation could change the soil properties. These changes might be hazard to sustainability of long duration land use.

Schipper et al. (1996) stated that wastewater application was attributed with the addition of nutrients into the soil rather than the additional water loading. The use of wastewater could make changes in the soil moisture contents, adding organic nutrients, might be additionally stimulate favorable changes in the soil properties.

Schaller and Diez (1991) studied the effects of soil properties; tree biomass production and the nutrient uptake soil physico-chemical properties for instance pH, contents of clay minerals, organic matter and mobility of metals in soils. The researchers showed that the higher cation exchanges the capacity of the sand-clay mixtures. Therefore, the soil pH not only affects the metal but also metal uptake into roots. However, the effect on the metal bio-availability seems to be similar or related to the properties of each metal.

Alloway (1995) explained that the sources could be major of pollutant from anthropogenic origin, the application of metal based pesticides, the manipulation of mines smelters, and metal-enriched sewage sludge in agriculture, combustion of fossil fuels, military training, industries electronics and metallurgical contribute to an increased input of heavy metals in soils.

2.9. Review of Earlier Investigations

2.9.1. Physico-Chemical Behavior

Foreman and Daniel (1986) varied the hydraulic conductivity of clay compacted and permeated with water, heptane and methanol. While at this experiment, a discovery that Atterberg limits of the clays changed when there was a change in the pore fluid. The hydraulic conductivity changed with the variation in permeates. Organic chemicals obliterated the plasticity of soil.

Bowders and Daniel (1987) studied the hydraulic conductivity of clay compared to dilute inorganic compounds through kaolinite and illite-chloride mediums. Chemicals less than 80% by volume in the aqueous mixture have less effect on the hydraulic conductivity. The extent which an organic fluid medium affects the conductivity in hydraulic parameters of compacted clay.

Jukwar et al. (1987) found that the effect of paper mill effluents on soil was an increase in the calcium compounds in surrounding area. This is after a cation exchange capacity (CEC) and exchange sodium percent (ESP) were performed.

Martin (1987) proved that there was a contribution of acid rain, storm water and floods to pollution of the soils and even lead to profound changes in the size of soil constituents and distribution of water in the soil. Pore fluids affected the index behavioral characteristics of soils and their temperatures. The volume changes of soils, therefore influenced by pore solutions. Contaminated fluids gave a rise to greater volumes on bentonite. Finally, the consolidative and engineering properties of soils were all influenced by the very pore fluid media.

Rao and Sridharan (1987) tested on clay liners' chemical permeation. Various pollutants reacted differently with the clay particles. The diffusion double layer in the clay compound is the determinant on how the clay will react to say, organic or inorganic compounds. Notably, the interaction with organic compounds leads to subtle changes. However, organic solvents had a deranged impact on the permeability of the clayey soils.

Uppot and Stephenson (1989) described clay permeability strengthened due to a chemical reaction with the components. A resultant loss of mass in the solution increased the clayey pore spaces and even the permeability.

Alemi et al. (1991) observed set adsorption of selenium in less saturated soil columns. The researchers used loamy clay soil and the selenium rapidly leached through the columns. Adsorption was greatest for selenite and least in selenite, which was modified to reduce moveable states. Selenium activated the ability for soil to concentrate in columns under stable conditions when adsorption coefficients were gotten from batch experimental studies.

Garnier et al. (1994) interacted typical alluvial soils with waste from a plant that manufactured fertilizers wastewater changed the soil characteristics. The soil consistency was increased; permeability and compression with a decreased compression and a damaged sheer strength characteristic were distinguished.

Bady and Rowe (1996) showed the transportation properties of effluents, sodium and chloride, in unsaturated collection stratum of stone. There was an evidence of swelling of the compacted silt strata. Hence, the contaminant conveyance through matric suction was minute when put into contrast with the migration due to advection and diffusion.

Locat et al. (1996) examined the mechanical and hydraulic properties of mixtures remolded with the addition of lime. The addition in sheer of lime changed the index behavior of the soil mixtures. The hydraulic conductivity could not be reduced compared to not treated soils.

Jain and Ram (1997) showed the utilization of wastewater for irrigation and their effects on the soil layers. Less migration took place within the soil layers and the soil components were retained almost in their places within the upper 75cm. The water sources nearby were not affected significantly.

Kim et al. (1997) studied on the effective of leakage and seepage in compacted clayey soil. Bromide was used to indicate the seepage velocity through the soils. The seepage velocity was half the expected percentages in the core pore water measurements. The hydrodynamic dispersion coefficient showed a direct proportion relation to the seepage velocity.

Cooper and Istok (1998) analyzed workout on the procedures to qualitative valuing of ground water pollutants at a toxic waste area in Hamilton, Ohio. A map on the differential toxicities of the chemicals was computed for each pollutant and their respective densities plotted simultaneously.

Stern and Schackelford (1998) analyzed the permeation of sand-clay mixtures which was used water mixed with Calcium Chloride, the ability to let solutions passed through decreased with increased percentages of clay even as a close relation to bentonite increased.

Bachewar and Mehta (2001) studied on the physio-chemical properties of the waste from a drug factory in Nanded, Maharashtra. The effluents were compared with water quality in the area. Toxicity of the waste products was compared to soil.

Maroto (2001) studied on the soil columns which had been polluted by lead, pH and carbonate of the soil were mathematically represented easy understanding of the lab analysis. A realization that the adverse effects on soil were due to heterogeneous contact was labeled to the discovery.

Row et al. (2002) studied the permeability of a natural clayey before pollutant and later after permeation of different ionic pollutes. It has been proved that the complex permeability may identify the difference in soil pore-water chemistry; this factor can be used for diagnosing soil pollutant. The permeability of kaolinite in sodium chloride with a certain concentration increased significantly. The porosity of soil has minimal effect on an increasing in permeability, since the pollutant seems to have low effects on the soil.

Das (2003) analyzed the effluents which released from a multitude sources and the characteristics on the effect of soil and water in the vicinity of the sources of waste. Later, samples were collected from the effluent and water resources in the area were analyzed. The potential hydrogen, nitrate concentrations, chloride, sulphate and phosphate together with the BOD and COD analysis was done for both the septic tank and the soil samples.

Yao and Anandarajah (2003) showed that leaching leads to an increase in permeability. Heptane was used to leach infiltrated water with clayey. This will lead to the founding of theories that suggested macro cracks are formed due to increased permeability.

Boardman et al. (2004) the influents; iron and lead, on the lime stabilized clay soil showed that the pollutants affected lime clay solutions which were developed and reacted in the process of cation formation and solidification.

Bose and Bhattacharyya (2008) showed that the physio-chemical properties of soil around and within a textile factory in Rangia, India, were indicated changes in soil properties. The percolations of purified water through the soil lead to the obliteration of the natural cementation and hence collapse and increased in permeability with decreased natural strength and more settlement.

Katsumi et al. (2008) performed the experiments on long term hydraulic properties and conduction of modified bentonite with inorganic chemicals. The materials showed swelling and chemical resistivity to electrolytic solutions with sodium chloride and calcium chloride.

2.9.2 Effects of Geotechnical Characteristics

Sridharan and Rao (1973) tested on one dimension volume difference of kaolinite and soils, about 8 organic pore fluids were used to investigate the antiparticle force of the samples. Later, the initial pore fluids were replaced with other pore fluids of differing dielectric properties. The changing behavioral patterns were dictated by two mechanisms. In the first mechanism, volumes were affected the shear strengths of the inter-particles. In the second mechanism, the long range diffusion within the double layers of forces expelling the particles was the determinant of the volumes. Therefore, the first mechanism rules the volume exchange of such types of soil as kaolinite while the second mechanism.

