| Title of dissertation | | | | |
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| **Potentially Toxic Element Contamination in Malaysian Closed Urban Landfill: Geochemical Indices and Geostatistical Analysis** | | | | |
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This thesis comprises of two main parts of analysis, i.e. geochemical indices assessment and geostatistical analysis for the evaluation of potentially toxic elements (PTEs) contamination in closed urban landfills.

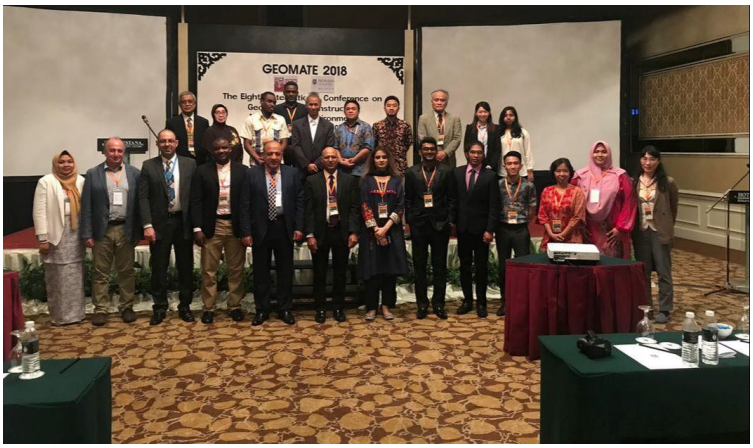
The geochemical indices assessment results showed that very slight contamination of the soils (finding from the analysis of C/p index) at both studied landfills, i.e. Air Hitam (AH) landfill and Ampar Tenang (AT) landfill, with low ecological risk for the stagnant water on both landfills' surface soils (finding from the analysis of $Er^{i}$-RI) and most of the PTEs in the plant species at AH landfill were formerly from contaminated surface soil of the closed landfill. The identification of a metal-sensitive plant, that is, *Ageratum conyzoides*, as a potential micropollutant indicator for PTEs contamination in both of the studied closed landfills discovered. This is noticeable when the overall results of PTEs concentration of this study demonstrated that the Cd was not detected in the soil of both landfills, but the concentration was present in the foliar organ of *A. conyzoides* and not in other plant species at both study sites. The highest uptakes in plant for Cd is in foliar organ of *A. conyzoides* (0.934 ppm) which grown on AT landfill.

The geostatistical analysis split into two sections, i.e. ordinary kriging and advanced kriging. The ordinary kriging analysis in AT landfill showed that Mn, Fe and Pb kriging estimates classified more accurate compared to Cr, Cu and Cd kriging estimates based on N/S ratio < 0.3 classification. However, AH landfill showed that Cr, Cd and Pb kriging estimates classified more accurate compared to Mn, Fe and Cu kriging estimates. Using ordinary kriging, we can find that the average value of Cr at AH landfill is expected to be over criteria at about 25%, but its ninety-five percentile value is expected to be over criteria at about 75%. It showed that the risk of the element of Cr cannot be negligible, although, it may overlook its risk if average value is utilised in the assessment. Based on ordinary kriging estimates all of the PTEs tested at both sites were below the permissible limits. Moreover, the interpolation area estimated gives useful understanding for monitoring the PTEs contamination by analysing the changes of the PTEs content at both closed landfills.

The advanced kriging analysis, i.e. regression kriging and guess-field kriging efficiency were tested by applying the regression relationship of auxiliary variables to generate estimation data for deriving target variable's spatial structure and kriging estimates. In this study, Pb and Cr data from the analysis of ICP-MS were used for analysis of the advanced kriging. In regression kriging analysis, regression error (regression residual) must be independent from each other and has spatially no correlation. It is showed in the analysis that distribution of regression error possess spatial correlation. Therefore, application of regression kriging to target variable, i.e. Pb (ICP-MS) using the data of auxiliary variable, i.e. Cr (ICP-MS) is thought not to be appropriate. In guess-field kriging analysis, guess-field kriging is efficient at area where sufficient number of auxiliary variable exist. Though, guess-field kriging may produce larger uncertainty than ordinary kriging at area where auxiliary variable does not exist. The application of indicator kriging is suitable for cases that normal distribution data to be interpolated showed existence of censored data where it is bend at point of non-detection (n.d.) limit of the instrumental method. The efficiency of indicator kriging was analysed in occasion that a decision to be made for polluted area to be removed, area of which pollution level calculated as over the prearranged criteria with a certain probability selected.

In essence, this work has suggested a potential biotic factor as micropollutant indicator for PTE at closed landfills, i.e. *A. conyzoides* and application of selected geochemical indices, i.e. C/p index, $Er^{i}$-RI and EF for assessing the PTEs contamination level. Application of ordinary and advanced kriging, i.e. regression kriging, guess-field kriging and indicator kriging were efficient in many circumstances such as limited number of data, missing data as well as the presence of censored data. Additionally, this work recommends a risk assessment framework and impact pathway for PTEs contamination assessment in closed urban landfills.

## Photos

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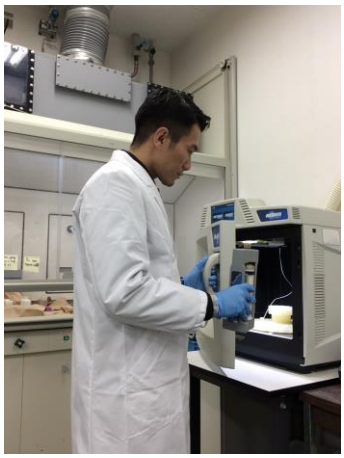

Acid digestion of samples in Environmental Risk Laboratory, Kyoto University, Japan