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Measuring Stability Period of Post-Closure Sanitary Landfill in Malaysia using Double Exponential Smoothing

(Pengukuran Tempoh Capaian Tahap Stabil bagi Landfill Sanitari Tutup di Malaysia menggunakan *Double Exponential Smoothing*)

Siti Khadijah Abdul Gani[a,c], Zulkifli Mohd Nopiah[b], Noor Ezlin Ahmad Basri[c], Wan Siti Adibah Wan Dahalan[d], Kohei Watanabe[e] & Hassan Basri[b]

[a]*Biodiversity Management Division, Ministry of Energy and Natural Resources (KeTSA)*
[b]*Department of Engineering Education, Faculty of Engineering and Built Environment, National University of Malaysia (UKM)*
[c]*Department of Civil Engineering, Faculty of Engineering and Built Environment, UKM*
[d]*Faculty of Law, UKM*
[e]*Faculty of Liberal Arts, Teikyo University, Japan*
**Corresponding author: zmn@ukm.edu.my*

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ABSTRACT

The stability period for post-closure dump and landfill sites in Malaysia is of least concern among scholars and policy makers. The current policy to manage these sites are based on the conventional practices by the local authorities and agencies which do not take into account the sustainability or how environmentally friendly these practices are. The aims of this paper are to identify the most suitable forecasting method for time series data of CO_2 *emission, to conduct simulation exercise to indicate the stability period of sanitary landfill by using the* CO_2 *emission, and to examine the current policy for the post-closure landfill sites and its current practice in the country. Datasets were obtained from literature and simulation was conducted for the Air Hitam Sanitary Landfill, Puchong, Selangor. The results indicate that the Double Exponential Smoothing is the most suitable forecasting method and another 120 years are required for the gas emission to reach stability, which is in September 2127. The current policy on post-closure dump and landfill sites in Malaysia are explored and other potential options are also discussed.*

Keywords: Forecasting method; landfill gas stabilization; post-closure sanitary landfill

ABSTRAK

Tempoh stabil bagi tapak pelupusan sampah tutup di Malaysia merupakan antara perkara yang kurang diberi perhatian oleh penyelidik dan pembuat dasar. Polisi semasa dalam mengurus tapak-tapak tutup ini adalah berdasarkan kelulusan Pihak Berkuasa Tempatan dan agensi berkaitan di mana komponen tahap stabil atau bagaimana pendekatan yang lebih mesra alam dapat dilaksanakan. Kertas ini bertujuan mengenalpasti kaedah simulasi yang sesuai terhadap kadar pembebasan gas karbon dioksida secara berkala bagi menentukan tahap stabil sesuatu tapak pelupusan sisa pepejal. Kertas ini juga membincangkan polisi semasa yang dilaksanakan di negara ini. Data sekunder diperolehi daripada Tapak Pelupusan Sampah Sanitari Tutup Air Hitam, Puchong, Selangor. Hasil analisis mendapati Model Pelicinan Eksponen Berganda merupakan simulasi paling sesuai dan sekurang-kurangnya 120 tahun diperlukan bagi tahap pembebasan gas karbon dioksida mencapai tahap stabil iaitu pada tahun 2127. Polisi semasa berkaitan pengurusan tapak pelupusan sampah tutup di Malaysia akan dibincangkan di dalam kertas ini.

Kata kunci: Kaedah simulasi; penstabilan penghasilan gas di tapak pelupusan sampah; tapak pelupusan sampah sanitari tutup

INTRODUCTION

Most landfill sites in developing and poor countries especially in Asia are classified as dumpsites without any containment (Borongan & Okumura 2010; Ferronato & Vincenzo, 2019; Johannessen & Boyer 1999; Sasaki & Araki 2014). Malaysia is facing the same situation (Aja et al. 2014; Jereme et al. 2015; Moh & Abd Manaf 2014) and as a tropical rainforest country, heavy rain had contributed to high production of leachate at the sites (Ishak et al. 2021). Sites without proper planning and treatment facilities for gas or leachate collection may trigger excessive methane and carbon emission to the atmosphere and wastewater to pollute groundwater. There are reports that improper wastewater treatment may give harm to public health (Abdullah et al. 2021; Akhter et al. 2021; Mohd et al. 2022; Nuhu et al. 2020).

Thus, the gas emission and leachate produced were directly exposed to the environment. The gas emission, mainly comprising of methane (CH_4) and carbon dioxide (CO_2) contributed to the climate change issues, while the leachate produced by the decomposition activity of organic waste will pollute the river and ground water (Aja et al. 2014). As there is no proper planning for these dumpsites, the amount of gas emission and leachate produced were unknown. There are cases all around the world, where disaster such as dumpsite collapse, landslide and massive heavy metal contamination that had put human life and public health at the risk of fatality (Díaz Rizo et al. 2012; Ferronato & Vincenzo 2019; Ihedioha et al. 2017; Johannessen & Boyer 1999; Kanmani & Gandhimathi 2013; Parameswari et al. 2015; Prechthai et al. 2008; Watanabe et al. 2018).

