Sustainability analysis on landfilling and evaluation of characteristics in landfill leachate: a case study

S N A Mohd-Salleh¹, M Z N Shaylinda¹*, N Othman¹, M O Azizan¹, G Yashni¹ and W M W Afnizan¹

¹ Department of Water and Environmental Engineering, Faculty of Civil and Environmental Engineering, Universiti Tun Hussien Onn Malaysia, 86400 Parit Raja, Johor, Malaysia

Corresponding author*: nursha@uthm.edu.my

Abstract. Issues on solid waste management in the most Asian developing countries is not recent. Unfortunately, Malaysia is still practicing landfilling method to dispose the solid wastes. The apparent consequence of this method is the production of highly polluted wastewater called leachate, which can cause several inconveniences and issues. The characterization of landfill leachate is merely important because it can guide towards the possible appropriate treatment. The main focus of this study was to analyse the leachate characteristics at Simpang Renggam Landfill Site, Johor, Malaysia for five consecutive months from January to May of 2018. There were 16 analyzed parameters; namely temperature, pH, total dissolved solids (TDS), conductivity, suspended solids (SS), colour, turbidity, ammonia (NH₃-N), dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), BOD₅/COD ratio, as well as heavy metals (iron (Fe), chromium (Cr), arsenic (As), lead (Pb)). All parameters were analyzed according to the Standard Methods for the Examination of Water and Wastewater, and have followed the procedures of respective instruments. Leachate in SRLS could be classified as stabilized ones, by considering the characteristics and the age of landfill. SRLS is recommended to upgrade its management system for better waste disposal and leachate treatment.

1. Introduction
The population of Malaysia is increasing so does the waste generation in this country. The skyrocketed economic and consumption activities typically in capital city contributes as one of the factors [1]. High waste generation leads to the high disposal volume rates make Malaysia’s available utilities insufficient to manage it, thus end up to the dump sites without proper management and close monitoring [2]. The management of solid waste is reaching the unfavourable phase, as a result of difficulty in providing the anticipated facilities for public services [3]. According to Ismail & Manaf [4], Malaysia comprises with thirteen states and three federal territories, is categorized as middle income countries alongside Myanmar, Thailand and India, which the rate was between 0.78 to 1.16 kg/capita/day. Therefore, it can be highlighted that the escalated countries’ development and activities will surge the solid waste generation as well.
1.1. The Viability of Landfill and Open Dumpsite

The establishment of Ministry of Housing and Local Government has crucial role in giving advice and proclamation as soon as possible to the community. While the authorized sub-unit such as Environmental Department and Economics Planning Unit have non-distinct tasks on controlling pollution arise from municipal solid waste and developing the competent waste management’s programs in national level respectively [1]. The problem is not only emerge in Malaysia as dearth of awareness, technical knowledge, legislation, policies, and strategies are major issues for solid-waste management in Asian developing countries [5]. Specially, only five percent of every day’s waste do not end up in the landfill or dumpsite. The recent decade of industrialization years have caused unrestrained consumption and lifestyle changes, which are the major causes of high wastes volume and problem in this country [6], [7]. The widespread economic through various programs initiated by the government through the enactment of Government Transformation Program (GTP) in 2009 has positively changed the landscape including at the isolated areas [8]. Throughout the years, various types and composition of wastes, including commercial, industrial and agricultural spin-off are dumped into the landfills without going through segregation process first. In addition, prior to this, as expressively stated by Ismail & Manaf [4], about 65% of wastes are expected to be generated in 2020, with landfilling is still the main choice of disposal method. In contrast, the intermediate processing and recycling attempts are predicted to change in a positive way, with an elevation of 15-20% from the total wastes. The figure shows increasing percentage but somehow, the recycling industry still needs to be augmented, via integrated participation and collaboration of expertise, local authorities, and public communities. It is undeniable that landfilling method is the major technique of disposal choice, with the capacity limit of present landfills and open dumpsites in Malaysia are getting filled with wastes. Furthermore, the newly-proposed sites for landfill is challenging to be established, since there is a lot of regulations need to be complied. In Malaysia, the types of landfills is commonly classified according to its operational purpose, which are in general consisting of four classes, namely as class I, class II, class III, and class IV. The characteristics of landfills according to its class is summarized as in table 1 below.

