GEOTECHNICAL SPECIAL PUBLICATION NO. 241

GEOENVIRONMENTAL ENGINEERING

SELECTED PAPERS FROM THE PROCEEDINGS OF THE 2014 GEOSHANGHAI INTERNATIONAL CONGRESS

May 26-28, 2014
Shanghai, China

SPONSORED BY
The Geo-Institute of the American Society of Civil Engineers

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Published by the American Society of Civil Engineers

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/bookstore | ascelibrary.org

Errata: Errata, if any, can be found at http://dx.doi.org/10.1061/9780784413432

ISBN 978-0-7844-1337-1 (CD)
ISBN 978-0-7844-1343-2 (E-book PDF)
Manufactured in the United States of America.

Preface

Geoenvironmental engineering has been becoming increasingly important in both geotechnical engineering and sustainable development. This ASCE Geotechnical Special Publication (GSP) on Geoenvironmental Engineering consists of papers that represent the latest developments in geoenvironmental remediation, municipal solid waste (MSW) properties and behavior, landfills, and characterization and beneficial reuse of waste and recycled materials.

All of the selected papers were presented at the GeoShanghai Conference, sponsored by the Geo-Institute of the American Society of Civil Engineers, held in Shanghai, China, May 26-28, 2014. The papers are organized into three technical sections: (1) Geoenvironmental Pollution: Assessment, Control and Remediation; (2) Municipal Solid Waste and Landfills; and (3) Geoenvironmental Materials: Characterization and Applications.

In the *Geoenvironmental Pollution: Assessment, Control and Remediation* section, studies on the characterization of site contamination, fate and transport of the contaminants, containment technologies, and remediation technologies are presented.

In the *Municipal Solid Waste Properties and Landfills* section, various studies on physico-chemical, biological and geotechnical properties of municipal solid waste are presented. This section also presents developments in analysis and design of municipal solid waste landfills, such as leachate recirculation, settlement, and slope stability, are presented.

In the *Geoenvironmental Materials: Characterization and Application* section, studies on characterization of a wide range of waste and recycled materials are presented. In addition, several applications of waste and recycled materials are proposed and investigated. Methods to improve the properties of waste and geologic materials are also presented.

Each paper published in this ASCE Geotechnical Special Publication was evaluated by two or more reviewers and the editors. All published papers are eligible for discussion in the Journal of Geotechnical and Geoenvironmental Engineering, and are also eligible for ASCE awards.

We would like to acknowledge the quality and timely peer reviews provided by the reviewers listed below. Without their professional contributions, this publication would not be possible.

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Wei Zhu, Hohai University, China

In producing this GSP, the editors would also like to acknowledge the assistance of Donna Dickert and Betsy Kulamer at ASCE Geo-Institute. In addition, the editors would like to extend their great appreciation to Professors Lianyang Zhang and Wenqi Ding (the GeoShanghai Conference Chairs) who were instrumental in organizing the GeoShanghai Conference.

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January 19, 2014

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Geoenvironmental Pollution: Assessment, Control, and Remediation

Municipal Solid Waste Properties and Landfills

Geoenvironmental Materials: Characterization and Applications

Phytoremediation of Mixed Contaminated Soils - Effects of Initial Concentrations

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ABSTRACT: Numerous contaminated sites exist worldwide that contain a mixture of organic and heavy metal contaminants. Very few technologies are proven to be efficient to address the problem of such mixed contamination. Most of these technologies are energy-intensive and expensive and they can disturb the natural ecosystem. Phytoremediation has potential to be a green and sustainable approach to decontaminate and restore the contaminated sites, maintaining the biological activity and physical structure of the soils. However, its effectiveness for mixed contaminants is not well understood. This study presents series of laboratory experiments conducted to investigate the effects of initial contaminant concentration on phytoremediation of mixed contaminated soils. A silty clay (typical field soil) was spiked with naphthalene, phenanthrene (representative organic contaminants), lead, cadmium and chromium (representative heavy metals), in different concentrations. Two plant species, specifically *Avena sativa* (oat plant), and *Helianthus annuus* (sunflower), were grown in these contaminated soils as well as in uncontaminated soil for comparison purposes. Results showed that the increase in contaminant concentrations in the soil negatively influenced the growth and biomass of the plants. *Helianthus annuus* showed lower germination, survival, growth rates, and biomass under increasing contaminant concentrations compared to *Avena sativa.*