Another concern is how long do these dump and landfill sites require to become less harmful to the environment and reach stability. The only approach to measure the duration for the sites to become harmless to the environment and reach stability is through continuous monitoring from a sanitary landfill upon its closure (Environment Protection Authority Southern Australia (EPA SA), 2009; United States Environmental Protection Agency (US EPA), 2005, 2012). The emission of CH_4 (maximum of 55.0%) and CO_2 (maximum of 45.0%) at the sites in operation changes based on the biodegradation process (Ahmed et al. 2013). However, the gas emission amount will gradually decrease after the site is closed.

Thus, the aims of this paper are to identify the most suitable forecasting method for time series data of CO_2 emission and to conduct simulation exercise to indicate the stability period of sanitary landfill by using the CO_2 emission. Finally, the current policy of the post-closure landfill sites and its current practice in the country are examined.

MATERIALS AND METHODS

SITE BACKGROUND

As only post-closure sanitary landfill is selected in this exercise, the authors had taken various initiatives to get a good dataset. As of 2021, there are 23 sanitary landfill sites in Malaysia and two proposed sites for Johor (Table 1). Only three sites were closed, including: (i) Air Hitam Sanitary Landfill (15 years old upon closure); Panchang Bedena Sanitary Landfill (Three years old upon closure); and (iii) Pulai Sanitary Landfill (One year old upon closure).

TABLE 1. List of Sanitary Landfill Sites in Malaysia

No	Sanitary Landfill Name, State	Start	Current Status
1	Air Hitam, Selangor*^	1995	Closed in 2006
2	Mambong, Sarawak*^	2000	In Operation
3	Pulai, Kedah^	2001	Closed in 2020
4	Pulau Burong, Pulau Pinang*	2001	In Operation
5	Kota Kinabalu, Sabah*	2001	In Operation
6	Kemuyang, Sarawak^	2001	In Operation
7	Bintulu, Sarawak*^	2002	In Operation
8	Sibu, Sarawak*	2002	In Operation
9	Sibuti, Sarawak^	2002	In Operation
10	Seelong, Johor*^	2004	In Operation
11	Kuching Integrated Waste Management Park, Sarawak^	2004	In Operation
12	Tanjung Langsat, Johor*^	2005	In Operation
13	Bukit Tagar, Selangor*^	2006	In Operation
14	Miri, Sarawak*^	2006	In Operation
15	Jeram, Selangor*^	2008	In Operation
16	Tanjung Dua Belas, Selangor*^	2010	In Operation
17	Panchang Bedena, Selangor	2016	Closed in 2018

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18	Pekan Nenas, Johor^	2016	In Operation
19	Sungai Udang, Melaka^	2016	In Operation
20	Belengu, Pahang^	2016	In Operation
21	Teluk Mengkudu, Perak^	2016	In Operation
22	Rimba Mas, Perlis^	2016	In Operation
23	Kg Tertak Batu, Terengganu^	2016	In Operation
24	Bukit Payong, Johor^	Proposed	
25	Pagoh, Johor^	Proposed	

Source: *Fauziah & Agamuthu (2012); ^Moh & Abd Manaf (2017)

Panchang Bedena and Pulai Sanitary Landfill are not suitable for this exercise as the age after closure is less than five years. At this stage, the leachate and gas production are still active. Discussions and meeting had been made with Air Hitam Sanitary Landfill operator to obtain the data. However, the researcher was advised to use the dataset that the operator had shared to another scholar.

As an alternative, the authors had gathered annual methane and leachate production at two closed cells at Bukit Tagar Sanitary Landfill. Cell 1 is closed in 2012 (9 years old upon closure) and Cell 2 is closed in 2017 (4 years old upon closure). The dataset was tested. Anyhow, the results indicate annual increment and insufficient for further analysis. The authors had also conducted a desktop study to obtain secondary data, and this is where data from Raja Yahya et al. (2019) were found.

The Air Hitam Sanitary Landfill was the first fully engineered landfill in Malaysia (Figure 1). The Selangor State had appointed a local company known as the Worldwide Holding for the development and operation of the site. It is categorised as the Level 4 Sanitary Landfill with Leachate Treatment (Japan International Cooperation Agency (JICA) & Ministry of Housing and Local Government (KPKT), 2004b). The landfill had been fully operational from 1995 until 2006 to receive Klang Valley annual waste of 6.2 million tonnes (Nadzri & Lajim 2017; Raja Yahya et al. 2019). The methane gas was harvested since the site was in operation (Raja Yahya et al. 2019).

FIGURE 1. Study Site Location (Google Maps)

The landfill is fully equipped with gas venting facility within the landfill layers (Figure 2). Trenches were installed beginning from the landfill base to every layer of the earth fill of the compacted layers. There were also sand layers and barriers between the earth fill to protect the trenches. The gas collection system, gas extraction wells, dewatering units and degassing unit were installed for continuous monitoring. There were 71 gas wells to facilitate the site.

