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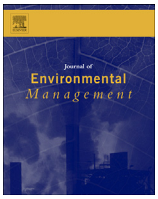

Research article

Effects of specimen size and mix ratio on the nickel migration behavior of landfill waste mixed mortar

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ABSTRACT

Landfill solid waste management system poses the potential source of silent wide-spread heavy metals like nickel poisoning in the entire ecosystem of nearby environment. Nickel containing demolish solid wastes are disposed at landfill zones to a great extent from where nickel migrate into the food chain through the surface water body as well as groundwater. Consequently, nickel exposure may cause different environmental problems. From this sense, it may be an attractive proposal to recycle the waste as a sustainable product. Herein is presented a long-term feasibility study on potential leaching behavioral pattern of nickel from different sizes and mixes based solidified landfill waste mixed mortar block. The calculated results revealed the larger sizes block entrapped more nickel content than the smaller in relation to the available for leaching. Moreover, the specimen bearing the higher amount of waste resulted the significant nickel immobilization within the crystalline structure. The study observed the fixation results 97.72%–99.35%, 97.08%–99.11%, 96.19%–98.58% and 95.86%–91.6% under the stabilizing agent to fine aggregate mixing combination 1:1, 1:1.5, 1:2 and 1:2.5 respectively where 30% of the total volume of fine aggregate was replaced by landfill waste. Although, mechanical strength test of all surrogate waste forms was also conducted that showed acceptable performance for land disposal, the current research pointing out that constructed green products were non-hazardous except the specimens having mixture ratio 1:2.5 because nickel ion release mechanism was observed under this ratio by surface decay or physical erosion of the monolithic matrices. Furthermore, semi-empirical based dominant leaching mechanism models were justified against the goodness of fit statistical parameters for interpreting the experimental observations of nickel transport profile where the adopted models possessed strong potential for predicting Ni content with high accuracy.

1. Introduction

In industrialized and developing countries, sanitary landfills are the most popular as well as ultimate disposal sites for both industrial and municipal solid wastes (Ahmed and Lan, 2012). As it is the most economic option in terms of capital and exploitation costs, is preferred over other waste management strategies such as incineration or composting (Ahmed and Lan, 2012; Aderemi et al., 2011). Despite of the economical and disposal facilities, landfills poses serious threat to the quality of the environment (Haque et al., 2014; Longe and Balogun, 2010; Jhamnani and Singh, 2009). Rainwater percolation, biochemical, chemical and physical reactions, and inherent moisture content of the wastes contribute to leachate formation (Ahmed and Lan, 2012; Renou et al., 2008) which conveys heavy metals that may get into the surface water and groundwater body through percolation causing potential water contamination (Mor et al., 2006; Haque et al., 2013). As a consequence, such metal pollution may possess substantial risk to the local natural environment at landfill sites. Furthermore, heavy metal percolates the soil layer of agricultural land near landfill sites which may transfer to the food chain through the bio-accumulation of plants (Ukpong et al., 2013). Likewise, the toxic elements may lead to enter the body system through food, air and water over a period of time (Yahaya et al., 2009).

Nickel (Ni) is a worldwide recognized contaminant that is found in many hazardous waste disposal sites specially the landfill sites which receives not only municipal solid wastes but also clinical and industrial wastes (Das et al., 2008; Mamtaz and Chowdhury, 2006). Hoque et al. (2014) noted that the concentration of Ni(II) in decomposed solid waste collected from Matuail sanitary landfill site during the dry (summer) season was 895.0 mg/kg which