| Landfill class | Criteria/Available facilities |
|---------------|-----------------------------|
| Class I       | Minimum facilities; fencing and perimeter drains e.g.; dumping into water bodies |
| Class II      | Additional facilities from Class 1; gas removal system, separate unloading and working area, daily cover and enclosing bund, elimination of scavenging activities and environmental protection facilities e.g.; open dumps |
| Class III     | Additional facilities from Class 2; leachate recirculation system allowing the collection, recirculation and monitoring of landfill leachate e.g.; controlled tipping (level I, II, III landfills) |
| Class IV      | Additional facilities from Class 3; leachate treatment system e.g.; sanitary landfill |

1.2. Pollution from Landfill and Open Dumpsite

The alternative of dumping high volume of solid wastes in the landfill at economical cost makes it one of the leading options for disposal method. The unsegregated wastes will cause biological, chemical and physical biodegradation to happen in the landfills, which lead to the harmful and risky emissions of methane gas and leachate. The generated severe pollution particularly leachate is mostly controlled
by the landfill operators using the technical barrier or liners [4]. The liners can assist to hold the leachate in the retention pond, but not until it reach its maximum limit, that can cause leakage via the bottom of the landfill, or through overflowing on the upper side. As eloquently stated by Daud et al. [6] leachate is the most concerned type of pollution originated from landfill, due to its strong wastewater characteristics that need multiple stages of remediation process, before it can be safely released to the surrounding areas. It contains few kinds of hazardous contaminants such as high level of ammonia and heavy metals, loads of organic matters, as well as unfavourable physical properties, such as stink odour and dark in colour. The operation of landfill and open dumpsite also cause other types of pollution, such as the preferred places for pest infestation and reproduction [11].

1.3. Landfill Leachate
The definition of leachate from the science perspective can be explained as the highly aqueous polluted effluent produced due to the biochemical processes happen between the percolated rainwater with the content of wastes themselves [12]. During the process, the solid waste substances and its moisture content leached into the incoming percolated water. It is always addressed as highly polluted wastewater, as it may contain great amount of biodegradable and non-biodegradable products such as; organic contaminants, suspended solid, inorganic salts, heavy metals, ammonia, and high COD concentration that surpass the permissible limit standard of leachate discharge effluent [13], [8], [4]. However, the concentration of each contaminants may be different due to the landfill age [14], as the duration of the solid waste have been located in the landfill will influence the quality of the leachate.

The complex leachate is known to carry the dissolve chemicals and other hazardous elements while migrating from its origin position to another [15]. It is squeezed out of waste trough the force of compaction and compression, that eventually increase the volume of leachate produced. Logically, the greater the landfill waste is compacted, the larger the produced leachate [4]. Furthermore, the climate condition also can affect its capacity volume [16], [4], which the warmer weather usually has influence to big leachate production compare to colder ones. The high volume of leachate lead to the overflow in retention pond that can cause significant environmental concerns such as groundwater and surface water. The hydraulic connections under the soil become the ordinary way of leachate to contaminate both types of water, either treated or not. Unless the leachate reaches the surface and may precede to overflow, it habitually to retain in the landfill’s vicinity area. The groundwater source below soil and landfill site can potentially migrate the contaminants to far zone, once leachate connect with the under aquifer [4].

1.4. Acceptable Conditions for Leachate Discharge in Malaysia
Malaysia is also one of the countries that on track by providing the official guideline, introduced in 1974, which is the Environmental Quality Act 1974: Second Schedule (Regulation 13). Prior to this act, in exercise of the powers conferred by sections 21, 24, and 51, the regulations regarding discharged leachate is established, known as Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009 (table 2).
Table 2. Second Schedule (Regulation 13): Acceptable Conditions for Discharge of Leachate

