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DEVELOPMENT OF ASSESSMENT FOR POTENTIALLY TOXIC ELEMENT CONTAMINATION INDICATOR IN CLOSED LANDFILLS AND PROSPECTIVE GEOSTATISTICAL ANALYSIS

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ABSTRACT: Post-closure management of landfill in Malaysia does not include assessment of the contaminant level in abiotic and biotic factors that inhabit the aged topsoil of closed landfills. Considering the bioaccumulation effect in the ecosystem, post-closure classification with the status of contaminant concentration below the permitted level does not promise safe closure to the ecosystem as time passes. Thus, substantial and constant qualitative analysis of contaminant concentration needs to be developed for sustainable management of landfill post-closure. In this work, heavy metals in common constituents (abiotic and biotic factors) of closed landfills were selected; that is, soil, stagnant water, and common communities of plant species in closed landfills in Selangor, both sanitary and non-sanitary, were studied. The results of the analysis demonstrated that the concentration of Cd was not detected in the soil of both landfills but the highest concentration was present in the leaves of *Ageratum conyzoides* compared to other plant species at both study sites. A parallel situation was discovered for the non-detection of Cd concentration in stagnant water at Ampar Tenang landfill, but the leaves of *A. conyzoides* contained this element. The sensitivity and affinity of *A. conyzoides* for accumulating heavy metals in this study were revealed particularly for Cd. Hence, this study suggests the use of *A. conyzoides* as a promising trace metals contamination indicator for closed urban landfills. Additionally, Guess-Field Kriging is believed to be a useful geostatistical tool to interpolate potential contamination area by utilising the abiotic and biotic factors as assistant variable to the target variable i.e. soil.

Keywords: Ageratum conyzoides; Environmental Risk; Landfill Aftercare; Solid Waste Management; Trace Metal

1. INTRODUCTION

Municipal solid waste management in a developing country with an upper middle-income economy such as Malaysia has now improved its path towards proper waste management. A recently mandated requirement for solid waste segregation at source is now imposed in several states, although there are certain flaws. As projected by Lau [1], the amount of municipal solid waste in Malaysia is estimated to increase from 292 kg/capita in 2000 to 511 kg/capita in 2025. This increment is possible due to Malaysia's status as a developing country with the rapid development of economic activities, which will produce more waste in the future. Among thirteen states and three federal territories in the country, the Selangor state is the most developed state in Malaysia. It is located on the west coast of Peninsular Malaysia and has a surface area of 7,930 km^2. Its population was estimated as 6.38 million people in mid-2017 [2]. The state encompasses the federal territories of Kuala Lumpur and Putrajaya (the capital city and the federal administrative center of Malaysia respectively), both of which were formerly part of Selangor. Following the statistics, the growing number of landfills in urban areas to cater the growing urban population will eventually increase the number of closed landfills.

Unfortunately, there is lack information regarding heavy metal content and monitoring in closed landfill although heavy metal pollution has become a severe problem in many parts of the world particularly in soil and its surrounding ecosystem [3]. Although it is known that heavy metal enrichment in environment results from natural processes and it is also believed as a consequence of widespread historical pollution, soils (topsoil) in urban areas are considered to be regional sinks of chemical emissions depending on the economic activities and definitely resource consumption are frequently rich in heavy metals [4]. Importantly, heavy metals enrichment or excessive accumulation of heavy metal in the soil can be transferred to other ecological resources, such as plants or water bodies (underground and surface) and affects the environmental quality.

Thus, the objective of this study is to assess the heavy metal contamination (inorganic micropollutants) in closed landfill areas by developing an effective and applicable methodology. This work also aims to identify a possible heavy metal contamination indicator in closed landfills for future assessment, principally for assessing the bioaccumulation of heavy metals and environmental risk that occur over time.

2. MATERIALS AND METHODS

2.1 Closed Landfills (Sanitary and Non-Sanitary)

The closed urban landfills (sanitary and non-sanitary) were both situated in the state of Selangor; they were Air Hitam (AH) landfill (sanitary landfill), located in Puchong, and Ampar Tenang (AT) landfill (non-sanitary landfill), located in Sepang. Both landfills were fed with non-segregated waste from the capital city and cities around the center and southern part of Selangor (including the capital city and the federal territory).