Norihiko Miura et al. (1998) assessed the effects of residual environment on the engineering abilities of deposits in a plain reported that soft deposits had higher sensitivity and compressibility with increased water content than the LL. Leaching of salt was seen to be the chief post-depositional alterations that had an effect on the engineering characteristics of soils. Thus, the sensitivity of the soils was increased by leaching. The deposition of soils showed light consolidation with higher compressibility and better sheer strength.

Jakhanwal and Singh (1991) studied on the properties of silt soils. The acoustic velocity increased with increasing percentages of CaCO3 in the silt soils. Liquid limit (LL), plastic limit (PI) and compressibility together with the acoustic velocity remained in the same plane of variation with the percentages of CaCO3. This finding was inconclusive and therefore, further studies are recommended.

Sivapulliah et al. (1994) studied and gave an analysis of the properties of soils in which sulphate was a component of black cotton soils stabilized in lime. The plastic, workable and strength capabilities of fine-grained soil mixtures were improved with the addition of lime. Calcium sulphate as gypsum affects the soil behavior. Soils infused with lime had an increased liquid limit (LL) due to the increased availability of sulphate. This (LL) better expressed in sodium sulphate than calcium sulphate soil mixtures.

Mario and Fenelli (1994) analyzed the importance of minerals on the strength of kaolin, bentonite and their solutions in distilled water. The sheer strength of kaolin is not altered. On the other hand, the resultant strength of bentonite changed significantly since there seems to be an inward pull of the salt solution towards the clayey.

Krishnaswamy et al. (1995) showed the impact of chrome deposits on soils. The investigators realized that soil properties varied a lot with pore medium concentration and the chemical complex. Aggregating and flocculating properties of cohesive soils are affected by potassium chromate. The shear strength increased in all the soils under scrutiny since conduit of pore fluid through the soil layers as well as the coefficient of soil permeability was reduced. This was because of precipitation of chromium hydroxide in the chemical reactions.

Al-Sanad et al. (1995) studied on the properties of Geotechnical parameters of oil-contaminated sands in Kuwait. Lab tests on the properties, permeability, and compaction together with triaxial consolidation on both contaminated as well as clean soils at same environment showed that small decrease in strength and permeability with corresponding increased compressibility was because of contamination of the soils.

Ramasarma (1995) researched on the soil characteristics that had been deliberated with effluents from industry. Clay soils showed more changes than silt loam soils. With clay, a decrease in liquid limit (LL), optimum moisture content (OMC) and permeability were evident. On the other hand, the plastic limit, plastic index (PI), cohesion, the angle of internal friction, maximum dry density and shear strength were higher in clay soils.

Stalin et al. (1996) showed the influences of pollutants from a fertilizer plant. The hydraulic conductivity, as well as the index property of the black and red soils, was shown. Pore fluids for testing the permeability were remolded into a better consistency with the effluents while determining the index properties. The effluents changed the permeability and index characters of the black cotton soils but not on the red earth soils.

Sobha Cyrus and Thomas (1996) experimented with the tannery waste effects on the soil behavior. The shear strength of these soils was markedly decreased after pollution with tannery waste products.

Sivapullaiah et al. (1997) listed the roles of dolomitic contamination on the character of lime treated soils. The quick lime stabilized the soils. Using black cotton soils mixed with calcium hydroxide and magnesium oxide, a report that magnesium oxide changed the index characteristics of lime treated soil (black cotton) drawn. It is important to note that the volume changes were unnoticeable although the strength of these soils was increased. Therefore, dolomite lime is preferred to pure lime since it is cheaper than the latter, yet early in the action.

Srivastawa and Pandey (1998) showed the effects of chemical pollutants on the engineering character of soils. The investigators' reports showed that there were differences in the chemical composition of soils. These changes include soil nature, permeability, and plasticity; consolidation and shear aspects of soil. The contaminants were manually mixed with the soil samples. The liquid limit (LL) test and pressure reduced as oil content n soil increased. More oil contamination has increased effects on soil compaction. Full dry density rises and the OMC decreases. The specific gravity of soil, and the soil undrained cohesion reduced since there was an increase in oil in the soil.

Alawaji (1999) enumerated the swell and compressibility characteristics of sand in bentonite with different concentrations. The swell potential aka SP, swell duration, volume and pressure declined with more concentrations of the mixtures.

Stalin et al. (2000) studied the effluent soil relationships of two soil samples and two effluents in Madras. The effluents used were dye and tannery. The LL and PL indices were not raised by lengthening the contamination period for both soils. These values were much reduced in tannery than dye pollutants. The coefficient of permeability gets raised with more exposure time for the soils. Still, the increasing in coefficient of permeability was more in tannery compared to dye pollutant.

Saikia and Goswami (2000) showed the effect of effluents from industries on the soil. Pharmaceutical waste, paper plant, crude oil, and soap plant waste products showed different results of permeability, shear, and consolidation.

Sivapullaiah et al. (2000) showed the efficiency of lime in soil solutions with sulphate. The sulphate components reduced the sheer strength of soils treated with lime over long durations. There is more efficient flow of soil mixture because of the total effects of electrical gradient and hydraulic gradient on the fine-grained soil, NaCl2 and acetic acid were used in photometry studies. An electro-kinetic cell was employed for the procedure.

Lo et al. (2002) investigated on the geotechnical properties of common enhanced primary treatment (CEPT). Mixtures' consolidation, permeability, and sheer strength showed stability and settlement aspects. When sludge and other solid effluents are disposed of together, a higher sheer strength and lower compressibility are achieved. Pure enhanced primary treatment (CEPT) sludge permits water at lower rates than the co-disposed sludge.

Singh et al. (2002) studied on physio-chemical changes in soil characteristics due to perennial irrigation using sewages. The quality of sewage water used for farming affects soil, and this continued use of sewage changed the quality of carbon, potassium, and other organic compositions. The organic matter was raised in all the experiments with the exception of only phosphorous.

Vandana and Chandrakaran (2002) studied the permeability properties of natural soils using two samples. On permeation with ammonium sulphate, sodium chloride and potassium chromate, differences in the values of coefficient of permeability was investigated. The permeability of laterite and clay soils was changed. The laterite soil had an increase in permeability and was retained throughout the experiment. $NaCl2$ permeation in laterite soil had a lesser effect on the soil's permeability. In clay soil, the permeability was increased when added with $NaCl2$.

Tiwari et al. (2003) measured the results of sheer strength samples which collected from landslides of soil in Japan. There was an increase in sheer strength made when the soils were passed through saline concentrates. This increase in sheer strength is due to increased soil adherence, and it also depends on the area from which the soil was obtained.

Chew et al. (2004) studied correlations between microstructures and engineering properties of treated marine clay (using cement). About four microstructural changes explain the different properties of the cement –treated clay obtained from a marine environment.

2.10. Factors Affecting Permeability

DeGroot et al. (2012) concluded that permeability is complicated process limited by physical quality of the soil and the permeating fluid. In a continual temperature of

20°C, the prevalent room temperature, the water that flow easily and the unit weight continue. Consequently, the physical quality including grain size distribution, density, void ratio, and soil texture and structure influence the great size of permeability.

2.10.1. Effect of Density and Void Ratio

Das (2008) claimed that void ratio is the proportion of the volume of voids to the volume of solids. Density and void ratio are also pertaining to each other. Permeability is decreased as density increases or void ratio decreases. Dry density is a proportion of the large amount of solids in a soil to its whole volume, the total of the volume of solids and volume of voids.

2.10.2. Effect of Soil Texture and Structure

Holtz et al. (2011) stated that texture and structure are pertaining to the organized of the form and size of mass soil particles. Moreover, particle form has a great impact on permeability so it has a great effect on the size and forms of joined together between particles. The more sharp and definite corners the grains are, the smaller the space and more bends the road will be. It can be said this is due to the fact that the sides of angular grains might be suit into voids.