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Nomenclature

ANS	American Nuclear Society
ASTM	American Society for Testing and Materials
CAL	Cumulative amount leach
CS	Compressive strength
DSW	Decomposed solid waste
DLM	Dominant leaching mechanisms
FST	Final setting time
MSLS	Matuail Sanitary Landfill Site
Ni(II)	Nickel with valence +2
NRC	Nuclear Regulatory Commission
OPC	Ordinary Portland cement
S/S	Solidification/stabilization
SWB	Solidified waste mortar
TCMA	total cumulative migration amount
WHC	Water holding capacity
$B_{CAL\ i}$	CAL of contaminant until period i (mg m $^{-2}$)
B_i	Contaminant leach in period i (mg m $^{-2}$)
t_i	Cumulative contact time after period i (s)
t_{i-1}	Cumulative contact time until the beginning of period i (s)
D_e	Effective diffusion coefficients (cm^2/s)
A_n	CAR of contaminant at leaching period n (mg)
A_0	Initial amount of contaminant present in the specimen (mg)
$(\Delta t)_n$	$=t_n-t_{n-1}$ = Duration of the leaching interval (s)
V	Volume of specimen (cm^3)
S	External surface area of the specimen (cm^2)
T_n	Elapsed time to the middle of the leaching period n (s)
log(B_t)	logarithm of cumulative release contents of contaminant (mg/m^2)
log(t)	logarithm of cumulative contact time of leaching test period (s)
U_{max}	Maximum leachable quantity (mg/kg)
d	Bulk density of the specimen (kg/m^3)
m	Slope of the linear regression line of log(B_t) versus log(t)
LI	Leachability index (cm)
n	Leaching period
N	Number of leaching periods
K_1	Surface wash-off phenomena
K_2	Rapid release of contaminant
K_3	Diffusion-controlled transport mechanism (cm^2/s)
K_4	Long term kinetically controlled dissolution (day^{-1})
M_s	Metal Concentration (mg/kg)
C_l	Metal Concentration(mg/l) (From AAS reading)
W_s	Mass of waste sample (kg)
I	Volume of mixing water in digested waste sample (Litre)
P	porosity (%)
W_D	Oven dry weight (g)
W_S	Submerged weight (g)
ρ_w	Density of water (g/cm^3)
V_T	Total volume of block specimen (cm^3)
W_A	Weight of specimen before the immersion in curing leachant (g)
W_B	Weight of specimen after the immersion in curing leachant (g)
N_i	Maximum leachable content of Ni(II) (mg)
W_s	Amount of waste in block (gm)
M_s	Concentration of Ni(II) in waste sample (mg/kg)
B_{RA}	Release amount of Ni(II) in period i (mg/cm^2)
A_1	Release amount of Ni(II) in period i (mg)
A_2	Total cumulative amount of Ni(II) release from S/S blocks (mg)
CF	Compacting factor
W1	Weight of empty cylinder
W2	Weight of partial compacted mortar with cylinder
W3	Weight of compacted mortar with cylinder

indicates that Ni containing demolish solid wastes such as electroplating, making color ceramics and nickel-cadmium battery production processes, jewelry, stainless steel materials, smoking tobacco, municipal incineration, and combustion of fuel oil and industries involved in nickel refining are disposed in that landfill site. In addition, Haque et al. (2014) also provided the information that same heavy metal contents were found to be reduced during the wet (monsoon) season which specifies the potentiality of Ni migration from landfill site to the near low land and surface water body through the overflow of rainwater and leachate disposal. Similarly, Mamtaz and Chowdhury (2006) reported the Ni content in the waste of landfill site where the concentration was detected about 23 mg/kg. Even, Adjia et al. (2008), Oluyemi et al. (2008) and Esakku et al. (2005) detected the significant values of Ni species in their respective studies at landfill site. As a result, nickel toxicity causes in humans is allergic skin, headache, vertigo, nausea, vomiting, insomnia and irritability (Das et al., 2008; Sunderman et al., 1975).

It is worth mentioning that acute nickel toxicity is responsible for some human health problems like kidney injury, frank haematuria etc. . Besides, Nickel exposure causes the formation of free radicals in various tissues in both human and animals which lead to various modifications to DNA bases and enhanced lipid peroxidation (Das et al., 2008). Hence, Nickel migration from landfill sites has received increasing attention today which can contribute the risk to human body through food chain.

In the current study, S/S containment technique was employed in order to reduce the Ni(II) contamination from landfill wastes which is widely used across the world for minimization of hazardous wastes (Vinter et al., 2016; Chaabane et al., 2016; Pan et al., 2015; Kameswari et al., 2015; Kogbara, 2014; Li et al., 2015). In S/S treated waste, the encapsulation of the contaminants is achieved by formation of chemical bonds or by physical encapsulation (Torras et al., 2011; Li and Wang, 2006) within the microstructure of the binder agent fabric (Loney and Tabatabaie, 2015). Therefore, hazardous wastes are insolubilizes, destroys and sorbs (Malviya and Chaudhary, 2006a) that makes the monolithic solid as less toxic. Physical encapsulation of waste materials by S/S, ensures the reduction of the quantity and release speed of contaminants to the environment to a large extent (Wanga et al., 2016a; Torras et al., 2011) as well as increases the structural integrity (Conner, 1990) and low permeability (Kameswari et al., 2015) of the monolithic waste form. The degree of effectiveness of the S/S products are assessed basically by two parameters such as strength to bear the functional load on it and the contaminant leaching resistance (Moon and Dermatas, 2006).

The contaminants leaching behavior in curing leachant from S/S waste matrices is an important way to obtain valuable information about the chemical speciation and their potential environmental risks (Huang et al., 2016; Barbir et al., 2012) as well as effectiveness