| Parameter                          | Unit   | Standard   |
|-----------------------------------|--------|------------|
| (i) Temperature                   | ºC     | 40         |
| (ii) pH value                     | -      | 6.0-9.0    |
| (iii) BOD₃ at 20°C                | mg/L   | 20         |
| (iv) COD                          | mg/L   | 400        |
| (v) Suspended Solids              | mg/L   | 50         |
| (vi) Ammonia Nitrogen             | mg/L   | 5          |
| (vii) Mercury                     | mg/L   | 0.005      |
| (viii) Cadmium                    | mg/L   | 0.01       |
| (ix) Chromium, Hexavalent         | mg/L   | 0.05       |
| (x) Chromium, Trivalent           | mg/L   | 0.20       |
| (xi) Arsenic                      | mg/L   | 0.05       |
| (xii) Cyanide                     | mg/L   | 0.05       |
| (xiii) Lead                       | mg/L   | 0.10       |
| (xiv) Copper                      | mg/L   | 0.20       |
| (xv) Manganese                    | mg/L   | 0.20       |
| (xvi) Nickel                      | mg/L   | 0.20       |
| (xvii) Tin                        | mg/L   | 0.20       |
| (xviii) Zinc                      | mg/L   | 2.0        |
| (xix) Boron                       | mg/L   | 1.0        |
| (xx) Iron                         | mg/L   | 5.0        |
| (xxi) Silver                      | mg/L   | 0.10       |
| (xxii) Selenium                   | mg/L   | 0.02       |
| (xxiii) Barium                    | mg/L   | 1.0        |
| (xxiv) Fluoride                   | mg/L   | 2.0        |
| (xxv) Formaldehyde                | mg/L   | 1.0        |
| (xxvi) Phenol                     | mg/L   | 0.001      |
| (xxvii) Sulphide                  | mg/L   | 0.50       |
| (xxviii) Oil and Grease           | mg/L   | 5.0        |
| (xix) Colour                      | ADMI*  | 100        |

2. Material and Methodology

2.1. Study Area
The case study area is located at Simpang Renggam landfill site (SRLS), in the Simpang Renggam district of Kluang, Johor, Malaysia (1°53'41"N 103°22'35"E) (figure 1). The nearest town is approximately about two kilometres away from the landfill. For the time being, SRLS can be classified as Class III landfill, based on the physical observations and the available leachate treatments in the study area (figure 2).
2.2. Leachate Sampling and its Characterization

In this study, the used sampling method was grab sampling, at three selected points. The raw leachate samples were collected manually by using high density polyethylene (HDPE) containers. Upon arrival at the landfill, a Portable Multi-parameter (HANNA HI9829) was used to obtain the in-situ parameters. This multi-parameter probe gave instant results for pH, temperature, total dissolved solid, conductivity, and dissolved oxygen. The probe was immersed in three sampling points at the leachate pond, to obtain the average readings. 15 containers of samples were collected and analyzed during the period of January to May 2018. The samples were collected every two-week interval within five-month duration. The attained data of SRLS leachate characteristics were compared with the study of previous researchers and Malaysia’s discharged leachate standard (table 2). The procedures of sampling and storage were conducted in accordance to American Public Health Association (APHA 2008) Standard Method as shown in table 3.
The collected leachate from retention pond and was immediately transferred into a cold room of 4°C at Waste Water Laboratory, Universiti Tun Hussien Onn Malaysia (UTHM). In the laboratory, the samples were tested as soon as possible for chemical oxygen demand (COD), biochemical oxygen demand (BOD), ammonia, colour, turbidity, suspended solids, and heavy metals using respective methods and instruments (table 4). For heavy metals’ measurement, the leachate samples were filtered using 0.45 μm cellulose acetate membrane and acidified to pH <2 using diluted nitric acid. Flame atomic absorption spectrophotometer (FAAS; PerkinElmer, Waltham, MA) was used to measure major element (Fe) while for minor concentration of Cr, As, and Pb, inductive couple plasma mass spectrometry (ICP-MS: PerkinElmer ELAN DRC-e) was used. Table 4 shows the list of used standard methods in this study according to Standard Methods for Water and Wastewater (APHA).

### Table 3. Recommended storage conditions to analytes in water samples.

All samples were stored in a refrigerator at 4°C.

| Analyte                      | Bottle Material | Preservative          | Max. storage time |
|------------------------------|-----------------|-----------------------|-------------------|
| COD                          | P, G            | H₂SO₄ to pH < 2       | 4 weeks           |
| Ammonia                      | P               | HNO₃ to pH < 2        | 4 weeks           |
| Suspended solids             | P, G            | None                 | 1 week            |
| Trace metals                 | P               | HNO₃ to pH < 2        | 6 months          |
| Dissolved oxygen             | G               | None                 | ASAP              |
| pH                           | P               | MnSO₄                 | ASAP              |