2.10.3. Effect of Weather

The changing in weather from different season has a great impact on the soil permeability. For instance, when the weather is wet, the soil contained moisture is more comparing the situation in the hot weather. However, the rain cannot enter the soil because this makes the top layer runoff during rainy season. In addition, when the weather is dry, the contained soil moisture will be reduced. The water can easily move through and enter to the ground.

It can be mentioned lots of factors that had a great impact on the soil permeability included vegetation management, initial soil condition, surface moisture, soil compaction, rainfall intensity and temperature. Furthermore, water passed through the level of the top layer is usually relying on the surface situation. Infiltration is also influenced by the amount of keeping it in the ground. It can be stated this might cause the flood (Cheng and Jack, 2005).

2.11. Soil Properties

Cheng and Jack (2005) stated that soils were contained three different kinds of structures includes organic soil, cohesive and cohesionless. Cohesion of soils means the state of cohering or uniting. Cohesion can be seen as interaction of joining particles together. However, the cohesive soil includes clay and by the force of water the particles can easily stick together. Little pores has lower permeability because of water could steady move through the soil slowly. It is possible to achieve zero permeability in a high porosity soil if the pores are isolated. Moreover, one of the significant factors that have a great effect on the structure of a soil is the form of the particles and the division of the shape of the grains. These factors impact on the geotechnical properties of a soil, for instance, strength, deformation and permeability properties.

Larsson (2008) claimed that the connections between all types of the soil amount have influenced on the geotechnical properties of a soil, such as density, porosity, water ratio. The dry layer on the surface of earth contains several types of soil including sand, till and clay. It can be said these types are belonged into two different structures which includes particles and pores. Moreover, the pores are replenished with water or gas and sometimes with both.

2.12. Soil Compaction

Soil compaction is a subject to numerous elements, for example, molecule size, thickness, natural material and mineralogy (Singer et al, 1981). Soils with a wide conveyance of particle size are viewed as the most compactable, although acceptable textured soils have been found to reduce to moderately high densities (Hazard et al., 1989; Page-Dumroese, 1993; Williamson and Neilson, 2000) demonstrate that dirt in dry backwoods on coarse gravely parent material opposed compaction more than soils in wet woodland or fine material.

Taylor (1979) found that penetrometer resistance expanded medium to coarse textured soils as moisture potential diminished, however mass thickness stayed consistent. Soil resistance seems to be significantly sensitive to changes in the soil moisture than soil mass thickness.

Soil compaction may influence a few physical and organic procedures. Physical impedance of roots may confine plant access to water and supplements by diminishing the volume of soil abused. Compaction may decimate soil basic units and change pore conveyance, along these lines abating water invasion and vaporous dispersion (Taylor and Brar, 1991).

Gomez et al. (2002) found that in sandy soil compaction expanded water accessibility because of good pore size dissemination, recommends that direct compaction on the soil might be valuable. The profundity and nature of natural material on a site can similarly influence the measure of compaction.

CHAPTER 3

EXPERIMENTAL STUDY

3.1. General

This chapter describes the materials, procedures and all the techniques which had been used through the experimental work for completing the tests. The materials which were used throughout this study had a great impact for engineering field. The samples of wastewater and infiltrated water that carried out were tested and achieved the results on the laboratory.

3.2. Experimental Equipment and Materials

3.2.1. Experimental Equipment

In this study, the experimental equipment used were box and hammer. The box was 2.08 cm length, 1 meters width and 60.3 cm depth. The box designed by AutoCAD which was drawing from all sides. Figures 3.1, 3.2, 3.3, and 3.4 illustrated the testing box from various aspects, which were drawn by AutoCAD software. Figure 3.5 showed the hammer which was used for compacting the soil, it was found to be about 40 kg. The hammer divided by two parts, the first part was handling and the height was 90 cm. The second part was the bottom of the hammer was 40 cm height, 20 cm width.