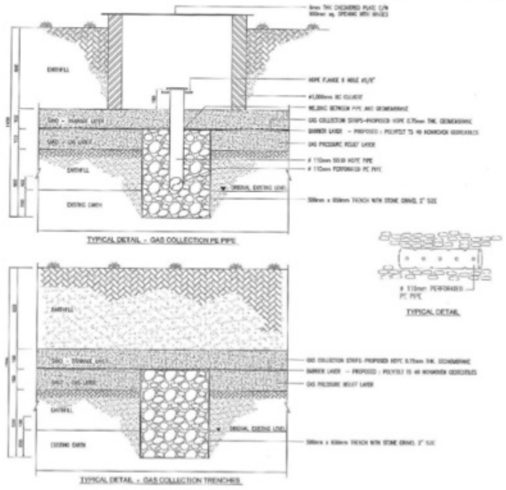

FIGURE 2. Gas Venting Facility at Air Hitam Sanitary Landfill
Source: Worldwide Holdings Bhd. (2010) in Raja Yahya et al. (2019)

This landfill was closed in December 2006 after receiving about 6,207,685 tonne of household waste. The annual estimation of emission reduction from 2007 to 2016 were obtained from (Raja Yahya et al. 2019) while the original data was kept by the company.

FORECASTING METHOD

The secondary data are analyzed using Risk Simulator RS2012 software (Lee, 2018; Ramlan et al. 2013). This software is a strong and easy to use Excel add-in software for applying simulation, forecasting, statistical analysis, and model optimization. The data patterns are tested for the suitable forecasting methods (Table 2). The forecast errors are compared to obtain the best forecasting method.

TABLE 2. Suitable Forecasting Methods

Nu.	Method
1	Single Exponential Smoothing (SES)
2	Double Exponential Smoothing (DES)
3	Single Moving Average
4	Double Moving Average
5	Holt-Winter’s Additive
6	Holt-Winter’s Multiplicative

SINGLE EXPONENTIAL SMOOTHING (SES)

The Single Exponential Smoothing (SES) is the most common forecasting method. The SES requires minimal computation. This method is utilised when the historical data pattern is almost horizontal or fluctuate about a constant level (Nazim & Afthanorhan 2014; Ostertagová & Ostertag 2013). The equation is as below:

$$F_{t+m} = \alpha y_t + (1-\alpha)F_t$$

Where:

F_{t+m} = The single exponential smoothed value in period *t*+*m* (this is also defined as forecast value when generated out of sample) for *m* = 1, 2, 3, 4….
y_t = The actual value in time period *t*
α = The unknown smoothing constant to be determined with value lying between 0 and 1
F_t = The forecast or smoothed value for period *t*

DOUBLE EXPONENTIAL SMOOTHING (DES)

The Double Exponential Smoothing (DES) is used for trend dataset. The exponential smoothing with a trend blend with latest each period-level and trend. The level is a smoothed estimate of the value of the data at the end of each period. The trend is a smoothed estimate of average growth at the end of each period (Nazim & Afthanorhan, 2014). The specific formula for simple exponential smoothing is:

$$F_{t+m} = \alpha y_t + (1-\alpha)F_t$$

$$a_t = 2S_t - S_t{}'$$

$$b_t = \frac{\alpha}{1-\alpha}(S_t - S_t{}')$$

$$S_t = \alpha y_t + (1-\alpha)S_{t-1}$$

$$S_t' = \alpha S_t + (1-\alpha)S'_{t-1}$$

Where:

S_t = Be the exponentially smoothed value of y_t at time *t*

S'_t = Be the double exponentially smoothed value of y_t at time *t*

α_t = Computes the different between the exponentially smoothed values

b_t = Computes the adjustment factor

F_{t+m} = The forecast for m-step-ahead period

MOVING AVERAGE (MA)

The Moving Average (MA) method is a predicting method for a group of research observing for the average value as a forecast for the upcoming time series. In this method, the moving average process occurs once (known as Single Moving Average) or twice (known as Double Moving Average) (Febrian et al. 2020).

Single Moving Average equation is:

$$S'_t = \frac{X_t + X_{t-1} + X_{t-2} + \Lambda + X_{t-n-1}}{n}$$

Double Moving Average equation is:

$$S''_t = \frac{S'_t + S'_{t-1} + S'_{t-2} + \Lambda + S'_{t-n-1}}{n}$$

HOLT-WINTER'S ADDITIVE (H-WA)

The Holt-Winter's Additive (H-WA) is adopted to forecast the base component of load for time series analysis with the combination of exponential smoothing and state space methods (Qiuyu et al. 2017). The equation is:

$$\chi_{t+1} = l_t + i.b_t + p_{t-k+i}$$

Where:

x_t = Represents actual load at time *t*

x_{t+i} = Represents forecasted load at time *t+i*

l_t, b_t and p_t = Represent the estimated value of level, trend and seasonal components

Subscript *k* = Represents the time period of the seasonal pattern

HOLT-WINTER'S MULTIPLICATIVE (H-WM)

The Holt-Winter's Multiplicative (H-WM) has three equations which were slightly different with Holt-Winter's Additive (H-WA) method. The three equations for the Holt-Winter's Multiplicative (Supriatna et al. 2019) are as follow:

Determine the overall smoothing value using the equation below:

$$F_t = \alpha \frac{X_t}{l_{t-1}} + (1-\alpha)(F_{t-1} + T_{t-1})$$

Determine the trend smoothing value using the equation below:

$$T_t = \beta(F_t - F_{t-1}) + (1-\beta)T_{t-1}$$

Determine the seasonal smoothing value using the equation below:

$$S_t = \gamma \frac{X_t}{F_{t-1}} + (1-\gamma)S_{t-1}$$

In the end of period t, the forecasting value for the period of t+k is determined using the equation below:

$$Y_{t+m} = (F_t + T_t m)S_{t-L+m}$$

Where:

F_t = The forecasting smoothing value for the period of *t*

X_t = The actual value for the period of *t*

T_t = The trend smoothing value for the period of *t*

S_t = Seasonality component value for the period of *t*

Y_t = Forecasting value on period *t* for the m consecutive periods

m = The number of forecasted periods

α = The smoothing parameter for trend ($0<\alpha<1$)

β = The smoothing parameter for trend ($0<\beta<1$)

γ = The number of forecasted periods

α = The smoothing parameter for trend ($0<\gamma<1$)

L = The number of periods within a seasonal cycle

RESULT AND DISCUSSIONS

SUITABLE FORECASTING METHOD

The forecasting methods that are suitable for the time series data were selected based on the trend and cyclical components. The selection forecasting methods were selected based on the suitable of six methods (Table 3) with the smallest Root Mean Squared Error (RMSE) value.

TABLE 3. Selected Forecasting Methods and their RMSE* Value

Nu.	Method	RMSE* Value
1	Double Exponential Smoothing (DES)	0.3972
2	Holt-Winter's Additive	2.7501
3	Holt-Winter's Multiplicative	2.7501
4	Double Moving Average	4.5866
5	Single Exponential Smoothing (SES)	6.1008
6	Single Moving Average	8.9578

(*Note*: RMSE* = Root Mean Squared Error)

The best forecasting method to predict the time series plot (month) for the carbon dioxide emission to reach stability is the Double Exponential Smoothing. The equation of this model is as below:

$$F_{t+m} = \alpha y_t + (1-\alpha)F_t$$

$$a_t = 2S_t - S_t{'}$$

$$b_t = \frac{\alpha}{1-\alpha}(S_t - S_t{'})$$

$$S_t = \alpha y_t + (1-\alpha)S_{t-1}$$

$$S_t' = \alpha S_t + (1-\alpha)S'_{t-1}$$

Where:

S_t = Be the exponentially smoothed value of y_t at time t

S'_t = Be the double exponentially smoothed value of y_t at time t

α_t = Computes the different between the exponentially smoothed values

b_t = Computes the adjustment factor

F_{t+m} = The forecast for m-step-ahead period

This selection is based on the lowest value of the RMSE value. The best fit test for the moving average forecast uses RMSE that measure the optimal alpha and beta parameters automatically through an optimization process that minimizes the forecast errors.

The study indicates that the Double Exponential Smoothing is the best method in this analysis. This method is used when the data exhibits a trend but has no seasonality. This method is not appropriate when used to predict cross-sectional data. It applies single exponential smoothing twice, once to the original data and then to the resulting single exponential-smoothing data. An alpha weighting parameter is used on the first or single exponential smoothing, while a beta weighting parameter is used on the second or double exponential smoothing. This approach is useful when the historical data series is not stationary. The software finds the optimal alpha and beta parameters automatically through an optimization process that minimizes the forecast errors.

The RMSE value for the Double Exponential Smoothing is 0.3972 as compared to the Holt-Winter's Additive and the Holt-Winter's Multiplicative with the value of 2.7501 as well as the Double Moving Average at the value of 4.5866. Other methods indicate the RMSE values are larger than 5.0.

FORECAST STABILITY DURATION

Based on the Double Exponential Smoothing method, the time series graph is plotted using the actual and forecast figures for the annual estimation of carbon dioxide emission reduction at the landfill site upon closure until it reaches stability (Figure 3). Upon closure, the carbon dioxide emission in 2007 is about 79.3950 in tonnes of CO_{2e} unit (Raja Yahya et al. 2019). Thus, the 1% value of this figure is 0.7940 in tonnes of CO_{2e} unit.