AH landfill was the first engineered sanitary landfill in Malaysia. It operated for 11 years from 1995 to 2006 (it is now more than 10 years since its closure) and is located approximately 25 km southwest of Kuala Lumpur city center. The landfill zone is near to the AH Forest Reserve in Puchong, Selangor, and is surrounded by developed residential area. A total of 6.2 million tonnes of non-segregated waste (municipal solid waste) was properly capped in the landfill. After five years of the landfill closure maintenance plan, the landfill was converted to park, and it has been officially open to the public since 2011. The landfill is operating leachate treatment and a renewable energy plant with recreational facilities around the landfill area.

AT landfill site is located near Kota Warisan, in Sepang area, approximately 49 km south of Kuala Lumpur city center. The landfill zone is bordered primarily by oil palm plantation, and housing projects are being developed in adjacent areas. The landfill site (a closed open-tipping site which was then upgraded to a controlled waste disposal site without a proper liner system) started operation in the year 2000 and ended it in 2010 (it has been closed for less than 10 years); it received about 100 tonnes of domestic waste per day [5]. Both landfills were first operated by local authorities and then privatised with a concession period to manage the operation or closure of the site.

2.2 Sample Preparation and Laboratory Analysis

Surface topsoil samples (0–30 cm) were collected randomly from the selected closed urban landfills in triplicate during the northeast monsoon season (November–March) under a tropical climate. The soil samples at each site were assembled together and the collection was performed using a stainless steel shovel. Samples of stagnant water and leaves/grass were also taken from the two sites with similar species or families of leaves and grass. All types of samples were located in close proximity to one another to analyse the heavy metal content in the abiotic and biotic factors. Water samples were acidified with concentrated HNO_3 to pH < 2. All samples were then sealed separately in airtight, clear glass bottles and then transported to the laboratory for pretreatment.

The samples of soil, stagnant water, and leaves/grass were sterilised in an autoclave at 121 °C for 15 minutes. Once sterilised, the soil and leaf/grass samples were air dried at room temperature. The air-dried soil and leaf/grass samples were then further dried in a microwave at 60 and 65 °C, respectively, until a constant dry weight was achieved before being powdered and homogenised in an agate mortar. Larger particles (2 mm) in the soil samples were then removed by sieving. For the microwave-assisted acid digestion procedure, approximately 0.5 g of dry homogenised soil and 0.1 g of dried leaf samples were weighed into a vessel and successively digested with 10 mL of concentrated HNO_3 in a microwave digestion system (MARS 6, CEM, USA). After cooling, the digest was transferred into conical centrifuge tubes and adjusted to a volume of 50 mL with Milli-Q water. Finally, the samples were filtered through a membrane filter (cellulose acetate with a pore size of 0.45 μm; Advantec, Japan).

Heavy metal concentrations in the stagnant water and the acid-digested soil and leaf/grass samples were determined by inductively coupled plasma mass spectrometry (ICP-MS; Thermo Scientific iCAP Q). Standard operating procedures, calibration with standards, analysis of reagent blanks, and replicates were performed to ensure the precision of analytical data. All samples were analysed in triplicate to obtain the mean as final data. These instruments and chemical analyses were performed at the Laboratory of Environmental Risk Analysis, Kyoto University. The samples were imported under a permit from the Ministry of Agriculture, Forestry and Fisheries, Japan in accordance with the Plant Protection Law.