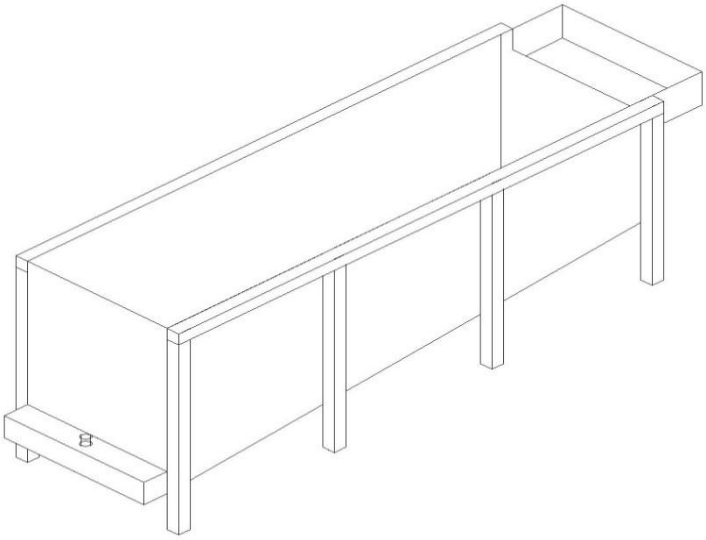

Figure 3.1 AutoCAD drawing for oblique view of the box

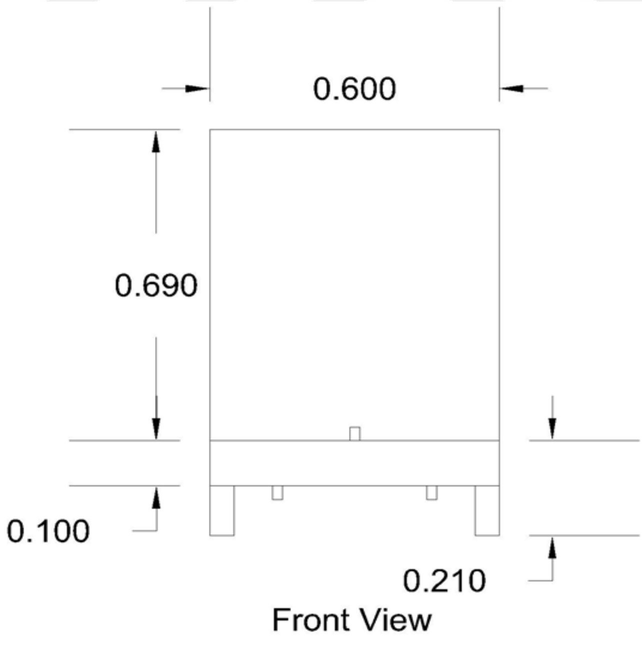

Figure 3.2 AutoCAD drawing for front view of the box

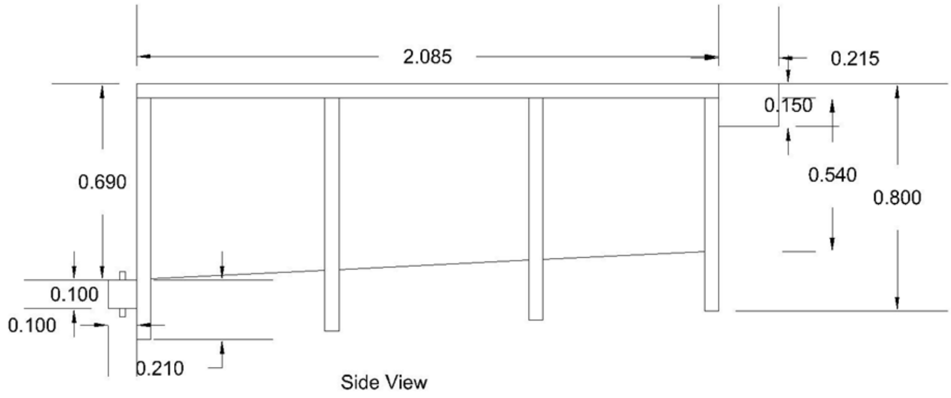

Figure 3.3 AutoCAD drawing for side view of the box

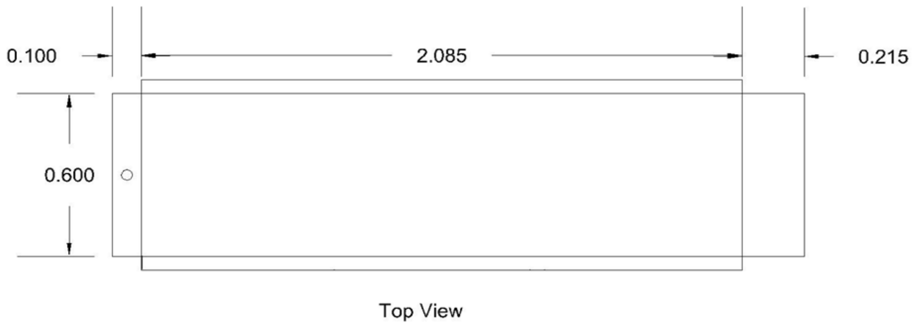

Figure 3.4 AutoCAD drawing for top view of the box

Figure 3.5 Hammer used for compacting the soil

3.3. Materials

Is this study, the materials used in the experimental study were natural sand, clay, gravel, tap water and wastewater.

3.3.1. Soil

Natural sand (S) was used in this study that obtained from Gaziantep city in Turkey. The sands were passed through sieving 4.75mm; more than two tones were used during the tests. The clay (C) used through the experimental work were provided in Turkey from Gaziantep city. The clays were passed through sieving 4.75mm; nearly five tones were used in the experimental study. Figure 3.6 showed the amount of dry clay after sieving.

Figure 3.6 Clay used during the experimental studies

3.3.2. Gravel

In this study, the gravels were used for filtration inside the box. The gravels were natural and obtained from Gaziantep city in Turkey; nearly 150kg were used in the experimental work, for each trial about 30kg were used in filtration. Figure 3.6 showed filtration inside the box.

Figure 3.7 Gravel used for filtration

3.3.3. Tap Water

In the experiments of this study, tap water was used for preparing the samples.

3.3.4. Wastewater

In this study, wastewater was used in the experimental work after the soils were compacted inside the box and put wastewater to estimate the results of permeability. The source of wastewater was in GASKI (Gaziantep Su ve Kanalizasyon Idaresi) plant in Gaziantep city. Figure 3.8 showed wastewater treatment plant, and the Figure 3.9 showed the last sedimentation tank in the wastewater treatment plant.

Figure 3.8 Wastewater treatment plant

Figure 3.9 Last sedimentation tank of wastewater

3.4. Suspended Solid (SS) Test

The aim of this test was to find out total dissolved and suspended solids in water. The term total dissolved solids in this study refer to materials which entirely dissolved in water. The solids were filterable in nature. It is characterized as residue upon evaporation of filterable sample. The term of the total suspended solids can be mentioned to the materials which are not melted in water and are non-filterable in nature (APHA, 2005).

3.4.1. Experimental Process

- Filtration apparatus should be place with weighed filter in filter flask.
- The sample should be mixed well and pour into a graduated cylinder to the selected volume.
- Making pressure to filter flask and seat filter with a small sum of condensed water.
- It should be drawing a sample with the filter into filter flask.
- Clean proportional cylinder into filtration apparatus with three consecutive 10 mL portion of condensed water, letting to complete the drainage between each cleaning.
- It should be making pressure for three minutes after filtration of the final rinse is completed.
- One important point must dry it in an oven at 103-105^{o}C for at least 1 hour.
- Cool filter in desiccator to room temperature.
- When it gets ready, weigh the filter and support (APHA, 2005).

3.5. Chemical Oxygen Demand (COD) Test

In this study, the aim of the test was to find out chemical oxygen demand. Chemical oxygen demand (COD) was commonly used in a way to measuring the amount of the natural mixes in the water. The majority of the applications in COD test are to discover the measure of waste material found in surface water. It is communicated in milligrams per liter (mg/L), which demonstrates the mass of oxygen devoured per liter of arrangement. In addition, COD is to decide the amount of oxygen required to oxidize the natural matter in water or wastewater test (APHA, 2005).

3.5.1. Experimental Process

- It should be taken three COD bottles with stopper which are (two COD vials for the sample and one for the blank).
- The sample should be added by 2.5 mL to each of the COD vials and remaining COD vial is for blank; to this COD vial add distilled water.
- Add 1.5 mL of potassium dichromate reagent – absorption answer for each of the three COD vials.
- Add 3.5 mL of sulphuric corrosive reagent – catalyst arrangement in the same way.
- Place the COD vials into a piece digester at 150ºC and heat for 2 hours.
- Get prepared with burette for measuring (APHA, 2005).

3.6. Power of Hydrogen (pH) Test

The aim of this test was to determine the pH of water. The pH refers to the measure of hydrogen particle is focus on an answer and characterized as the negative log of H^+ particles fixation in water and wastewater (APHA, 2005).

3.6.1. Experimental Process

- In a perfect dry 100 mL container take the water test and place it in an attractive stirrer, embed the Teflon covered blending bar and mix well.
- Take the terminal from the water test; wash it with refined water and after that wipe delicately with delicate tissue (APHA, 2005).

3.7. Biochemical Oxygen Demand (BOD) Test

The aim of this test is to determine biochemical oxygen demand in the water. The biochemical oxygen demand determination is a substance technique for deciding the measure of dissolved oxygen required by vigorous creatures in water to moderate the natural materials that determined temperature over a particular timeframe. For the most part, the time was taken as 5 days and the temperature is 20ºC (APHA, 2005).

3.7.1. Experimental Process

- Take four 300 mL glass stoppered BOD bottles (two for the example and two for the clear).
- Add 10 mL of the example to each of the two BOD bottles and the fill the remaining amount with the weakening water. The staying to BOD containers is for clear.
- Add 2mL of manganese sulfate to the BOD bottle by embedding the adjusted pipette just beneath the surface of the fluid.
- Titration should be begun instantly after the exchange of the substance Erlenmeyer carafe. Allot 203 mL of the arrangement from the container and exchange to an Erlenmeyer cup (APHA, 2005).

3.8. Standard Proctor Compaction Test

The aim of this test is to determine the MDD and OMC of soil with various percentages of sand-clay mixtures, standard proctor compaction tests were carried out. Standard proctor compaction test was accomplished with ASTM D 698-12. Sand-clay mixtures were added water different water content and taken the weights to find out water content.

3.9. Unconfined Compression Strength (UCS) Test

In this study, UCS test was carried out for the soils as clay and sand-clay mixtures according to the (ASTM 2166). The strategy of this test was revised for an adequate number of elaboration water contents to build up a relationship between the dry unit weight and the decorating water content for the soil. The estimations of optimum water content and adjusted dry unit weight are resolved from the UCS test. The Figure 4.10 showed the UCS equipment samples and hammer as prepared for the tests. Finally, the samples of the soil were put on oven the temperature 100±5ºC, and the MDD and OMC were carried out.

Figure 3.10 The compaction hammer and the plastic split mold used for UCS test

In this study, clay and sand-clay mixtures were used. The UCS test was employed with different percentages of soil such as 100% clay, 90% clay with 10% sand, 80% clay with 20% sand, 70% clay with 30% sand, 50% clay with 50% sand and 20% clay with 80% sand were mixed. The Figures 3.11 and 3.12 are the soil samples after UCS test.