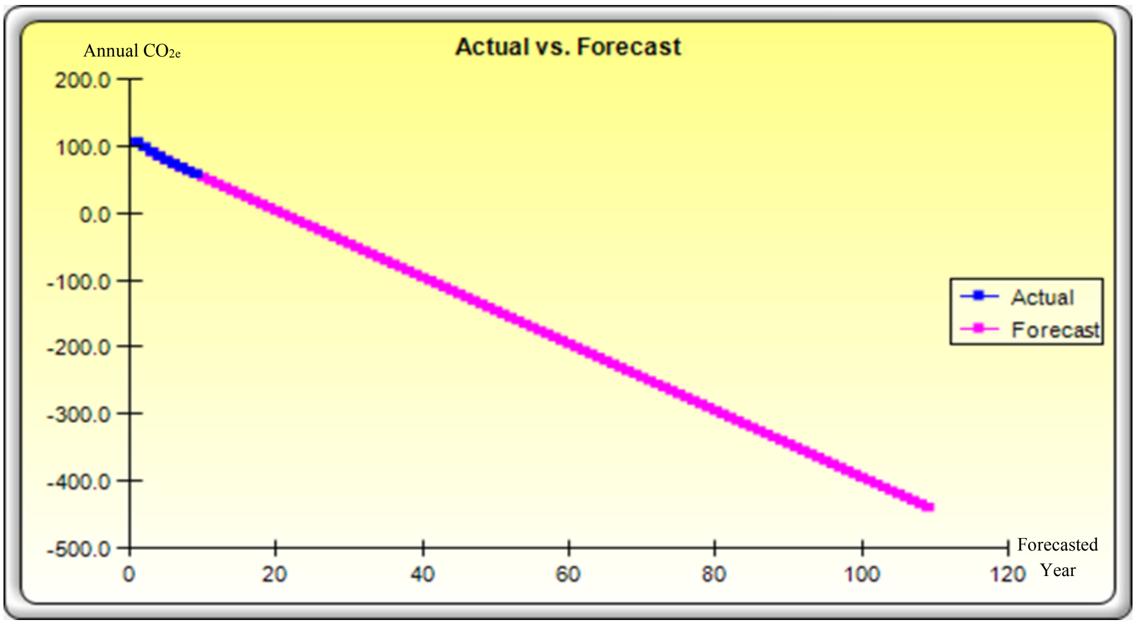

FIGURE 3. Actual and forecast time series plot for the carbon dioxide emission to reach stability

Figure 3 clearly indicates that another 120 years are required for the carbon dioxide emission to decrease until it reaches 1.0% (0.7940 in tonnes of CO_{2e} unit). Hence, the site could only reach stability after September 2127 upon closure.

This forecasting is in line with Obersteiner et al. (2007) who reported that gas emission and leachate production are significant even after 100 years after post-closure based on their study at open dumps, landfills and sanitary landfills at selected European countries including Austria, Denmark, Germany and Switzerland. However, other than Obersteiner et al. (2007), there are limited studies that could confirm this finding. Studies by Sizirici & Tansel (2009, 2010) on a closed landfill in the United States only indicate selected parameters for landfill stability while data in the Asian setting is unavailable as there is no similar study done in Asian countries. Therefore, it is recommended that further studies are done to collect more data on this matter.

CURRENT POLICY ON POST-CLOSURE LANDFILL SITES

The current policy in Malaysia stated that landfill stabilization is measured by using three parameters, including: (i) leachate produce below the Malaysian Department of Environment (DOE) standard mainly for Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS) and heavy metals; (ii) landfill gas emission is below 1.0 percent; and (iii) the subsidence rate is below 2cm per year (Japan International Cooperation Agency (JICA) & Ministry of Housing and Local Government (KPKT), 2004a).

Under the current policy, monitoring would be conducted for a ten-year period upon physical closure. After that duration, or at the completion of the criteria mentioned above (whichever is reached first, if continuous monitoring is made), the piece of land could be proposed for other development after approval is received from the local authority (JICA & KPKT 2004).

The Ministry of Housing and Local Government (KPKT) had stated that post-closure landfill sites could be converted to five types of facilities, namely: agricultural areas, parking areas and roads, public parks, housing areas, commercial or industrial areas (National Physical Planning Council 2004).

In another study, Ahmed (2001) reported the leachate migration at the Sri Petaling Dumpsite had polluted the waters of Sungai Kuyoh. This piece of land had been converted to Bukit Jalil National Stadium in 1998 prior to the 1998 Commonwealth Games hosted by Malaysia and the dumpsite area is now a parking area. Other than parking area, Fauziah & Agamuthu (2010) had reported a dumpsite in Kelana Jaya that was converted into residential areas.

This policy in Malaysia is different from the practice in other developed countries. The United Kingdom, for example, had stated that landfill operators must cover the post-closure cost for at least 30 years upon surrender and no development are allowed on any post-closure landfill sites (Environment Agency, 2009). All landfills in the United Kingdom are sanitary landfills since the enforcement of the Control of Pollution Act 1974 (Abd. Gani et al. 2018). There are cases where post-closure dump and landfill sites are still considered as not stable even after 100 years (Obersteiner et al. 2007).

However, the long-term post-closure dump and landfill sites management in Malaysia is still unclear. The Malaysia Standard had reported landfill safe closure requirement to secure public health and risk prevention of closed sites (Department of Standards, 2014). But the post-closure component was not covered in this standard.

POTENTIAL AS BROWNFIELD GREENSPACE

The Department of Town and Country Planning of Peninsular Malaysia in 2010 had proposed the standard of 2 hectares of green areas per 1,000 urban population. This commitment is directed to the city administrator, mostly local authorities. The inability to comply with this target will hamper the sustainable urban status in the National Urban Policy and Garden Nation Policy under the Department of Town and Country Planning of Peninsular Malaysia and the National Landscape Department.

Different countries may have different approaches to tackle this initiative. England and Germany, for example had involved different corporate companies to undertake various projects related to this initiative as their Corporate Social Responsibility (CSR) (Dixon 2007; Maliene et al. 2012).

This concept is also known as sustainable Brownfield Greenspace. Currently the status of this initiative in Malaysia is very low. For instance, in 2012 the achievement throughout the country is only less than 25.0%, with Kuala Lumpur's at only 20.0% (Mazifah et al. 2014). There are six Brownfield Greenspace categories in Malaysia, in which Category B is stated as ex-landfill areas full of solid waste or no longer in use permanently (Simis & Awang 2015; Simis et al. 2016). Hence, based on this definition, Category B would refer to post-closure dump and landfill sites.

This initiative seems like a feasible approach especially when most of the post-closure dump and landfill sites are now located within the urban areas. It is understood that most of the sites are located outside the human settlement during their operation. However, as most urban areas gradually experience rapid expansion, these old sites are now located within the urban space. There were 115 post-closure dump and landfill sites and 40.0% were within urban areas in 2003 and this figure will be increased to 296 sites in 2020 with more than 70.0% falling in the same criteria (Raja Yahya et al. 2019).

