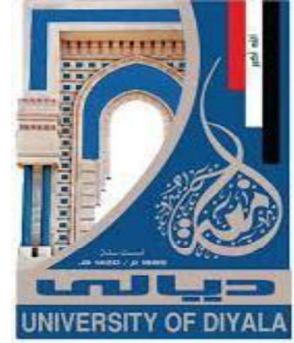


**Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering**



FINITE ELEMENT SIMULATION OF ELECTRO-OSMOTIC CONSOLIDATION FOR IMPROVING CONTAMINATED SOIL

**A Thesis Submitted to the Council of the College of
Engineering, University of Diyala in Partial Fulfillment of the
Requirements for the Degree of Master of Science in Civil
Engineering**

By

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IRAQ

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ
الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ^١ الرَّحْمَنِ الرَّحِيمِ^٢
مَلِكِ يَوْمِ الدِّينِ^٣ إِيَّاكَ نَعْبُدُ وَإِيَّاكَ نَسْتَعِينُ^٤
اهْدِنَا الصِّرَاطَ الْمُسْتَقِيمَ^٥ صِرَاطَ الَّذِينَ أَنْعَمْتَ
عَلَيْهِمْ^٦ غَيْرِ الْمَغْضُوبِ عَلَيْهِمْ وَلَا الضَّالِّينَ^٧

صدق الله العظيم
سورة الفاتحة

CERTIFICATION

We certify that the thesis entitled “**Finite Element Simulation of Electro-Osmotic Consolidation For Improving Contaminated Soil**” was prepared by “Tasneem Mageed Awad” under my supervision at the Department of Civil Engineering-College of Engineering-Diyala University in a partial fulfillment of the Requirements for the Degree of **Master of Science in Civil Engineering**.

Signature:

Supervisor: Assist. Prof. Dr. Qasim A. Mahdi

Date:

Dedication

**I Wish to Dedicate My
Thesis to The Light of My Eyes
My Beloved Parents (My Mother
and Father) With All My Respect,
Love and Gratitude**

Tasneem mageed Awad

2021

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ABSTRACT

In recent years, geotechnical soil problem have increased because various types of contaminants such as petroleum products, organic contaminants and heavy metals as a result of expansion and development of urban and industrial activities, so it is very important to investigate the impacts of contaminants on the geotechnical properties of soil and investigate a suitable technique for the remediation of soil.

In this study a numerical model is proposed for electro-osmotic consolidation of improved contaminated soil by coupling the seepage field, electric field, and the stress and strain field. The soil mass deformation, pore-water pressure and the electrical voltage are the basic variables in the governing equations. Two-dimensional finite element model by used software Comsol v.5, developed to simulate the electro-osmotic consolidation process, predicting of soil mass displacement. As a methodology of research in general three interface model, first one is mechanical solid model to explain displacement and deformation under constant load (250kN/m) .

The second model is Darcy's model to variety of hydraulic permeability of soil mass during consolidation is incorporated in the control equations. The boundary conditions for electrical field, seepage flow and displacement can be adequately simulated.

Third model deals with the effect of electrical model where used various dimension of electrode (anode and cathode) various length (2.5, 3, 4m)and distance between as.(1.5, 2, 2.5m)

The last model is developed to explain behavior of soil mass with the effect of various concentrations when these spread contaminates in soil.

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Examination Committee Approval

Dedication

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LIST OF SYMBOLS

Symbol	Definition
Cu	Copper
pd	Lead
γ	Unit Weight, kN/m ³
ε	Strain, %
σ	Normal Stress, kN/m ²
C max	Maximum Concentrations, ppm
C min	Minimum Concentrations, ppm
DC	Direct Electrical Current
EC	Electrical Conductivity
Ek	Electro kinetics Experiment
HMs	Heavy Metals

Chapter One

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Recently years, rapidly developing and changing technologies plus industrial products and practices frequently carry with them the increased generation of materials. That, if improperly dealt with, can threaten both public health and the environment, thus found the need to formulate and implement studies and actions leading to a compatible balance between human activities and the ability of natural resources to support and raise life.

In general, there are many sources of soil pollution, man-made sources including automobiles, power generation and the industrial activities. They represent the main source of air pollution and thus causes soil pollution by precipitation; especially, oil industry activities using huge amount of consumable fuel, like power plants and oil refinery; due to the high rate emission of fume, solid particulates and toxic gases more than other industry in quantity (Afaj and Al-Khashab, 2007).

The problem of contamination is one of the important and serious problems that have developed around the world in recent years. Human activities such as agriculture, industry and mining are considered the fundamental reasons that lead to the emergence of contamination problems. There are several types of contaminants, including heavy metal, volatile organic matter and semi-volatile organic matter. The contamination usually arises from the break of underground storage tanks and pipes, application of fertilizers and pesticides, percolation of polluted surface water to subsurface strata, leaching of wastes from landfill or direct disposal of industrial mechanical squanders to the soil.

