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Leaching Behavior of Cadmium through Compacted Granitic Residual Soil Using Column Infiltration Test

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Abstract. This study investigates the physico-chemical properties of granitic residual soils and comparison between two sorption tests; batch and column infiltration tests in evaluating the mobility of Cadmium (Cd) using granitic residual soils. The granitic residual soil has undergone the physical tests (eg: particle size distribution, Atterberg Limits, specific gravity and compaction), chemical tests (eg: pH, organic matter, specific surface area (SSA) and cation exchange capacity (CEC)) and sorption tests. For Batch test, the effect of Cd concentration in single and mixture solutions were studied. The result showed the K_d value of single solution (K_d=0.0062 L/g) was higher compared to mix solution (K_d=0.0022 L/g). For column infiltration test, several factors were studied in this research such as different g-force, different types of solutions and different soil thickness. Results showed that both sorption tests have different effects on mobility of heavy metals through soils. The column infiltration test gave the exact K_d values compared to the batch test since the condition of columns method applied were similar to the natural soil conditions.

1 Introduction

Human activities such as agricultural, domestic waste, municipal sewage, industrial effluent, mining activities, and landfill introduced the contaminant/ heavy metals to our natural environment [1], [2], [3]. Adsorption is one of the most common method to remove heavy metals due to its low cost and efficient absorbents [4]. According to [5] and [6], column leaching techniques was widely used to evaluate the transport model and determined the migration of contaminant through soils. The objectives of this study are to investigate the chemical-physical properties of granitic residual soils and to compare the batch and column techniques in evaluating the mobility of Cadmium (Cd) through granitic residual soil.

2 Materials and Method

Granitic residual soil was collected from Broga, Selangor, Malaysia. Sample was air-dried and sieved less than 0.125mm. Physico-chemical tests were analyzed according to [7]. Batch test and column infiltration tests were conducted according to [8], [9] methods; respectively.

3 Results and Discussions

3.1 Physico-Chemical Characteristics

The physical and chemical characteristic of the soil were presented in Table 1 and Table 2. Granitic residual soil has higher percentage of sand ranged between 54%-63% followed by percentage of silt (32%-42%) and clay (1%-6%). Due to this, granitic residual soil has classified as intermediate plasticity index (9.90%-11.99%). According to [10], low plasticity index indicates lower adsorption capacity. Granitic residual soil showed low pH value (acidic) ranged between 5.35-5.85. In acidic conditions, heavy metals were mobile and adsorption of heavy metals onto soils became less effective [11]. This study also showed the soil has low values of organic matter (0.22%-0.34%), SSA (17.96m^2/g-21.93m^2/g) and CEC (0.79meq/100g-1.35meq/100g) where it indicates low adsorption capacity.

3.2 Sorption Test

In this sorption test, Batch test and Column Infiltration test were chosen to obtain partition coefficient (K_d). K_d can be defined as the amount of contaminant adsorbed in the soil solid phase to the metal concentration in the soil solution, at equilibrium [12]. The K_d values in all parameters calculated from the column and batch test were presented in Table 3.

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3.2.1. Batch Test

The partition coefficient (K_d) of Cd in single and mixture solutions is summarized in Table 2. K_d value of single solution (K_d=0.0062 L/g) was higher compared to mix solution (K_d=0.0022 L/g). Cd in mixture solution needs to compete with other metals in order to obtain active sites in soils. Thus, the amount of heavy metal reduced and subsequently lowering the K_d value [13]

Table 1. Physical Characteristics of granitic residual soil

Physical Characteristics	BGR
Particle size distribution:	
Sand (%)	54-63
Silt (%)	32-42
Clay (%)	1-6
Atterberg Limit:	
Plastic Limit (%)	38.01-38.69
Liquid Limit (%)	48.50-50.00
Plasticity Index (%)	9.90-11.99
Specific Gravity	2.50-2.59
Max Dry Density (g/cm^3)	1.64-1.71

Table 2. Chemical Characteristics of granitic residual soil

Chemical Characteristics	BGR
pH	5.32-5.54
Organic Matter (%)	0.39-0.50
SSA (%)	17.96-21.93
CEC (meq/100g)	0.79- 1.35

SSA: Specific Surface Area; CEC: Cation Exchange Capacity

3.2.2 Column Infiltration Test

i. K_d in Different G-Forces

The calculated K_d values showed the K_d values reduced when G-force were increased. At higher G-force, the contact between heavy metals and soil particle was limited, thus reduced the sorption and K_d values. However, there was overestimated K_d values due to the non-homogeneous particle size distribution and uneven compaction process of the soils. The overestimated K_d values can be seen at 10mm soil thickness and 520G in a single solution, where the K_d value showed 23.449 L/kg.