INTRODUCTION

Many sites worldwide are contaminated with a mixture of organic and heavy metal contaminants. Since many remediation technologies aim to degrade or immobilize only a particular type of contaminant, remediation of sites co-contaminated with organic and heavy metal contaminants can be a difficult task. Many of the methods used for mixed contaminated soils are energy intensive or expensive. For large sites with shallow and moderate contamination, phytoremediation can be a practical option to remediate mixed contaminants. Phytoremediation is a low cost method which has the potential to treat both organic and inorganic contaminants. Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water (Sharma and Reddy, 2004). This technology has been receiving attention lately as an innovative and cost-effective alternative to more established treatment methods used at hazardous waste sites (USEPA, 2000). The inherently aesthetic nature of planted sites makes phytoremediation an attractive option compared to other cleanup methods (ITRC, 2009). The nature of on-site contaminants and the concentrations of these contaminants are governing factors in phytoremediation (Kranner and Colville, 2011, Henner et al. 1999). Higher phytotoxicity of the chemicals at higher concentrations can negatively affect the germination and survival of the plants, which in turn affect the phytoremediation efficiency. Understanding the contaminant concentrations above which the plants are expected to survive better is important in phytoremediation implementation.

BACKGROUND

Many historically industrialized former wetland and grassland sites in Chicago have been found to be contaminated with a mixture of organic and heavy metal contaminants. Naphthalene, phenanthrene, lead (Pb), cadmium (Cd), and chromium (Cr) are observed to be the most common contaminants at many of the sites (City of Chicago, 2005). The 100 % concentrations used in this study are the concentrations similar to the maximum concentrations found at the sites considered.

This study has attempted to understand the range of contaminant concentrations above which plant survival and growth are considerably affected by the initial contaminant concentrations. This is expected to give better understanding of site contaminant concentrations, below which phytoremediation can be effectively implemented.

EXPERIMENTAL METHODS

Selected Plant Species

The plant species for the study were selected based on biomass and capability of survival in mixed contaminated soil based on some previous results. The plants selected were *Avena sativa* (oat plant), and *Helianthus annuus* (sunflower). *Avena sativa* was studied for its phytoremediation efficiency for heavy metal (Ebbs and Kochian, 1998) and organic contaminants (Miya and Firestone, 2001) in the past. *Helianthus annuus* species was also involved in phytoremediation studies of both organic (Rosado and Pichtel, 2004) and heavy metal (Meers et al. 2005. contaminants.

Soil Selected

Clean gray silty clay, which represents typical Chicago glacial till, was obtained from a field site in Chicago, IL, and was used for the pot experiments. The aim is to use the experimental results for the phytoremediation of some sites with mixed contamination in Chicago. The physic-chemical properties of the soil used in the study are presented in Table 1.

Table 1: Physico-chemical properties of soil used for the experiments

Soil water content	0.95 %
Soil organic content	2.3 %
Specific gravity	2.7
Liquid limit	33.1 %
Plastic limit	18.91 %
Plasticity index	14.19 %
Clay (< 0.002mm)	42 %
Silt (0.002 - 0.05mm)	42 %
Sand (0.05 – 2 mm)	14.3 %
USCS Classification	CL
USDA Classification	Silty clay

Soil Spiking Procedure

The reference uncontaminated soil was prepared by mixing the soil with 15 % water. The contaminated soil was prepared by spiking the soil with naphthalene, phenanthrene, Pb, Cd and Cr. For that, measured amount of naphthalene and phenanthrene were dissolved in hexane by mixing using a magnetic stirrer. The hexane containing naphthalene and phenanthrene was mixed with dry soil. The mixed soil was kept for 3 to 4 days in the fume hood for drying and to ensure that all hexane evaporated. Soil was mixed once every day during drying to ensure uniformity. Measured amounts of $PbCl_2$, $K_2Cr_2O_7$ and $CdCl_2$.½ H2O were mixed in water (to yield approximate water content of 15 % in soil) for one hour using magnetic stirrer. The solution was added to the soil, previously spiked with naphthalene and phenanthrene. The soil was mixed well to ensure homogenous distribution of contaminants. By varying the amount of chemicals in the mixture, soils with different contaminant concentrations were prepared. The maximum contamination used here is taken as 100 % contamination. The amounts of contamination for different percentages mentioned here are listed in Table 2.

Table 2: Contaminant Concentrations Used in the Experiment

Notation Used	**Concentration of Contaminants in Soil (mg/kg)**				
	Pb	Cd	Cr	Naphthalene	Phenanthrene
100 %	500	50	200	50	100
50 %	250	25	100	25	50
25 %	125	12.5	50	12.5	25
10 %	50	5	20	5	10

Measured properties of the contaminated and uncontaminated soil at the time of seeding are presented in Table 3.