CONCLUSIONS

As the future direction of the post-closure dump and landfill sites are still debatable, the current practice to convert the area to become other facilities especially related to development of new buildings (residential, commercial or industry) may not be the best option. This may expose the public and the environment to the risk of pollutants buried as well as gas emission produced within the sites.

The study clearly indicates that another 120 years are required for the carbon dioxide emission to decrease until it reaches stability in Air Hitam Sanitary Landfill. Hence, upon its closure in 2006, the site could only reach stability after September 2127. Thus, the current Malaysian policy to observe the post-closure sites for 10 years seems questionable and too short. However, it may be too long to wait for the sites to reach stability within the next 100 years. Therefore, the practice of other developed countries for the land to be redeveloped within 30 years could be a feasible option.

As such, the initiatives to convert post-closure dump and landfill sites to Brownfield Greenspace regeneration may be another viable option by converting the area into green parks while letting the gas and leachate production to reach stability. However, this may require permission from related city administrators and local authorities.

KPKT should play an active role to promote these initiatives as this Ministry has the jurisdiction to advice the five main agencies related to waste and the Brownfield Greenspace initiative with the related agencies being (i) the National Solid Waste Management Department; (ii) the Solid Waste and Public Cleansing Management Corporation (SWCorp); (iii) the National Landscape Department; (iv) the Department of Town and Country Planning of Peninsular Malaysia (PLANMalaysia); and (v) the Local Government Department. The Local Government Department is in-charge of all the 155 local authorities.

As a developing nation, Malaysia is facing various challenges to put in place sustainability component in its policy-making processes. In order to become a developed nation, most of the economic sectors are expanding. This require more land to be converted, more industries to be built, more human settlements to be opened especially in urban spaces and more waste to be handled. All this, without further consideration on its impact to the environment, may bring harm to the environment. Thus, the sustainability component must be embedded in all policy-making processes and actions taken by the relevant local authorities.

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REFERENCES

Abd. Gani, S. K., Watanabe, K. & Basri, H. 2018. Factors that have influenced the landfill sites in the United Kingdom. The ISWA World Congress, October, 1-7. https://iswa2018.org/iswa-2018/ (accessed 12 January 2019).

Abdullah, N. A., Hanna, W., Wan, M. & Awam, J. K. 2021. Kesan penyusupan dan aliran masuk terhadap kekuatan air sisa kumbahan perbandaran. *Journal of Engineering* 33(4): 1027-1035. DOI:https://doi.org/10.17576/jkukm-2021-33(4)-24

Ahmed, A. M. 2001. *Assessment of Sri Petaling Landfill Towards Pollution in an Unconfined Aquifer*. University Putra Malaysia.

Ahmed, S. I., Johari, A., Hashim, H., Mat, R. & Alkali, H. 2013. Landfill gas and its renewable energy potentials in Johor, Malaysia. *International Journal of Emerging Trends in Engineering and Development* 3(1): 506-520. https://d1wqtxts1xzle7.cloudfront.net/30911854/50.pdf?1363042907=&response-content-disposition=inline%3B+filename%3DLandfill_gas_and_its_renewable_energy_po.pdf&Expires=1611772789&Signature=P1R4SzDRpFtHH1EmQ4~EkhxwhFrnvbI9bHrUfZC1ZOWV9T0QRUtdHGedzcYV~wKed

Aja, O. C., Aseghale, S. D. & Al-Kayiem, H. H. 2014. Review and evaluation of municipal solid waste management Practices in Malaysia. *Journal of Solid Waste Technology and Management* 40(3): 215-232. DOI:https://doi.org/10.5276/JSWTM.2014.215

Akhter, F., Soomro, S. A., Siddique, M. & Ahmed, M. 2021. Plant and non-plant based polymeric coagulants for wastewater treatment: A review. *Journal of Engineering* 33(2): 175–181. DOI:https://doi.org/10.17576/jkukm-2021-33

Asnor Nadirah Ishak, Noor Hidayah Tauhid Ahmad & Singh, M. S. J. 2021. Penganalisaan taburan hujan diurnal terhadap Angin monsun di Malaysia dengan menggunakan data satelit TRMM. *Journal of Engineering* 33(3): 719-731. DOI:https://doi.org/10.17576/jkukm-2021-33(3)-30

Borongan, G. & Okumura, S. 2010. Municipal waste management report: status-quo and issues in south east and East Asian countries. In AIT/UNEP Regional Resource Center for Asia and the Pacific. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Municipal+Waste+Management+Report:+Status+Quo+and+Issues+in+Southeast+and+East+Asian+Countries#0 (accessed 21 March 2017).

Department of Standards. 2014. *Landfill Safe Closure - Requirements: Vol. MS 2547:20*. Department of Standard Malaysia.

Díaz Rizo, O., Hernández Merlo, M., Echeverría Castillo, F. & Arado López, J. O. 2012. Assessment of metal pollution in soils from a former Havana (Cuba) solid waste open dump. *Bulletin of Environmental Contamination and Toxicology* 88: 182-186. DOI:https://doi.org/10.1007/s00128-011-0505-7

Dixon, T. 2007. The property development industry and sustainable urban brownfield regeneration in England: An analysis of case studies in Thames Gateway and Greater Manchester. *Urban Studies* 44: 2379-2400. DOI:https://doi.org/10.1080/00420980701540887

Environment Protection Authority Southern Australia (EPA SA). 2009. EPA 842/09 waste guidelines: Waste definitions. www.epa.sa.gov.au/files/4771336_guide_waste_definitions.pdf (accessed 29 June 2016).