Iraq has several contaminated sites ensuing from a mixture of general industrial activities, military activities and post-conflict damage and pillage (UNEP Report, 2005).

Heavy metals are generally defined as metals with relatively high densities, atomic weights, or atomic numbers such as copper, zinc, lead, nickel, cobalt and cadmium. Heavy metals have the most harmful effects on the physical and mechanical properties of soil. Soil contamination by heavy metals is increasing in different local sites including residential areas near industrial complexes and repositories of drinking water. More than 65% of superfund locales in the United States are contaminated with heavy metals and in rice paddies in Taiwan and Japan (Hussein, 2012). It has enormous impacts on the

quality of ground 2 water and geotechnical properties of soil. However, the solubility and extent of these contaminants in the subsurface system are influenced by the chemistry of the soil and groundwater. Factors like pH, redox potential (Eh), cation exchange capacity (CEC) and complexation/chelation with organic matter (OM) directly have an influence on the metal solubility (Evanko'and Dzombak, 1997; Kim'et al., 2003; and Saeedi'et al., 2009).

When the contaminants are introduced into the soil, they are held in the soil matrix structure through chemical absorption and are trapped within pore spaces encompassing the soil grains. Recently, the introduction of industrial contaminants into the soil pore spaces has gained a great attention. However, in the majority of the studies that have been conducted, researchers have focused on the movement of contaminants in soil rather than their effect on the soil properties (Shehzad et al., 2015). Generally, heavy metals in soil can be available as soluble compounds like ions and metal complexes or in exchangeable forms. These metals are generally bounded with different soil fractions and compartments such as carbonate, oxide, hydroxide, organic matter and residual materials (Srivastava et al., 2007).

1.2 Statement of contamination problem

In July 2004, the United Nations Environment Program (UNEP) granted a project for strengthening environmental governance in Iraq through environmental evaluation and capacity building. This project was supported by the UN Trust Fund for Iraq through funds made available by the government of Japan. One of the major elements of the project was to assess contaminated sites in Iraq, in partnership with Iraq's Ministry of Environment.

This project estimated that Iraq has several contaminated sites resulting from a mixture of general industrial activities, military activities, post-conflict damage and looting. (UNEP, 2005).

1.3 Engineering Behavior of Contaminated Soils

External contaminants are penetrating a soil mass through wet or dry precipitation which behave differently with regard to each soil type according to the absorption properties, texture, density, humidity, and other factors. This is due to the fact that these properties are not homogeneously developed in a certain soil and change largely with stratified layers of soil (Rahman et al., 2010). Clayey soils are considered electro-chemically active and mostly affected by the environment. Oil contamination might affect the stability and permeability of compacted clay in landfill sites and oil leaks might cause expansion or contraction of the soil on which pipelines are laid. The industrial wastes in contact with soil, or accidental spillages of chemical substances, may lead to changes in soil properties, resulting in improvement or degradation of the engineering characteristics of soil and sometimes leading to

functional or structural failure of structures. Any change in engineering properties or behavior of soil strata may lead to loss of bearing capacity and an increase in the total or differential settlement of foundation under the structure (Rahman et al., 2010). The extent of contamination depends on the chemical composition of the contaminated and the properties of the soil. Also, in connection with the cleanup works, and for any possible applications of contaminated soils, knowledge of the geotechnical properties and behavior of contaminated soil is required. In this case, it is necessary to determine the effect of crude contamination on the existing structures (Albaocy, 2011).

1.4 OBJECTIVES OF STUDY

Due to higher increase in oil industry activities in Iraq, since there are a little information of the environmental status of the areas around the refinery locations, and the concerns of a possible environmental pollution that will cause health and life threats to living organisms, this study was carried out. The study will also be useful as a base for decision making to protect the environment in areas surrounding various oil refineries in the country. The specific Objectives

1. To determine the concentration of the heavy metals, such as zinc, nickel, lead and cadmium in the soil and illustrate the distribution of these pollutants within the production units of the refinery and in the area around the refinery by using finite element Comsol software; and to indicate the areas of high concentration for the selected pollutants after comparison with the standards values.
2. To study the relation between the pollutants and power water pressure of soil within the depth soil .

3. To study the effect pollutants with various electric field on settlement of soil.

1.5 LAYOUT OF THESIS

There are five chapters to this study the first chapter offers general an overview and knowledge of the impact of pollution the purpose of this study.

Chapter Two: Includes a short description of soil contamination and the essential scientific literature available about the impacts of contaminants on the geotechnical properties of soil. Also, involves a brief description of remediation techniques and the method utilized in remediation of contaminated soils.

Chapter Three: A mathematical model for the simulation of contaminant heavy metals removal from soils by electric fields was performed in 2-D geometry.

Chapter Four: Contains the results and the discussion of these results.

Chapter Five: Includes the significant conclusions and recommendations for future works.

CHAPTER TWO

LITERATURE REVIEW