REMOVAL OF LEAD, CADMIUM AND NICKEL BY SAWDUST-MODIFIED TROPICAL CLAY FOR USE AS LANDFILL LINER MATERIAL

By

AKINWUMI, ISAAC IBUKUN

Matric. Number: CUGP080208

July, 2017

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A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING, COLLEGE OF ENGINEERING, COVENANT UNIVERSITY, OTA, OGUN STATE, NIGERIA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY (Ph.D) DEGREE IN CIVIL ENGINEERING

July, 2017

ACCEPTANCE

This is to attest that this thesis is accepted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Civil Engineering in the Department of Civil Engineering, College of Engineering, Covenant University, Ota.

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(Secretary, School of Postgraduate Studies)	Signature & Date
Professor Samuel T. Wara	....
(Dean, School of Postgraduate Studies)	Signature & Date

DECLARATION

I, **AKINWUMI, ISAAC IBUKUN** (CUGP080208), declare that this research was carried out by me under the supervision of Dr. Oluwapelumi O. Ojuri of the Department of Civil and Environmental Engineering, Federal University of Technology Akure and Dr. Adebanji S. Ogbiye of the Department of Civil Engineering, Covenant University, Ota. I attest that the thesis has not been presented either wholly or partly for the award of any degree elsewhere. All sources of data and scholarly information used in this thesis are duly acknowledged.

AKINWUMI, ISAAC IBUKUN ....

Signature & Date

CERTIFICATION

We certify that this thesis titled "Removal of Lead, Cadmium and Nickel by Sawdust-modified Tropical Clay for use as Landfill Liner Material" is an original work carried out by AKINWUMI, ISAAC IBUKUN (CUGP080208), in the Department of Civil Engineering, College of Engineering, Covenant University, Ota, Ogun State, Nigeria, under the supervision of Dr. Oluwapelumi O. Ojuri and Dr. Adebanji S. Ogbiye. We have examined and found the work acceptable as part of the requirements for the award of Doctor of Philosophy (Ph.D) degree in Civil Engineering (Geotechnical Engineering Option).

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Professor Emmanuel A. Okunade ....
(External Examiner) Signature & Date

Professor Samuel T. Wara ....
(Dean, School of Postgraduate Studies) Signature & Date

DEDICATION

This research work is dedicated to the Producer of the 'movie' of my life, the Ultimate Deliverer, the Way Maker, the Capable One, the King over all storms, the All Sufficient One, the Father of the fathers and the Father to the fatherless, the Great Provider, the Ever-loving One, the Never-erring but Forgiver of all sins, and the Timeless One that is always right on time - the Almighty God.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAS: Atomic Absorption Spectrometer

As: Arsenic

BS: British Standards

BSI: British Standard Institution

Cd: Cadmium

CH: Clay of high plasticity

CL: Clay of low plasticity

Co: Cobalt

Cr: Chromium

Cu: Copper

Fe: Iron

FEPA: Federal Environmental Protection Agency

MDUW: Maximum Dry Unit Weight

ML: Silt of low plasticity

Mn: Manganese

Mo: Molybdenum

Ni: Nickel

OMC: Optimum Moisture Content

Pb: Lead

SC: Sandy clay

SEM: Scanning Electron Microscopy

SM: Sandy silt

UCS:	Unconfined Compressive Strength
USCS:	Unified Soil Classification System
US EPA:	United States Environmental Protection Agency
WHO:	World Health Organisation
XRD:	X-ray diffractometer
XRF:	X-ray fluorescence spectroscopy
Zn:	Zinc

ABSTRACT

Access to groundwater, a major source of direct drinking water in many developing countries, should not be assumed as access to safe drinking water. There is a need to prevent or minimize the contamination of groundwater, especially arising from solid waste disposal. This research work investigated the suitability of using clay and bentonite modified with sawdust as landfill liner materials for minimizing the migration of Pb^{2+}, Cd^{2+} and Ni^{2+} in order to protect the environment and public health. Series of laboratory tests were carried out to determine the chemical and mineralogical composition, microstructural analysis of the clay and bentonite in order to characterize the samples. The effects of adding varying percentages of sawdust to the clay and bentonite on their geotechnical properties were determined. The removal of each of Pb^{2+}, Cd^{2+} and Ni^{2+} by the clay, bentonite, sawdust-modified-clay and sawdust-modified-bentonite was investigated using the batch equilibrium adsorption technique for varying initial metal ion concentrations and contact times, while the pH, adsorbent dosage and temperature were kept constant. Results obtained show that the application of up to 8% sawdust to the clay satisfies standard geotechnical properties requirements for use as clay landfill liner, whereas the bentonite and its modification with sawdust did not. Each of the sawdust-modified-clay and sawdust-modified-bentonite removed more Pb^{2+}, Cd^{2+} and Ni^{2+} than the clay and bentonite without sawdust, respectively. The Dubinin-Radushkevich model was found to be the best adsorption isotherm that described the Pb^{2+}, Cd^{2+} and Ni^{2+} adsorption by the sawdust-modified-clay, while the pseudo-second-order kinetic model best described the rate of adsorption of these metal ions by the sawdust-modified-clay. The adsorption by the modified clay can be described as physical adsorption due to weak van der Waals forces. The order of removal of the metals by the clay and sawdust-modified-clay followed a trend of $Pb^{2+} > Cd^{2+} > Ni^{2+}$, while that of bentonite and sawdust-modified-bentonite followed a trend of $Pb^{2+} > Ni^{2+} > Cd^{2+}$. The clay and sawdust-modified-clay removed Pb^{2+} and Cd^{2+} better than the bentonite and sawdust-modified-bentonite, respectively, while the bentonite removed Ni^{2+} better than the clay. Clay modified with sawdust was found suitable and recommended for use as a landfill liner material in a composite lining system, thereby providing a low-cost and sustainable approach to improving the capacity of the clay to minimize the migration of Pb^{2+}, Cd^{2+} and Ni^{2+} from landfills, and protecting the environment (particularly groundwater resources) and public health.

Keywords: Adsorption; Environment; Groundwater pollution; Heavy metals; Sustainability; Waste management