Fauziah, S. H. & Agamuthu, P. 2010. Closure and post-closure of landfills in Malaysia: Lessons learnt. *Malaysian Journal of Science* 29(3): 231-238. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Closure+and+Post-closure+of+landfills+in+Malaysia%3A+Lessons+Learnt&btnG= (accessed 8 July 2021).

Febrian, D., Al-Idrus, S. I. & Nainggolan, D. A. J. 2020. The comparison of double moving average and double exponential smoothing methods in forecasting the number of foreign tourists coming to North Sumatera. Paper presented at 6th Annual International Seminar on Trends in Science and Science Education, 16-17 September, North Sumatera Province, Indonesia. DOI:https://doi.org/10.1088/1742-6596/1462/1/012046

Ferronato, N. & Vincenzo, T. 2019. Waste mismanagement in developing countries: A review of global Iissues. *International Journal of Environmental Research and Public Health* 1-28. DOI:https://doi.org/10.3390/ijerph16061060

Ihedioha, J. N., Ukoha, P. O. & Ekere, N. R. 2017. Ecological and human health risk assessment of heavy metal contamination in soil of a municipal solid waste dump in Uyo, Nigeria. *Environmental Geochemistry and Health* 39: 497-515. DOI:https://doi.org/10.1007/s10653-016-9830-4

Japan International Cooperation Agency (JICA) & Ministry of Housing and Local Government (KPKT). 2004a. The study on safe closure and rehabilitation of landfill sites in Malaysia: Guideline for safe closure and rehabilitation of MSW Llandfill. 2(Sites 3): Issue November. https://jpspn.kpkt.gov.my/resources/index/user_1/Sumber_Rujukan/kajian/GUIDELINE_FOR_SAFE_CLOSURE_AND_REHABILITATION_OF_MSW_LANDFILL_SITES.pdf (accessed 1 January 2020).

_____________. 2004b. The study on safe closure and rehabilitation of Landfill lites in Malaysia: The technical guideline for sanitary landfill, design and operation. In Japan International Cooperation Agency (JICA) 5: Issue November. https://jpspn.kpkt.gov.my/resources/index/user_1/Sumber_Rujukan/garis_panduan_jpspn/THE_TECHNICAL_GUIDELINES_FOR_SANITARY_LANDFILL_DESIGN_AND_OPERATION.pdf (accessed 11 January 2020).

Jereme, A. I., Siwar, C., Begum, R. A. & Alam, M. M. 2015. An assessment of waste management operation in Malaysia: Case study on Kuala Langat and Sepang. *International Journal of Environment and Waste Management* 16(2): 133-144. https://www.google.com/search?q=local+authority+landfill+dumpsite+plan+malaysia&oq=local+authority+landfill+dumpsite+plan+malaysia+&aqs=chrome..69i57.25619j1j7&sourceid=chrome&ie=UTF-8 (accessed 27 January 2021).

Johannessen, L. M. & Boyer, G. 1999. *Observations of Solid Waste Landfills in Developing Countries: Africa, Asia, and Latin America*. United State of America. http://www.worldbank.org/urban/solid_wm/erm/CWG folder/uwp3.pdf (accessed 3 July 2016).

Kanmani, S. & Gandhimathi, R. 2013. Assessment of heavy metal contamination in soil due to leachate migration from an open dumping site. *Applied Water Science* 3(1): 193-205. DOI:https://doi.org/10.1007/s13201-012-0072-z

Lee, C. K. 2018. Understanding decisions to suspend works: When employers do not pay. *E3S Web of Conferences* 65: 1-16. DOI:https://doi.org/10.1051/e3sconf/20186503001

Maliene, V., Wignall, L. & Malys, N. 2012. Brownfield regeneration: Waterfront site developments in Liverpool and Cologne. *Journal of Environmental Engineering and Landscape Management* 20(1): 5-16. DOI:https://doi.org/10.3846/16486897.2012.659030

Mazifah, S., Azahan, A., Kadir, A. & Nor Zalina, H. 2014. Urban public park from ex-landfill: Impact to community health. *Health and the Environment Journal* 5(2): 28-40. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Closure+and+Post-closure+of+landfills+in+Malaysia%3A+Lessons+Learnt&btnG= [Accessed 8 July 2021]

Moh, Y. C. & Abd Manaf, L. 2014. Overview of household solid waste recycling policy status and challenges in Malaysia. *Resources, Conservation and Recycling* 82: 50-61. DOI:https://doi.org/10.1016/j.resconrec.2013.11.004

Mohd, Z., Hanna, W., Wan, M., Aina, N., Hafizal, H., Hamid, A., Sabariah, T. & Manan, A. 2022. Pharmaceutical compounds in Malaysian urban domestic wastewater. *Journal of Engineering* 34(2): 269-275. DOI:https://doi.org/10.17576/jkukm-2022-34(2)-11

Nadzri, N. I. I. & Lajim, F. 2017. Taman atas sampah: Landfill park di Ayer Hitam Puchong simpan 6.2 juta tan sisa pepejal terurai. *Harian Metro*. https://worldwideenvironment.com.my/taman-atas-sampah/ (accessed 10 March 2020).