2.3 Quantification of C/p for Heavy Metals in Soil

The contamination/pollution index (C/p) and its significance interval were analysed by adapting the method of Lacatusu [6], as follows:

$$C/p = \frac{C_{soil}}{C_{reference\ soil}} \quad (1)$$

where C_{soil} is the concentration of an examined metal in soil, and $C_{reference\ soil}$ is the concentration of the reference metal in soil from the Malaysian Naturally Occurring Range of the Department of Environment (DOE). The following terminology may be used for the C/p value as specified by Lacatusu [6]: C/p < 0.1 = very slight contamination; 0.10–0.25 = slight contamination; 0.26–0.50 = moderate contamination; 0.51–0.75 = severe contamination; 0.76–1.00 = very severe contamination; 1.1–2.0 = slight pollution; 2.1–4.0 = moderate pollution; 4.1–8.0 = severe pollution; 8.1–16.0 = very severe pollution; C/p > 16.0 = excessive pollution.

2.4 Quantification of RI for Heavy Metals in Water

The potential ecological risk index (RI) was utilised as a diagnostic tool for water pollution control purposes. The RI was adapted from Hakanson [7] as follows:

$$\mathrm{RI} = \sum_{i=1}^{m} \boldsymbol{Er^i} = \sum_{i=1}^{m} \boldsymbol{Tr^i} \cdot \boldsymbol{C_f^i} \quad (2)$$

where m is the total number of studied metal, Er^i is the potential ecological risk factor for the studied metal (i), Tr^i is the toxicity response factor for the studied metal [7], and C_f^i is the contamination factor. The following terminology may be used for the RI value as specified by Hakanson [7]: RI < 150 = low ecological risk; 150 ≤ RI < 300 = moderate ecological risk; 300 ≤ RI < 600 = considerable ecological risk; RI ≥ 600 = very high ecological risk.

2.5 Quantification of EF for Heavy Metals in Plant

The enrichment factor (EF) was analysed to measure the origin of metals by comparing the relative concentration of metals in the plant to that in the soil. The EF was adapted from Klos, Rajfur and Waclawek [8] as follows:

$$\mathrm{EF} = \frac{(C_x/C_{Fe})_{plant}}{(C_x/C_{Fe})_{soil}} \quad (3)$$

where C_x is the concentration of the examined metal in plants or soil and C_{Fe} is the concentration of the reference element, namely iron (Fe), in plants or soil. An enrichment factor close to unity (EF = 1) indicates that the element can be considered to originate from the soil.

2.6 Statistical Analysis

The descriptive statistical analysis was conducted by applying SPSS 24.0 (IBM, Chicago, Illinois, USA). Regression analysis was done to understand the relationship between heavy metals in soil and water samples in both landfills. The differences among the heavy metals in soil and stagnant water samples at each landfill were tested using a parametric test, the one-sample *t*-test, while the heavy metals in plants' foliar organs (leaves) at both landfills were tested by one-way analysis of variance (ANOVA). Differences were considered significant when $P < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Heavy Metals in Soil

The concentrations of heavy metals in soil for AH landfill followed the decreasing order of Mn > Pb > Cr > Cu > Fe > Cd; for AT landfill the order was Fe > Mn > Cr > Pb > Cu > Cd. The concentration of Cd was not detected in the soil of either landfill as it was below the detection limit. The result showed that all the mean contents of heavy metals in both landfills' topsoils were lower than the limits except for Mn at AT landfill, whose maximum content was slightly higher than the naturally occurring content range. Despite the below permissible limits, C/p index of all heavy metals tested shown in Table 1 described that both landfill soils were very slightly contaminated.

Table 1 C/p indices of the heavy metals in soils of Air Hitam and Ampar Tenang landfills

HM	[a]AH	[b]AT	Symbol
Cr	8.252×10^{-3}	0.124×10^{-3}	v.s.l.
Mn	0.381×10^{-3}	0.873×10^{-3}	v.s.l.
Fe	1.152×10^{-8}	6.254×10^{-7}	v.s.l.
Cu	3.874×10^{-5}	3.412×10^{-5}	v.s.l.
Cd	ND	ND	-
Pb	4.682×10^{-5}	3.930×10^{-5}	v.s.l.

Note: HM- heavy metal; [a]AH- Air Hitam landfill; [b]AT- Ampar Tenang landfill; v.s.l.- very slightly contamination.