Figure 3.11 The samples of compacted soil

Figure 3.12 Soil samples in the oven

3.9.1. UCS Test Procedure

- It depends on the type of mold that is used to get a sufficient quantity of air-dried soil in a small bag and shaking it to mix soils well. For our test nearly about 5 kg was used.
- The weight of the soil should determine as well as the weight of the compaction mold with its base with the tighter by using the balance and record the weights.
- It should be measuring or balancing the water and add it to the soil, and then mix it into the soil using the small bag so as the soil gets wet as its need for compacting.
- The soil should completely fill the mold and the last compacted layer must extend on the top of the mold. If the soil is below the collar joint at the compaction of the drops, the test point must be repeated.
- The compacted soil in the mold should be weight, and recording the mass.
- The compacted soil in the mold has to be removed by opening the tighter and take soil moisture content samples from each side such top, middle and bottom.
- Finally, after 24 hours the samples in the oven should be taking out and balancing it again so as to determine the water content (ASTM 2166).

3.10. Atterberg Limit

Atterberg limit is the amount of water contents in soils. It was followed by some apparatus such as; liquid limit devise, accurate balance, wash bottle filled with distilled water, cans and oven. According to its procedure, this test was completed to find out the hardness of mud, liquid limit (LL) and reduction of plastic (PL). The behavior of soil in the plasticity index (PI) was found. Figure 3.13 showed the preparation to making the tests with the equipment (IS: 2720, 1973).

PI= LL-PL

LL= Liquid Limit

PL= Plastic Limit

PI= Plasticity Index

Figure 3.13 Preparation for the LL, PL and PI tests

3.10.1. Liquid Limit (LL)

Liquid limit, it is the concept of the water content in the clay which is characterized and it was changed from plastic to liquid. The Figure 3.14 showed the sample that prepared for making the LL test.

Figure 3.14 Samples prepared for liquid limit test

3.10.2. Plastic Limit (PL)

Casagrande (1932) recommended that the basic approach to carry out this test is by rolling a string of soil until caving in a distance across of 3mm. The example reflects of the wet reaction of decreasing plastic if the subject can be followed in diameter under 3mm, the subject was separated before it achieves the 3mm diameter. The best approach to finding the PL included embellishment and rolling totally mixed specimen with the palms to a threadlike framed stick of around 3mm distance across, as far as possible was demonstrated by the moisture content contrasted with the period when the stick initially disintegrated.

3.10.3. Plasticity Index (PI)

Plasticity index is the water content of the soil when it is plastic. Moreover, it is numerically equal to the differences or comparing between the LL and the reduction of PL.

3.11. Permeability Test

Permeability test is the measure of the rate of water that penetrates through soil. In this test, water is obliged by a known constant pressure through a soil sample of known dimensions and the ratio of flow is finding out. The permeability test is used to find out the suitability of sand-clay mixtures and gravels were used for filtration. According to this study, the wastewater saturated through the soil and the equipment when used for this study was different. Figure 3.15 and 3.16 shows the permeability of wastewater and the samples of wastewater before and after used during the work.

Figure 3.15 Permeability test

Figure 3.16 Samples of wastewater before and after the test

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Standard Proctor Compaction Test

In this study, the tests were carried out and determined the results of the basic engineering soil properties. Tables 4.1 and shows the results of the test samples that necessary for each step on the laboratory work. This test was carried out according to the American Standard for Testing and Materials (ASTM 2166).

Table 4.1 Results of the samples of basic engineering properties of soil

Maximum Dry Density (gm/cm^3)	1.68
Optimum Moisture Content (%)	22.60
Liquid Limit (%)	31.20
Plastic Limit (%)	22.14
Plasticity Index (%)	9.06

Tables 4.1 showed that maximum dry density increased, while the results of optimum moisture content decreased. The reason behind this decrease may the rate of the sand which had affected the capability of the clay soil (Nuruzzaman and Hossain, 2014).

The tests were completed with different percentages such as 100% clay, 90% clay and 10% sand, 80% clay and 20% sand, 70% clay and 30% sand 50% clay with 50% sand and 20% clay with 80% of sand. The maximum dry density and optimum moisture content were determined according to the ASTM (2166) showed on the Table 4.2 and the Figures 4.1, 4.2 and 4.3.

Table 4.2 The MDD and OMC results of all contents

Soil ratios	Maximum Dry Density (gm/cm^3)	Optimum Moisture Content (%)
100% clay	1.68	22.60
90% clay + 10% sand	1.71	21.50
80% clay + 20% sand	1.81	18.80
70% clay + 30% sand	1.86	17.10
50% clay + 50% sand	2.26	7.98
20% clay + 80% sand	1.71	21.50