P = Polyethylene, G = Pyrex glass

### Table 4. List of used standard methods in this study according to Standard Methods for Water and Wastewater (APHA)

| Parameter                                  | Methods                        |
|--------------------------------------------|--------------------------------|
| Temperature, pH, Conductivity, Total dissolved solids (TDS), Dissolved Oxygen | Portable Multi-parameter (HANNA HI9829) |
| Chemical oxygen demand (COD)               | APHA Method: 5220 C            |
|                                            | HACH Method:8000               |
| Biochemical oxygen demand (BOD)            | APHA 5210                      |
|                                            | HACH Method: 8043              |
| Suspended solids                           | APHA Method:2540 D             |
|                                            | HACH Method:630                |
| Turbidity                                  | APHA Method:2130               |
| Colour                                     | HACH Method: 8025              |
| Ammonia (NH₃-N)                            | HACH Method: 8038              |
| Fe, Cr, As, Pb                             | APHA Method:3120               |

3. Result and Discussion

3.1. Simpang Renggam Landfill Site (SRLS)

The operation in SRLS started in 1996 with six hectares of land and is still operating until now [17]. Based on the physical observations and interviews with the staffs and workers, SRLS was started as class II landfill, which was an open dumping site. However, as the time passed by, it now can be categorized as class III landfill, due to the additional treatments on the site (table 1). Class III landfill has additional facilities from class II; such as leachate recirculation system that allowing the collection, recirculation, and monitoring of landfill leachate. The upgrade of landfill class seems does not help much due to the limited available treatments for solid waste and generated leachate. As for now, the available treatments in SRLS for leachate are aeration pump, degradation using
microorganisms, and reverse osmosis tank. Nonetheless, these treatments do not able to treat the generated leachate in order to comply the discharge permissible limit. Even though SRLS is surrounded by palm trees as its buffer zones, the overflow of leachate from retention pond leads to the leakage to the groundwater and nearby river, especially during the rainy seasons. In the last few years, several incidents have happened in the landfill such as the broke out of the retention pond that caused the leak of leachate into the surrounding. Due to this, the landfill was ordered to close for a while, following to the necessary of repairing steps. Residents around Simpang Renggam town are always in torture feelings every time the rain hits hard in the area. Since this was not the first time the retention pond broke out due to the rainy seasons, which cause the contamination of raw and clean water sources. The future potential of SRLS as sanitary landfill seems brighter when the current authorities and respective high-level of educational institutions (e.g UTHM) show their concerns and take extravagant measures to handle the landfill and leachate problems of SRLS. It is expected that few constraints might be faced by the authorities in order to upgrade to the class IV of sanitary landfill, which needs meticulous planning. Approximately of 500 tons of solid waste are disposed into SRLS daily, which is over the limit practice. As an alternative, the generated leachate is collected and transferred to Seelong sanitary landfill, which is located in Kulai district, Johor. Nowadays, Seelong sanitary landfill is claimed as one of the best sanitary landfills in the country, other than Bukit Tagar sanitary landfill in Selangor state. Based on the previous studies of leachate characterization, the 22 years old landfill site is alleged to generate stabilized leachate [17]. The recent characterization studies for comparison regarding leachate from SRLS was in 2017, which was a study done by Zailani et al. [17] while the oldest data was done by Daud et al. [18]. Therefore, in order to validate the type of generated leachate in SRLS, characterization studies was accomplished for a duration of five consecutive months, as shown in table 5.

3.2. Characteristics of leachate in SRLS
There were 15 containers of leachate sample for the 5 months of study period. Three readings were taken for every parameter in order to take the average reading. The obtained characterization data of leachate sample from SRLS is shown as in table 5. Comparison studies was done as well to validate and verify the data, as shown in table 6. However, not all past studies analysed the same parameters as present.