Both of the studied landfills were closed less than 20 years ago and contamination with heavy metals exceeding the acceptable limits occurs after a closure period longer than that. It was reported that a non-sanitary landfill in Beijing, China that was closed for almost 30 years was contaminated with Zn, Cd, Ni, and Hg, whereas the As, Cu, Cr, and Pb contents met the regulatory limits [9]. In addition, long-term artisanal gold mining activities that operated for more than 30 years in Shanxi, China resulted in serious contamination of soils by heavy metals, that is, Hg and Cd, because the tailings produced as mining waste were dumped untreated [10]. Moreover, increased accumulation of Cd, Cu, Pb, and Zn was detected in Planty Park's surface soil surrounding the Historic Centre of Krakow, Poland. Although the source of heavy metals enrichment was

Table 2 Heavy metal content (mg/kg) in soil at studied areas compared with maximum allowable limits (M.A.L.) used in different countries and Malaysia site screening levels (SSLs)

Heavy metal	Air Hitam Landfill (AH)	Ampar Tenang Landfill (AT)	Malaysia [b]Site screening levels (SSLs)		UK [c]CLEA Soil Guideline Value (SGV)		Japan [d]M.A.L	US [e]U.S. EPA	[b]Natural occurring content range
			Residential	Industrial	Residential	Commercial			
Cr	[a]$0.595 \times 10^{-3} \pm 0.80 \times 10^{-5}$bc	$0.891 \times 10^{-3} \pm 1.65 \times 10^{-5}$c	280	14,000	130	5,000	-	3,000	0.02 - 14.40
Mn	$1.513 \times 10^{-3} \pm 1.40 \times 10^{-5}$de	$3.464 \times 10^{-3} \pm 4.45 \times 10^{-5}$b	1,800	23,000	-	-	-	-	3.95 - 3.99
Fe	$0.258 \times 10^{-3} \pm 0.86 \times 10^{-5}$ab	$14.01\mathbf{1} \times 10^{-3} \pm 8.42 \times 10^{-5}$d	55,000	720,000	-	-	-	-	301 - 44,500
Cu	$0.461 \times 10^{-3} \pm 0.42 \times 10^{-5}$ae	$0.406 \times 10^{-3} \pm 0.20 \times 10^{-5}$a	3,100	41,000	-	-	125	4,300	4.0 - 19.8
Cd	ND	ND	70	810	10	230	-	85	0.09 - 11.90
Pb	$0.847 \times 10^{-3} \pm 1.16 \times 10^{-5}$cd	$0.711 \times 10^{-3} \pm 1.16 \times 10^{-5}$e	400	800	450	750	400	420	0.18 - 36.00

[a] Heavy metal content; values are mean and standard error (mean ± S.E.M.; n =3) followed by different letters is statistically different. (*t*-Test, $P < 0.05$).
[b] Site Screening Levels (SSLs), DOE [21]
[c] CLEA: Contaminated Land Exposure Assessment [22] are updated technical documents issued by the Environment Agency, UK
[d] M.A.L.: Maximum allowable limits for heavy metals in soil [23]
[e] U.S. EPA: United States Environmental Protection Agency [24]

treated as complex in origin, intensive historical metallurgical industry beginning in the nineteenth century is believed to be the source of the enrichment [4].

Comparison of heavy metals content in soil from the study sites and maximum allowable limits from different countries are shown in Table 2. The high contents of Mn and Fe in the topsoil of AT landfill could have originated from the previous land use of the site as palm oil plantation. Moreover, palm oil plantation is still actively operating in the area surrounding the closed landfill. This parallels to Olafisoye, Oguntibeju and Osibote [11] regarding contents of Mn and Fe, which were high but below the permissible limits, in palm oil plantation soils under a tropical climate in Nigeria. The very slight contamination with Cr, Cu, and Pb in both closed landfills reflects the content of heavy metals in sediment or the pedogenic factor in the topsoil layer of the landfills as they are generally present in trace concentrations and result in low toxicity [12]. A possible anthropogenic source of Cr in the closed landfills could be from the abundance of chrome plating or stainless steel apparatus disposed of in the landfills, for example, cutlery, saucepans and other rust-resistant alloy-based tools. Hence, this mixed type of waste that has weathered in the landfills could be the main source of availability of the metals. Furthermore, the vehicles carrying waste and soil, for example, waste and soil compactors or roll-off dump trucks, used during landfill operation contribute to the availability of the metals. As reported by Smichowski, Gomez, Frazzoli and Caroli [13], brake wear and loss of lead wheel balance weights promote the enrichment of soil Pb. Similarly, Cu is released to the environment through the corrosion of metal components due to oxidation of lubricants at high temperature [14].