ii. K_d in Different Types of Solutions

In 10 mm of soil thickness, the comparison between K_d values of single and mixture solution was determined. K_d in single solutions was higher compared to mixture solution due to no competition in single solution. Thus, Kd values increased.

iii. K_d in Different Soil Thickness

In this study, the K_d values in 520G of all soil thickness showed the decreasing values of K_d with increasing of soil thickness (10mm= 23.449 L/kg, 15mm= 0.648 L/kg, 20mm=0.109 L/kg). The flow rate of contaminant in clay liner will decrease with increasing of soil thickness. Thus, the active site also decreased, subsequently lowering the adsorption and K_d values.

iv. K_d in Column Test versus Batch Test

For both single and mixture solutions, K_d in batch test showed higher values (single solution, K_d= 6.2 L/kg and mixture solution, K_d= 2.2 L/kg) compared to all K_d values in column infiltration test. In Batch test, the adsorption of contaminants was in 'closed system' where secondary reaction such as precipitation may occur. In this case, the concentration of contaminants in equilibrium concentration reduced and caused the increasing of K_d values [9]. However, K_d value for mini column infiltration test (G-force; 520g in single solution) showed a higher value (K_d=23.449 L/kg) compared to K_d for batch test (K_d=6.2 L/kg). This overestimated value was due to the non-homogeneous particle size distribution and uneven compaction process of the soils.

Table 3. K_d value in all parameters calculated from the column and batch test.

Column Infiltration Test				Batch Test			
Weight (g)/ Thickness (mm)	Velocity (RPM)/ G-Force	K_d in Single Solution L/kg	K_d in Mixture Solution L/kg	Single Solution		Mixture Solution	
				K_d (L/kg)	R^2	K_d (L/kg)	R^2
10	1000 /230G	0.514	0.777	6.2	0.913	2.2	0.838
	1500/520G	23.449	1.079				
	2000/ 920G	0.793	0.420				
	2500/ 1440G	0.981	0.417				
15	1000 /230G	0.668	-				
	1500/520G	0.648	-				
	2000/ 920G	0.811	-				
	2500/ 1440G	0.473	-				
20	1000 /230G	3.840	-				
	1500/520G	0.109	-				
	2000/ 920G	0.562	-				
	2500/ 1440G	1.448	-				

4 Conclusions

This study concludes that physico-chemical properties have a great influence in sorption and migration of Cd in soils. Through K_d values, the comparison of both batch test and column infiltration test on mobility of Cd through soils can be determined. Batch test occurred in a ‘closed system’ where secondary reaction such as precipitation thus the concentration of contaminants in equilibrium concentration reduced and caused the increasing of K_d values. While the column infiltration occurred in ‘open system’ where no interference occurred. The adsorption was continuously leached out from the system as similar to the natural conditions.

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References

1. Vega F A, Covelo E F and Andrade M L 2006 *J. Colloid Interface Sci* 298 582–592
2. Kwon J, Yun S, Lee J, Kim S and Young H 2010 *Journal of Hazardous Materials* 174 307–313,
3. Liew C Y and Zuhairi W Y W 2010 *The Adsorption of Lead, Copper, Zinc, Cadmium, Cobalt and Nickel in Residual Soils Using Batch and High Speed Centrifuge Mini Column Test* Seminar UKM-UNRI Ke-6 ”Penyelidikan Terkehadapan Sains dan Teknologi UKM-UNRI” 463–465
4. Lukman S, Essa M, Nuhu D M, Bukhari A, and Basheer C 2013 *Journal of Environmental Science and Technology* 1 1-15
5. Seaman J C, Vulava V M, Sowder A G, Jackson B P, Aburime S A, and Bertsch P M 2005 *Environmental Geoscience* 4 235–242
6. Masipan T, Chotpantarat S, and Boonkaewwan S 2016 *Sustainable Environment Research* 26 97–101
7. British Standard Institution, BS1377 1990 *Method of Test for Soils for Civil Engineering Purpose Part 1*
8. USEPA 1992 *Batch-Type Procedures for Estimating Soil Adsorption of Chemicals, EPA/530/SW- 87/006-F*
9. Antoniadis V, Mckinley J D, and Zuhairi W Y W 2007 *Journal of Environmental Quality* 60 53–60
10. Zulfahmi A R, Umar H, and Noorulakma A 2011 *Sains Malaysiana* 40 293–300
11. Ouhadi V R, Yong R N, Shariatmadari N, Saeidijam S, Goodarzi A R and Safari-zanjani M 2010 *Journal of Hazardous Materials* 173 87–94
12. Vidal M, Santos M J, Abrão T, Rodríguez J and Rigol A 2009 *Geoderma* 149 189–198
13. Zarime N A and Zuhairi W Y W 2016 *Sains Malaysiana* 45 pp. 1905–1912