| Parameter                  | Range       | Average   | EQA Regulations 2009 |
|----------------------------|-------------|-----------|----------------------|
| Age (years)                | > 10        | -         | -                    |
| pH                         | 8.18-8.76   | 8.46      | 6.0-9.0              |
| Temperature (°C)           | 26.3-30.14  | 27.5      | 40                   |
| Total Dissolved Solid (mg/L)| 2197-6142   | 4231      | N.A.                 |
| Conductivity (mS/cm)       | 2951-12270  | 7857.8    | N.A.                 |
| Suspended Solid (mg/L)     | 144-291     | 225       | 50                   |
| Colour (ADMI*)             | 4180-7101   | 4555      | 100 ADMI*            |
| Turbidity (NTU)            | 120-160     | 141.6     | N.A.                 |
| Ammonia (mg/L)             | 131.21-920.4| 557.69    | 5                    |
| Dissolved Oxygen (mg/L)    | 0.02-0.76   | 0.324     | N.A.                 |
| COD (mg/L)                 | 1516-2954   | 2343.4    | 400                  |
| BOD at 20 °C (mg/L)        | 54.38-240.75| 139.57    | 20                   |
| BOD5/COD                   | 0.02-0.16   | 0.0678    | N.A.                 |
| Iron (Fe) (mg/L)           | 5.88-14.31  | 7.974     | 5                    |
| Total Chromium (Cr) (mg/L) | 0.131-0.56  | 0.354     | 0.2                  |
| Arsenic (As) (mg/L)        | 0.019-0.067 | 0.0452    | 0.05                 |
| Lead (Pb) (mg/L)           | 0.036-0.147 | 0.0758    | 0.10                 |

*Number of sample: 15  *N.A. = Not Available
Table 6. Leachate characteristics at SRLS from this study, [17]-[20]

| Parameter          | This study | Zailani et al. [17] | Fatihah [19] | Abd. Kadir et al. [20] | Daud et al. [18] |
|--------------------|------------|---------------------|--------------|------------------------|------------------|
| Duration           | January-May 2018 | January-April 2017 | 2015         | 2014                   | 2013             |
| Number of samples  | 15         | 12                  | -            | -                      | -                |
| Age (years)        | >10        | >10                 | >10          | >10                    | >10              |
| pH                 | 8.46       | 7.6 – 8.3           | 8.31-8.47    | -                      | 8.31-8.47        |
| Temperature (ºC)   | 27.5       | -                   | -            | -                      | -                |
| TDS (mg/L)         | 4231       | -                   | -            | -                      | -                |
| Conductivity (mS/cm) | 7857.8    | -                   | -            | -                      | -                |
| Dissolved Oxygen (mg/L) | 0.324     | -                   | -            | -                      | -                |
| COD (mg/L)         | 2343.4     | 1836-2150           | 9839-15680   | 13166-13500            | -                |
| BOD<sub>S</sub>/COD | 0.0678    | 0.085               | 0.24         | -                      | -                |
| Ammonia (mg/L)     | 557.69     | 692-1272            | 755-2670     | -                      | 755-2670         |
| BOD<sub>S</sub>    | 139.57     | 110-230             | 2340-4026    | -                      | -                |
| SS (mg/L)          | 225        | 78-268              | 1200-1240    | -                      | 270-1200         |
| Turbidity (NTU)    | 141.46     | 84-244              | 2200-2300    | -                      | -                |
| Colour (ADMI)      | 4555       | 3949-5126           | 2010-10420   | -                      | 2010-10420       |
| Fe (mg/L)          | 7.97       | -                   | -            | 16.10                  | -                |
| Cr (mg/L)          | 0.35       | -                   | -            | 0.623                  | -                |
| As (mg/L)          | 0.045      | -                   | -            | -                      | -                |
| Pb (mg/L)          | 0.076      | -                   | -            | -                      | -                |
| Cu (mg/L)          | -          | -                   | -            | 0.065                  | -                |
| Zn (mg/L)          | -          | -                   | -            | 0.380                  | -                |