3.2 Heavy Metals in Water

The heavy metals concentration in stagnant water samples at AH landfill followed the decreasing order of Mn > Fe > Pb > Cd > Cu > Cr and that at AT landfill followed the decreasing order of Fe > Cr > Mn > Cu > Pb > Cd. The concentration of Cd in the stagnant water sample from AT landfill was not detected as it was below the detection limit. The concentrations of Cr in water samples at both landfills were higher compared to the landfill soils. Conversely, the Fe content in water samples was lower compared to soils from both landfills. The Mn, Cu, and Pb contents in water samples at AH landfill showed a similar trend of being higher compared to the landfill soil. Conversely, the Mn, Cu, and Pb contents in water samples at AT landfill were lower compared to its landfill soil. Cadmium was found only in the water sample at AH landfill but was not present in its landfill soil. Linear regression was calculated to predict the relationship of heavy metals based on their concentrations in soil and water samples. A close relationship was obtained with $R^2 = 0.871$ for heavy metals in soil and water samples at AT landfill. It is inferred that the source of heavy metals in the water samples at AT landfill was originally from the landfill soil. Some researchers have considered the effect of dissolved oxygen concentration on potential metal release and accumulation and found that the increase of the dissolved oxygen concentration could enhance the mobility of heavy metals [15]. Furthermore, the mobility of heavy metals in an aerobic water-soil interface condition is intensified under a tropical climate due to high temperature.

The potential ecological risk factor (Er^{i}) and the potential ecological risk index (RI) for both closed landfills (presented in Table 3) were adapted to evaluate the potential risk of heavy metal content in the stagnant water at both landfills. It is indicated that both landfills have a low ecological risk, suggesting that there are no threatening effects on the environment.

Table 3 Heavy metal content (mg/kg), Er^{i} and RI in a stagnant water sample at studied areas in Air Hitam and Ampar Tenang landfill

Heavy metal	Air Hitam Landfill (AH)	Ampar Tenang Landfill (AT)	${}^{b}Er^{i}$ Air Hitam Landfill (AH)	Ampar Tenang Landfill (AT)
Cr	${}^{a}0.863 \times 10^{-3} \pm 0.14 \times 10^{-5}$b	$1.927 \times 10^{-3} \pm 2.33 \times 10^{-5}$a	1.92×10^{-5}	4.28×10^{-5}
Mn	$13.892 \times 10^{-3} \pm 6.27 \times 10^{-5}$d	$1.318 \times 10^{-3} \pm 2.29 \times 10^{-5}$f	-	-
Fe	$3.774 \times 10^{-5} \pm 0.07 \times 10^{-5}$e	$3.915 \times 10^{-5} \pm 0.71 \times 10^{-5}$b	-	-
Cu	$1.586 \times 10^{-3} \pm 0.56 \times 10^{-5}$c	$0.151 \times 10^{-3} \pm 0.39 \times 10^{-5}$c	15.86×10^{-5}	1.51×10^{-5}
Cd	$2.342 \times 10^{-5} \pm 0.39 \times 10^{-5}$a	ND	70.26×10^{-5}	-
Pb	$3.730 \times 10^{-3} \pm 3.50 \times 10^{-5}$f	$0.105 \times 10^{-3} \pm 0.10 \times 10^{-3}$e	26.64×10^{-5}	0.75×10^{-5}
^{c}RI (Cr, Cu, Cd and Pb)			114.68×10^{-5}	6.54×10^{-5}

[a]Heavy metal content; values are mean and standard error (mean ± S.E.M.; n =3) followed by different letters is statistically different (*t*-Test, $P < 0.05$).
[b]Er^{i} – the potential ecological risk factor
[c]RI – the potential ecological risk index adapted from Hakanson [7],
ND – not detected and blank cells denoted no citable information of BPI (the bioproduction index) for Er^{i} estimation.