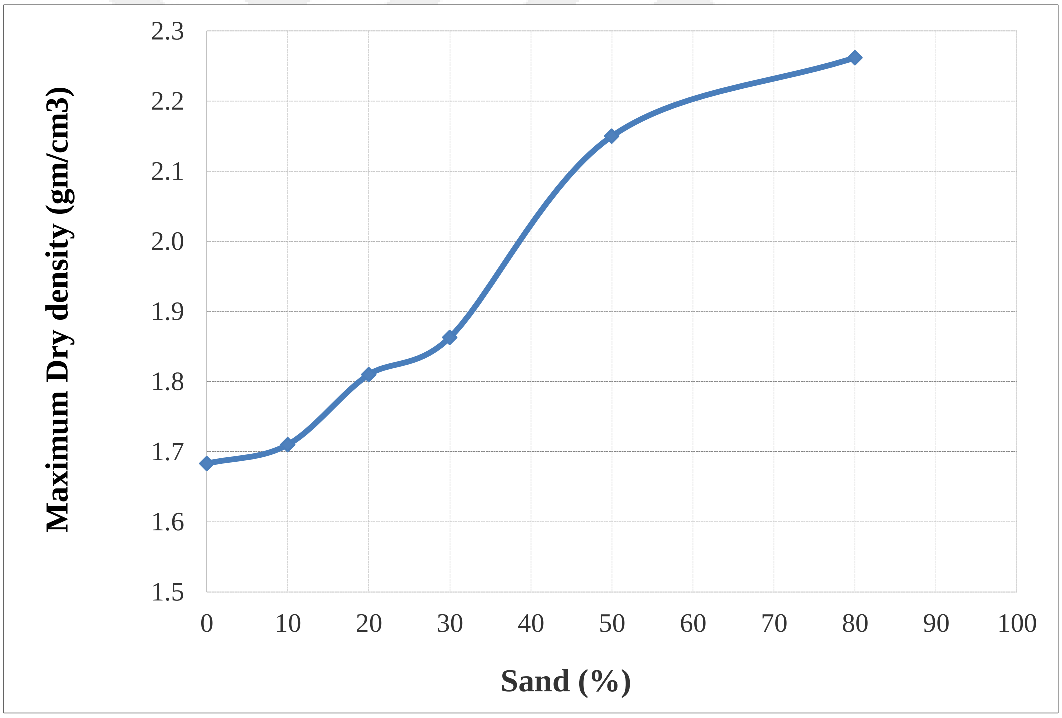

Figure 4.1 The MDD results for clay and sand-clay mixtures

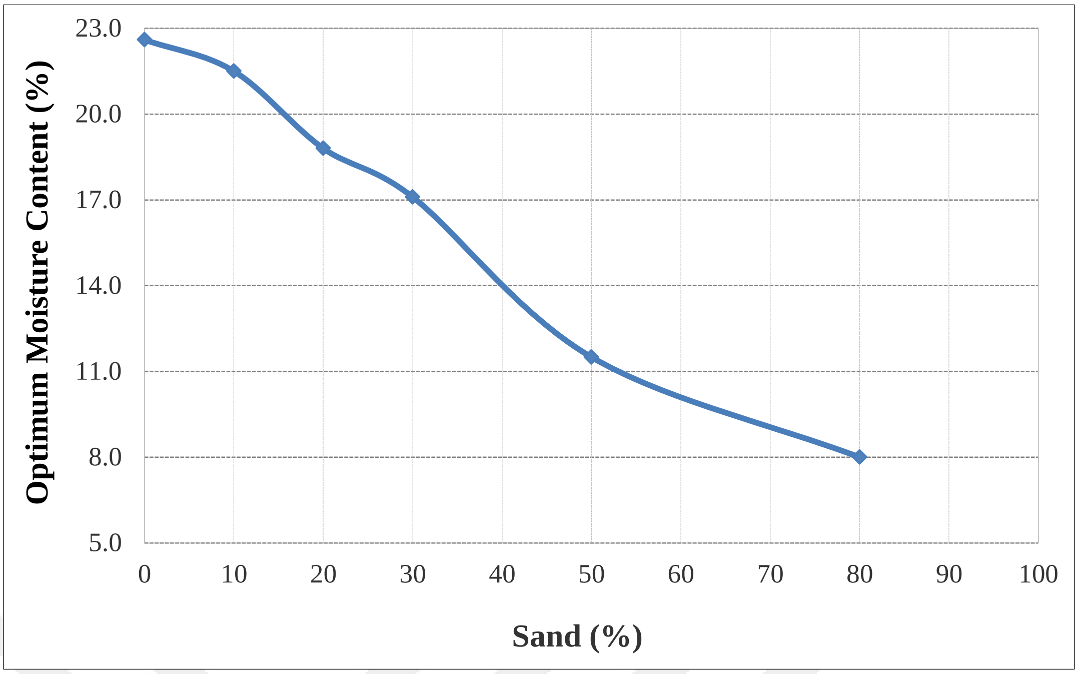

Figure 4.2 The OMC results for clay and sand-clay mixtures

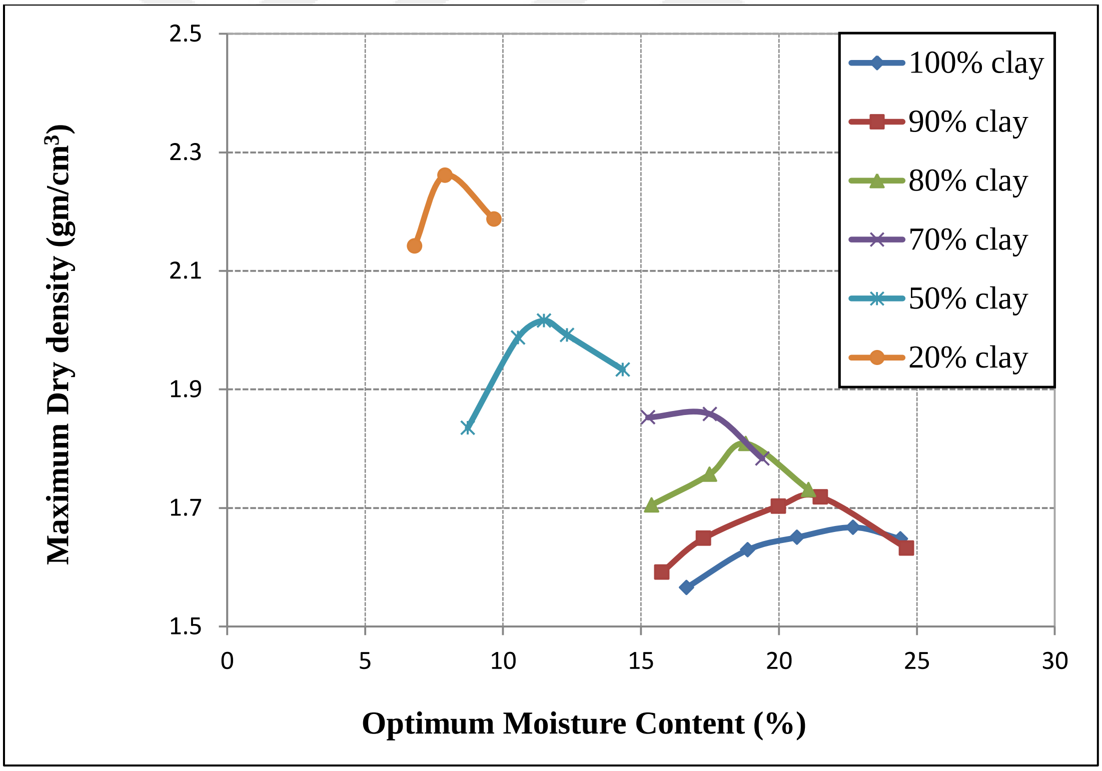

Figure 4.3 Relationship between MDD and OMC

The results of MDD and OMC showed in the figures. The MDD results increased and the OMC decreased Nuruzzaman and Hossain (2014).

4.2. Permeability Test

Permeability test was carried out in this study at Gaziantep GASKI Plant (GGP). This test was measured when the wastewaters put on the compacted soil inside the box until the water filtrated on the bottom taps. Five trials were conducted during the work. The samples of the both wastewater and the infiltrated water saved in the plastic bottle; three bottles with 1.5 liter has been taken. The Tables 4.3-4.8 shows the results.

Table 4.3 Permeability of wastewater with the accurate time measured

Sand-clay mixtures ratio	Time required for the first drop of wastewater
90% Clay + 10% Sand	02: hours 56: minutes 39: seconds
80% Clay + 20% Sand	01: hour 49: minutes 21: seconds
70% Clay + 30% Sand	01: hour 01: minutes 33: seconds
50% Clay + 50% Sand	00: hour 36: minutes 53: seconds
20% Clay + 80% Sand	00: hour 19: minutes 20: seconds

Table 4.4 Permeability results for the first trial

Fourth trial 90% Clay+10% Sand	Plastic bottle (1.5 L)	Time required for the first drop of wastewater
First Attempt	1.5	00: hour 06: minutes 12: seconds
Second Attempt	1.5	00: hour 05: minutes 31: seconds
Third Attempt	1.5	00: hour 05: minutes 02: seconds

Table 4.5 Permeability results for the second trial

Fourth trial 80% Clay+20% Sand	Plastic bottle (1.5 L)	Time required for the first drop of wastewater
First Attempt	1.5	00: hour 04: minutes 12: seconds
Second Attempt	1.5	00 hour 05: minutes 26: seconds
Third Attempt	1.5	00: hour 04: minutes 58: seconds

Table 4.6 Permeability results for the third trial

First trial 70% Clay+30% Sand	Plastic bottle (1.5 L)	Time required for the first drop of wastewater
First Attempt	1.5	00: hour 02: minutes 49: seconds
Second Attempt	1.5	00: hour 04: minutes 55: seconds
Third Attempt	1.5	00: hour 03: minutes 11: seconds

Table 4.7 Permeability results for the fourth trial

Second trial 50% Clay+ 50% Sand	Plastic bottle (1.5 L)	Time required for the first drop of wastewater
First Attempt	1.5	00: hour 02: minutes 07: seconds
Second Attempt	1.5	00: hour 01: minutes 36: seconds
Third Attempt	1.5	00: hour 01: minutes 42: seconds

Table 4.8 Permeability results for the fifth trial

Third trial 20% Clay+ 80% Sand	Plastic bottle (1.5 L)	Time required for the first drop of wastewater
First Attempt	1.5	00: hour 01: minutes 41: seconds
Second Attempt	1.5	00: hour 01: minutes 32: seconds
Third Attempt	1.5	00: hour 01: minutes 25: seconds

According to the results showed on the tables, the permeability decreased when there were added more sands, and the permeability increased when added more clay.

4.3. Suspended Solid (SS)

The results of this test were obtained through the experimental work, carried out within 24 hours. Soil percentages were 90% clay with 10% sand, 80% clay with 20% sand, 70% clay with 30% sand, 50% clay with 50% of sand and 20% of clay with 80% of sand. The samples of both wastewater and infiltrated water were tested and the results obtained at the end of 24 hours. The Table 4.9 and the Figure 4.4 show the results. According to the results, when added more clay the efficiency were decreased and when added more sands the efficiency were increased.