National Physical Planning Council. 2004. Report of National Physical Planning No. 2/2004.

Nazim, A. & Afthanorhan, A. 2014. A comparison between single exponential smoothing (SES), double exponential smoothing (DES), holt's (brown) and adaptive response rate exponential smoothing (ARRES) techniques in forecasting Malaysia population. *Global Journal of Mathematical Analysis* 2(4): 276-280. DOI:https://doi.org/10.14419/gjma.v2i4.3253

Nuhu, M., Gö, H. & Uzun, D. 2020. Comparative analysis of wastewater treatment technologies. *Journal of Engineering* 32(2): 221-230. DOI:https://doi.org/10.17576/jkukm-2020-32(2)-06

Ostertagová, E. & Ostertag, O. 2013. Forecasting using Simple Exponential Smoothing Method. *Acta Electrotechnica et Informatica* 12(3): 62-66. DOI:https://doi.org/10.2478/v10198-012-0034-2

Parameswari, K., Padmini, T. K. & Mudgal, B. V. 2015. Assessment of soil contamination around municipal solid waste dumpsite. *Indian Journal of Science and Technology* 8(36): 9-10. DOI:https://doi.org/10.17485/ijst/2015/v8i36/87437

Prechthai, T., Parkpian, P. & Visvanathan, C. 2008. Assessment of heavy metal contamination and its mobilization from municipal solid waste open dumping site. *Journal of Hazardous Materials* 156: 86-94. DOI:https://doi.org/10.1016/j.jhazmat.2007.11.119

Qiuyu, L., Qiuna, C., Sijie, L., Yun, Y., Binjie, Y., Yang, W. & Xinsheng, Z. 2017. Short-term load forecasting based on load decomposition and numerical weather forecast. *IEEE Conference on Energy Internet and Energy System Integration EI2* 1-5. DOI:https://doi.org/10.1109/EI2.2017.8245603

Raja Yahya, R. N. A., Mohamad Taram, E. & Othman, A. A. 2019. Sustainable management of brownfield greenspace: A study of worldwide landfills park Air Hitam, Puchong, Malaysia. *Alam Cipta* 12(1): 8-17. https://frsb.upm.edu.my/upload/dokumen/20190628164126Article_2.pdf (accessed 11 May 2021).

Ramlan, R., Atan, S. A., Ismail, S. N. & Xin, W. M. 2013. Demand forecasting with univariate times series model: A case study in electric and electronic manufacturing company. *2nd International Conference on Global Optimization and Its Application (ICoGOIA2013)* 145-148.

Sasaki, S. & Araki, T. 2014. Estimating the possible range of recycling rates achieved by dump waste pickers: The case of Bantar Gebang in Indonesia. *Waste Management & Research* 32(6): 474-481. DOI:https://doi.org/10.1177/0734242X14535651

Simis, M. & Awang, A. 2015. Planning for ex-landfill redevelopment: Assessing what community have in mind. *Asian Social Science* 11(15): 136-145. DOI:https://doi.org/10.5539/ass.v11n15p136

Simis, M., Awang, A. & Arifin, K. 2016. From ex-landfill to public park: Impact on local community's quality of life and living environment. *Procedia - Social and Behavioral Sciences* 222: 763-771. DOI:https://doi.org/10.1016/j.sbspro.2016.05.157

Sizirici, B. & Tansel, B. 2010. Projection of landfill stabilization period by time series analysis of leachate quality and transformation trends of VOCs. *Waste Management* 30: 82-91. DOI:https://doi.org/10.1016/j.wasman.2009.09.006

Sizirici, B. & Tansel, B. 2009. Time series analysis of performance data from closed landfills to forecast post closure monitoring needs. *Proceedings of World Environmental and Water Resources Congress 2009 - World Environmental and Water Resources Congress 2009: Great Rivers* 2520-2529. DOI:https://doi.org/10.1061/41036(342)254

Supriatna, A., Lesmana, E., Aridin, L., Sukono & Napitupulu, H. 2019. Comparison between multiplicative Holt Winter and decomposition method in predicting the number of incoming international tourists to Indonesia. *IOP Conference Series: Materials Science and Engineering* 567. DOI:https://doi.org/10.1088/1757-899X/567/1/012047

United States Environmental Protection Agency (US EPA). 2005. Landfill gas emissions model (LandGEM) user's guide (Issue May).

United States Environmental Protection Agency (US EPA). 2012. International Best Practices Guide for Landfill Gas Energy Projects. United State of America, Global Methane Initiative (GMI). DOI:https://doi.org/10.1017/CBO9781107415324.004

Watanabe, K., Okayama, T., Siti Khadijah, A. G., Tetsuya, A., Cristina, L., Iderlina, M.-B., Prijono, T. & Adelia, L. 2018. An explorator y study on waste management in Southeast Asian megacities and Tokyo. *Teikyo Journal of Sociology* 31: 115-128. https://tk-opac2.main.teikyo-u.ac.jp/webopac/syakai31-08._?key=FQUYXF (accessed 2 April 2019).