3.3 Heavy Metals in Plants

Figure 1 depicted comparisons of heavy metals content according to the plant species collected from both landfills. The highest uptakes at both landfills were as follows: Cr was found in *Cynodon dactylon* (6.063×10^{-3} ppm; 16.65% in the plant) at AH landfill, Mn in *Imperata cylindrica* (14.24×10^{-3} ppm; 42.18% in the plant) at AH landfill, Fe in *Ageratum conyzoides* (28.84×10^{-3} ppm; 63.97% in the plant) at AH landfill, Cu in *Leucaena leucocephala* (7.827×10^{-3} ppm; 34.92% in the plant) at AH landfill, Cd in *A. conyzoides* (0.934×10^{-3} ppm; 3.20% in the plant) at AT landfill, and Pb in *I. cylindrica* (6.707×10^{-3} ppm; 24.15% in the plant) at AH landfill. It can be hypothesized here that most species showed the highest metal accumulation after a longer period of landfill closure since AH landfill has been closed for more than 10 years whilst AT has been closed for less than 10 years. It is essential to note that *A. conyzoides* showed sensitivity by percentage accumulation of all of the selected heavy metals compared to other common plant species from both landfills. This is evident from the percentage content of Cd in *A. conyzoides* compared to other plant species. The percentage of content for each plant species based on the concentration (mg/kg) is shown in Fig. 1. The contents of Cd accumulated in the leaves of *A. conyzoides* were 3.20% and 2.38% for AT landfill and AH landfill, respectively, in contrast to other plant species at both landfills, which showed percentages below 0.5%.

Ageratum conyzoides L., or commonly known as billy goat weed is a tropical plant found in some regions of Africa, Asia and South America [16], and occupation by *A. conyzoides* succeeds easily because of its wide adaptability in the environment and its superior reproductive potential [17].

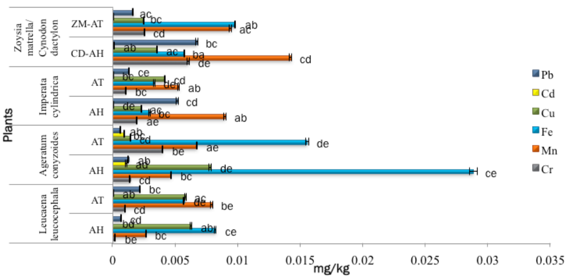

Fig. 1 Comparison of the heavy metal content (mg/kg) among selected plants in closed non-sanitary Ampar Tenang (AT) landfill and closed sanitary Air Hitam (AH) landfill, Selangor. Values are the mean and standard error (mean ± S.E.M.; n = 3); different letters indicate a statistical difference (one-way ANOVA, $P < 0.05$).

Apart from that, it is widely used in traditional medicine in several countries around the world as a purgative, febrifuge, anti-inflammatory, analgesic, anesthetic and in the treatment of ulcers [18]. Although there is vast information about the chemical property, biochemical activity as well as its anatomical description, there are few studies on the heavy metal uptake in relation to heavy metal sensitivity of the species, particularly in closed landfill areas. Hence, this study proposing the species as a biotic indicator for potentially toxic metal contaminated land such as closed landfill.