Table 4.9 Results of all trials for SS test

Parameters Suspended Solid (SS)	Wastewater (mg/L)	Permeate (mg/L) Sand- clay mixture	Efficiency (%)
90% clay+ 10% sand	586	4.0	99.3
80% clay+ 20% sand	586	10	98.3
70% clay+ 30% sand	872	24	97.2
50% clay+ 50% sand	136	28	79.4
20% clay+ 80% sand	136	72	47.1

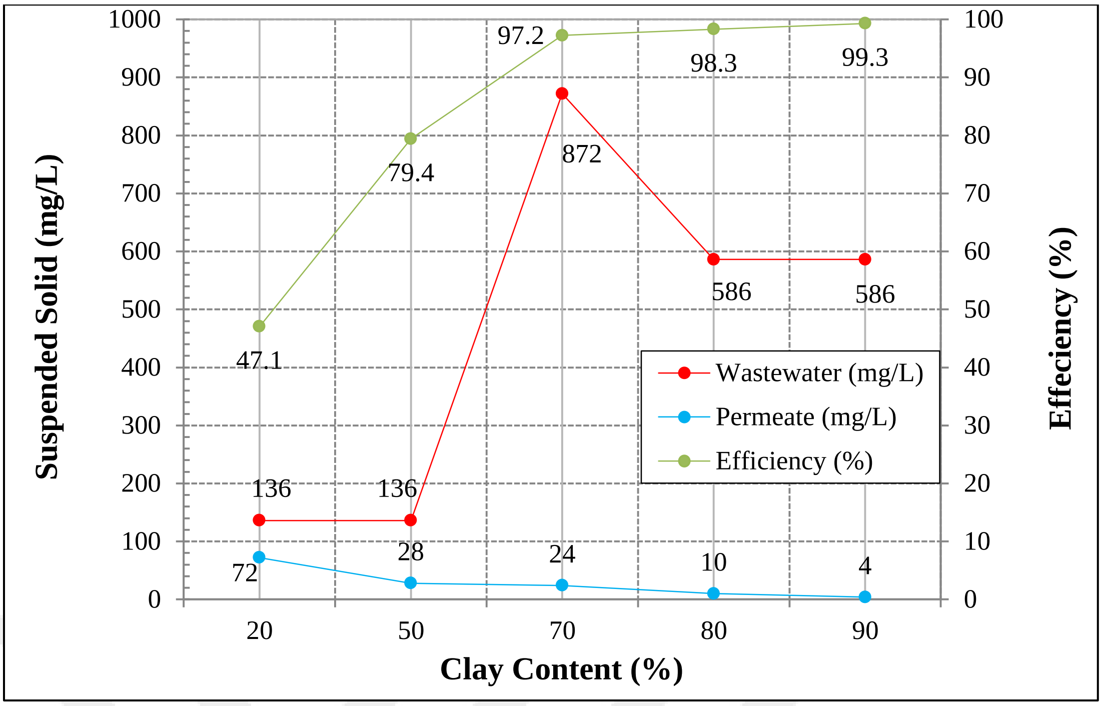

Figure 4.4 Relationship between SS and the ratio of sand and clay

4.4. Chemical Oxygen Demand (COD)

In this study, the results of the COD test were obtained through the experimental work. The samples of both wastewater and infiltrated water were saved in the plastic bottles separately and then tested; the results were carried out in 24 hours. It should be known that when added more clay with less sand the efficiency were high, it means that the sand soil has a great impact on the clay soil. The results showed on the Table 4.10 and the Figure 4.5 were described the test results for COD test values. The efficiency term is the ability to avoid wasting materials, energy and efforts in producing desired results. In another definition means the ability to do things well without waste. In general, efficiency is a measurable concept, quantitatively determined by the ratio of useful output to total input.

Table 4.10 Results of all trials for COD test

Parameters COD	Wastewater (mg/L)	Permeate (mg/L) Sand- clay mixture	Efficiency (%)
90% clay+ 10% sand	786.8	48	93.9
80% clay+ 20% sand	786.8	58	92.6
70% clay+ 30% sand	1545.6	134.4	91.3
50% clay+ 50% sand	566.4	158.6	72
20% clay+ 80% sand	566.4	177.6	68.6

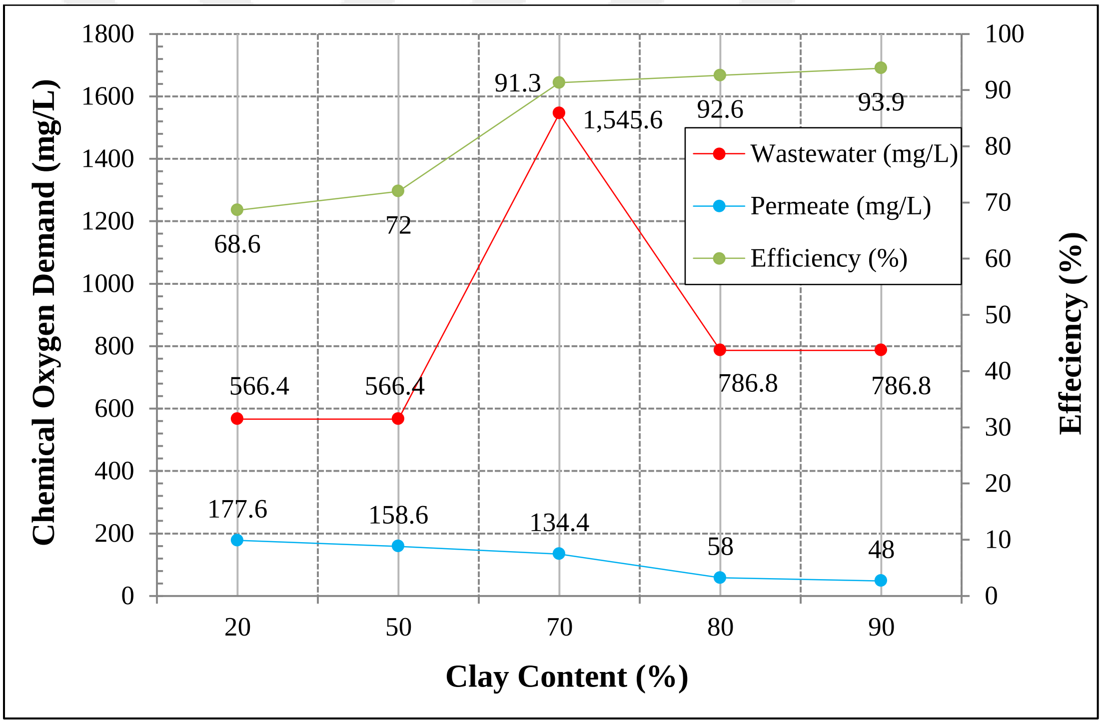

Figure 4.5 Relationship between COD and ratio of sand and clay

4.5. Power of Hydrogen (pH)

The experiments of this test were performed to find out the pH of wastewaters. The results were carried out on five various trials with the different ratio of soil. The period of the pH test was 24 hours. The results show on the Table 4.11 and the

Figure 4.6 for all ratios, except efficiency result, because pH is not including efficiency (APHA, 2005).