Age of landfill can be a helpful indicator of predicting the type of generated leachates. Two obvious phases can be identified from the transition of shorter to longer waste decomposition period, which are acidic and methanogenic phases [21]. Based on the characterization analysis (table 5), the pH of leachate samples remain at alkali range, which is above 8.0, according to the acidity and alkalinity tests. The value of pH is an important parameter in leachate effluent discharge, which could represent the biochemical conditions of solid wastes. Next, the temperature recorded values of the landfill leachate portray to normal lithospheric temperature in the country [22]. The conductivity values in the analysis resemble the total concentrations of anions and cations as well as the dissolved inorganic components [22]. It basically measures the ability of electric flow that depends on the dissolved salts and inorganic substances. The high conductivity value here was supported by the high content of ions and total dissolved solids (4231 mg/L) as well. By using Ion Chromatography (IC) to characterize the leachate in this study, the high content of ions was observed by having 1095.45 mg/L of chloride (Cl<sup>-</sup>), 40.46 mg/L of nitrate (NO<sub>3</sub>–), 10.06 mg/L of fluoride (F<sup>-</sup>), 19.18 mg/L of orthophosphate (PO<sub>4</sub>3–), and 15.11 mg/L of sulfate (SO<sub>2</sub>4). While for COD parameter that indicated the organic strength of the leachate, the concentration of it was decreasing, as the age of the landfill get older. The highest COD concentrations was in Daud et al. [18] study, with the average value more
than >10,000 mg/L, which the same trend was found in Fatihah study [19] as well. Nevertheless, the value of COD showed the decreasing in concentrations, proven by Zailani et al. [17] and present studies, the COD level in the leachate still did not comply the discharge standard to be 400 mg/L or less before it could be released into the environment. This was because as the landfill aged, the leachate experiences the changes in characteristics as well [23]. While for BOD\textsubscript{5}, a big range gap was spotted between Fatihah studies [19] and onwards. The BOD\textsubscript{5} concentration in 2015 was about between 2340-4026 mg/L, while this study obtained about 139.57 mg/L averagely. There is a strong correlation between the concentrations of COD and BOD\textsubscript{5} that could be used as the initial indicator to describe the pollution levels in the wastewater [23]. The higher COD value over BOD\textsubscript{5} showed that more compounds could be oxidized chemically than biologically. A low BOD\textsubscript{5} value here indicated that the generated leachate had low biodegradability, which was not a match with the process of biological treatment [24]. The obtained low BOD\textsubscript{5} and BOD\textsubscript{5}/COD with low mean values at 139.57 mg/L and 0.096 respectively here for stabilized leachate agreed with literature stated by Naveen et al. [23].

Leachate is well known for its high ammonia content that become the major toxicant for living organisms. For ammonia parameter, there was not much difference between all values, which shows the lessening in concentration from year to year. The mean values for ammonia content was 557.69 mg/L in this study, which the reducing of it to be less than 5 mg/L needed to be carried out in order to comply the allowable limit of discharge standard. For colour parameter, the concentrations in ADMI shows the increasing in value, which indicated that the leachate become more blackish than before with the mean value of 4555 ADMI in this study. The greater concentration of leachate colour was predominantly contributed by the recalcitrant dissolved organic compounds such as the humic substances [24]. The dark browned of landfill leachate colour also indicated the presence of high concentration of humic acids [25]. The trends for suspended solids and turbidity also decreased, from thousands to hundreds of mg/L. The obtained 225 mg/L of suspended solids here was greater than the acceptable concentration of 50 mg/L. Suspended solids, true and apparent colour, turbidity, TDS, total suspended volatile solids and total solids are the parameters that related to the organic colloid particles in leachate [26]. For heavy metals, the comparison was only available for Fe and Cr, from Abd Kadir et al. studies [20]. From both studies, it showed that the heavy metals concentration were decreasing across the year. Despite the lower concentration of heavy metals in the leachate sample, it was still above the Malaysia discharge standard especially for iron (Fe) and total chromium (Cr) with 7.97 mg/L and 0.35 mg/L respectively. Heavy metals could accumulate in the living organisms and become the major cause of toxicity as well. Overall, based on the comparison, only parameters of pH, temperature, As, and Pb complied the discharged standard while others recorded high values of concentrations. Since the sample taken was the raw one, it was rationale and making sense for most of the parameters to not be able to be below than the safe values. Therefore, the generated leachate must be treated by according to its types and composition, to ensure the efficiency of the remediation.

The five months duration of analyzing the leachate sample from SRLS showed satisfying results with the increasing and decreasing of concentration values of some tested parameters. Overall, the decreasing in value could be seen in all parameters, except for colour and pH parameters. Even though most of the values decreased, it still did not comply the discharge standard of leachate in the country. The availability of land and its low cost management have become the solid reasons for the country to practice landfilling to dispose wastes at most of the states. The management of wastes is important to ensure hygiene surrounding with magnificent sceneries. Nonetheless, the production of leachate from these landfills has become bad agent to the environment. Through the characterization studies, it was obtained that SRLS produced stabilized leachates during the period of January to December of 2018.