Table 4 Enrichment factor (EF) of heavy metals in plant species from Air Hitam and Ampar Tenang landfill

Plant species	Landfill	Heavy metal					
		Cr	Mn	Fe	Cu	Cd	Pb
LL	AH	0.010	0.055	1.000	0.428	-	0.025
	AT	2.641	5.598	1.000	35.160	-	7.528
AC	AH	0.021	0.028	1.000	0.152	-	0.013
	AT	4.032	1.749	1.000	7.258	-	0.782
IC	AH	0.287	0.523	1.000	0.434	-	0.535
	AT	5.064	6.467	1.000	43.491	-	7.752
Grass (CD/ZM)	AH (CD)	0.460	0.425	1.000	0.350	-	0.358
	AT (ZM)	4.045	3.890	1.000	8.717	-	3.289

LL: *Leucaena leucocephala*; AC: *Ageratum conyzoides;* IC: *Imperata cylindrica*; CD: *Cynodon dactylon*; ZM: *Zoysia matrella*; AH: Air Hitam landfill; AT: Ampar Tenang landfill

The source of the studied metals is evaluated by the enrichment factor (EF) as shown in Table 4. All of the heavy metals resulted in EF below 1.0 for plant species in AH landfill whereas only Pb in *A. conyzoides* showed EF below 1.0 for plant species in AT landfill. From the results, it can be postulated that most of the heavy metals in the plant species at AH landfill were formerly from contaminated topsoil of the closed landfill. In the case of AT landfill, other than non-segregated municipal waste disposal, a possible anthropogenic source of the heavy metals in the foliar organ (leaves) could be from the deposition of heavy metal-rich vehicle exhaust transferred from a neighboring area where a residential area was actively under construction. It has been discovered that the heavy metals can be transported further, mainly by the wind, beyond the vicinity of the source activities [19]. This is in contrast to the ambiance of AH closed landfill, which opened functionally as an urban recreational park adjacent to the city's Forest Reserve with restrictions on entrance by vehicles.

3.4 Potential Geostatistical Analysis

It is anticipated to estimate the possibility of environmental risk by means of spatial interpolation that might occur in the future by applying Guess-Field Kriging. The estimation is by regression relation between the target variable and assistant variable as shown in Eq. 4.

$$Z_1(X) = g[Z_2(X)] + \varepsilon(X) \quad (4)$$

where $g[Z_2(X)]$ is the arbitrary regression equation and $\varepsilon(X)$ is the error term of average 0 (independent each other).

In this work, the target variable is the content of heavy metals in the surface topsoil of the closed landfills. Whereas the assistant variable is the heavy metals content in water and plants collected at a similar area of the soil sampled. In this interpolation calculation, it is also possible to measure the possibility of the contamination in surface topsoil by utilising an accurate method of measurement i.e. instrumental analysis, coarse sampling grid, etc. and simple method measurement i.e. portable measurement, narrow sampling grid, etc. at the same time resulting in more efficient of field investigation.

The Guess-Field Kriging is preferable compared to other geostatistical methods due to the comparison of hotspots of the measured contaminants and the deduced area resulted from the geostatistical analysis. This ensued certain hotspots where are not thought to be contaminated. Although there are uncertainties, the resulted contourlines can be useful as a guide for sampling strategy. Consequently, sampling can be intensified in locations with large kriging errors [20]. Therefore, contamination assessment in the tested area is close to accuracy.

4. CONCLUSION

This study showed that potential contamination by toxic metals is strongly based on the resident time in the closed landfills' abiotic and biotic factors. Both landfills showed very slight contamination of the soils, with low ecological risk for the stagnant water on the landfills' topsoils, and identification of a metal-sensitive plant, that is, *Ageratum conyzoides*, as a potential indicator for heavy metal contamination in urban closed landfills. It is known that the plant has beneficial latent qualities in traditional medicine or agricultural use in regions with a tropical climate and yet precautions are needed when it comes from a contaminated area due to its affinity for the accumulation of micropollutants, particularly in its foliar organ, that is, the leaves. Hence, the results of heavy metal contamination of the soil, stagnant water, and plants in the closed landfills can be developed as an indicator to comprehend the level and source of contamination as well as for the selection of a potential indicator from abiotic and biotic factors for future constant assessment. This study proposes an assessment plan i.e. assessing contaminants' indicator and geostatistical analysis for heavy metal contamination in closed landfills that can be a useful tool for avoiding costly environmental risk assessments in countries with a limited financial endowment. Nevertheless, caution must be restored in the evaluation of a single index for abiotic and biotic factors selected to estimate contamination, as such a value could obscure metal contamination.

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