Table 4.11 Results of all trials for pH test

Parameters pH	Wastewater	Permeate Sand- clay mixture
90% clay+ 10% sand	7.27	7.86
80% clay+ 20% sand	7.27	7.69
70% clay+ 30% sand	7.15	7.70
50% clay+ 50% sand	7.39	7.59
20% clay+ 80%sand	7.39	7.53

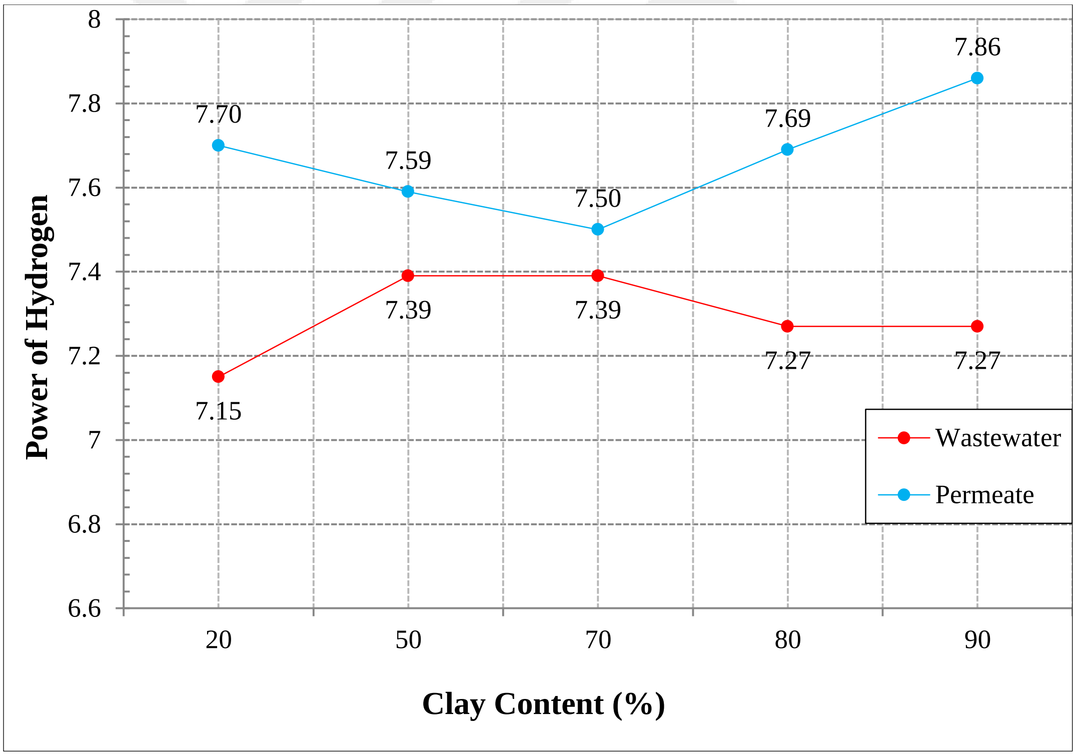

Figure 4.6 Relationship between pH and ratio of sand and clay

4.6. Biochemical Oxygen Demand (BOD)

The test results were carried out during the experimental work. The samples were taken from both wastewater and the infiltrated water. This test was necessary for the environmental engineering. The test period of this test was five days after the limited period, the results were obtained. The results showed on the Table 4.12 and the Figure 4.7, when added more sands to clay the results increased than the other trials when used more clay. The term permeates means passing through as the wastewaters permeate sand easily than clay.

Table 4.12 Results of all trials for BOD test

Parameters BOD	Wastewater (mg/L)	Permeate (mg/L) Sand- clay mixture	Efficiency (%)
90% clay+ 10% sand	386	10	97.4
80% clay+ 20% sand	386	18.6	95.2
70% clay+ 30% sand	536	39	92.7
50% clay+ 50% sand	320	30	90.6
20% clay+ 80% sand	320	35	89.1

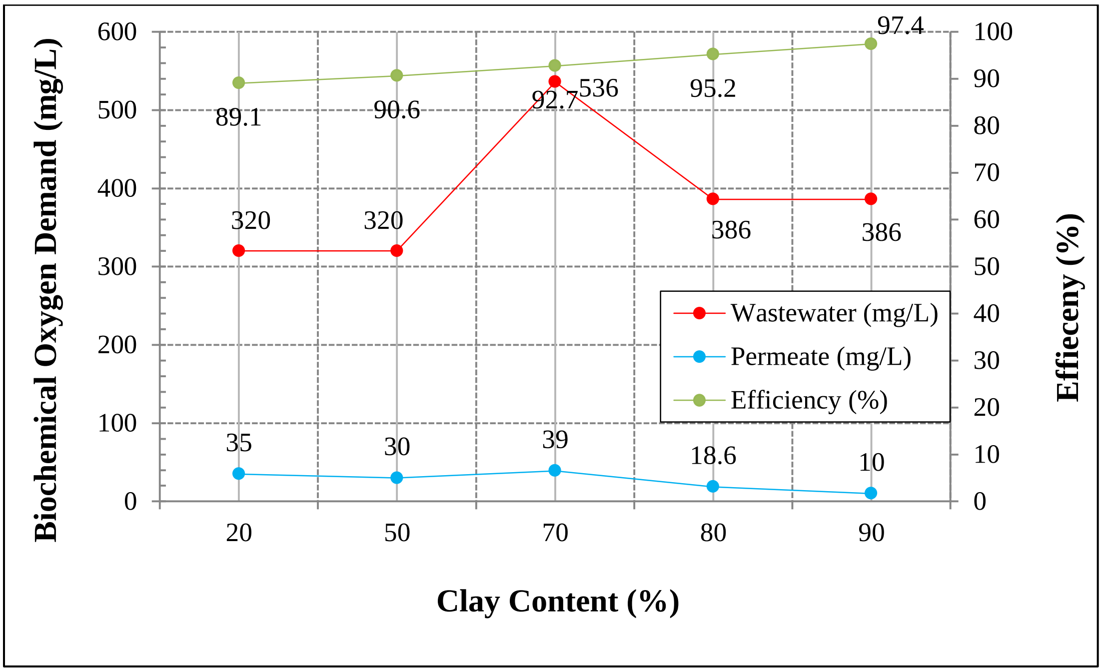

Figure 4.7 Relationship between BOD and the ratio of sand and clay

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, the effects of wastewater application on soil properties were carried out. The soils were used in the experiments of this study were clay and sand. The ratio of the soils were used: 90% clay with 10% sand, 80% clay with 20% sand, 70% clay with 30% sand, 50% clay with 50% sand and 20% clay with 80% of sand were mixed. The UCS test was carried out for the ratios of the soils were mentioned. The clay was mixed with sand and achieved the MDD, OMC and the permeability of wastewater. The following points show the results according to the tests:

- According to the results for both MDD and OMC by using 100% clay, it shows that the MDD decreased and the OMC increased, because of the effect of weight which related to the maximum unit weight directly. The other trials when used sands, the results changed in the ratio of 80% sand, 50% sand, 30% sand, 20% sand and 10% sand.
- The compaction test helped this study to find water content, LL, PL and PI with the MDD and OMC. The tests were carried out for 100% of clay and the other mentioned ratio.
- According to the tests for permeability that showed in the results, whenever added more sands to clay, the permeability of dropped water was decreased than the other trials when added more clay.
- The parameters for all trials according to the results in wastewater that were mg/L for both 30% and 50% sand were equal, but the result of 80% sand was increased among all the trials and there were differences among each of them.
- The efficiency results for SS, COD, pH and BOD tests different from each other, during the test results when used more sands the efficiency were decreased, while used more clay like 90% the results increased. While, there were no efficiency result for pH according to its procedure.

5.2 Recommendations

The following recommendations as given below can be made for future research:

- It should be known that, wastewater has a great impact on the sand-clay mixtures and will change the results in anytime while putting wastewater on and taking its permeability.
- The findings of this study indicated that the experimentation on the mixing soils such as sand and clay with different percentages.
- This study has to be validated with the using of natural sands and clays from different location.
- The conception of the permeability should be corroborated and processed using additional soils.

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