3.3. Factors Affecting Classification and Composition of Leachate
The operation period of landfills eventually effect the characteristics of waste inside them, as it degrade over the time. The composition of leachates are actually representing the vary constituents of wastes end up in the landfill [27]. As eloquently stated by Aziz et al. [13] and El-Gohary & Kamel
[27], besides the wastes’ characteristics, few factors are named as contributors to the temporal leachate quality as well, for instance, the site location, management practice, depth of solid wastes, rainfall pattern, water percolation’s rate, soil characteristics, internal treatment processes, and age of landfill. The surrounding temperature and moisture content also play big roles in the composition of leachate [23]. At this point, based on the landfill age, it can be categorized as young (below than five years), which produce young type of leachate, medium age (between five to 10 years), that resulted in intermediate leachate, and old landfill (exist more than 10 years), which influence the production of stabilized leachates [27], [14]. As the landfills get older, the activity of anaerobic decomposition in the site will reduce the biodegradable fraction of organic pollutants, thus cause stabilized leachate become higher polluted wastewater compare to the young ones [13]. Typically, old leachate is harder to be treated. This address that it is important to carry out leachate characterization first to have a successful treatment strategy [28]. Table 7 shows the BOD5/COD ratio, which is corresponding to landfill age.

Table 7. BOD5/COD corresponding to landfill age [23]

| COD  | BOD5/COD | Age of landfill    |
|------|----------|--------------------|
| >10,000 | ≥ 0.5     | Young (<5 year)   |
| 500-10,000 | 0.1-0.5  | Medium (5-10 year) |
| <500  | <0.1     | Old (>10 year)     |

BOD is an indicator of biological degradation organic compound, by measuring the microorganism’s oxygen uptake. It is commonly used as guide to quantify the strength of organic contaminants [29], [16]. While COD has also factually reflect the measurement of organic matter in wastewater. However, there are many other constituents of inorganic compounds that influence the COD concentration, thus it cannot be merely counted on the presence of organic matter, even though it is the dominant component [30], [31]. Hence, biological treatment processes are noticeably effective for young leachate but do not work well with stabilized leachate [32]. The characteristics of leachate versus the age of the landfill is summarised as in the table 8.

Table 8. Characteristics of leachate versus the age of landfill [17], [33]

| Types of leachate | Stabilized | Intermediate | Young          |
|-------------------|------------|--------------|----------------|
| Age               | >10        | 5-10         | <5             |
| pH                | >7.5       | 6.5-7.5      | <6.5           |
| COD (mg/L)        | <4,000     | 4,000-10,000 | >10,000        |
| BOD5/COD          | <0.1       | 0.1-0.5      | 0.5-1.0        |
| Organic compounds | Humic and Fulvic acid | 5%-30% VFA + Humic anf fulvic acid | 80% volatile fatty acid (VFA) |
| Ammonia nitrogen  | >400       | N.A.         | <400           |
| TOC/COD           | >0.5       | 0.3-0.5      | <0.3           |
| Kjeldahl nitrogen | N.A.       | N.A.         | 0.1-0.2        |
| Heavy metals      | Low        | Low          | Low to medium  |
| Biodegradability  | Low        | Medium       | Important      |

The high accumulation of inorganic toxic compounds such as heavy metals and ammonia over a long period time are recognized as toxicants to the living organisms, which can cause further damaging consequences [14]. Therefore, a significant attention should always be given towards landfill especially the ones which are located near the municipal area. Although the landfill operation is shut down, it will continue to produce polluted leachate, which the process could last for decades
The raising population and industry activities contribute a major impact of increasing solid waste generation, thus affect the leachate production to become more serious. Leachate has many negatives potential consequences, which further tough cleaning up processes are needed once they enter the water bodies [23]. It also contain such risky contaminants that do not comply the standard permissible limits, such as COD, suspended solids, ammonia, and heavy metals. Improper waste disposal may lead to such toxic compounds present, with leachate characterization could give the clue of possible associated wastes such as battery components and plastic bags [22]. Hence, based on all the characterization studies, it was concluded that leachate from SRLS was a stabilized ones.

4. Conclusion
The five months duration of analyzing the leachate sample from SRLS shows satisfying results with the increase and decrease of concentration values of some tested parameters. Overall, the decreasing in value can be seen in all parameters, except for color and pH parameters. Even though most of the values decrease, it still do not comply the discharge standard of leachate in this country. The availability of land and its low cost management have become the solid reasons for the country to practice landfilling to dispose wastes at most of the states. The management of wastes is important to ensure hygiene surrounding with magnificent sceneries. Nonetheless, the production of leachate from these landfills has become bad agent to the environment. Through the characterization studies, it was obtained that SRLS produced stabilized leachates during the period of January to May of 2018. Current available treatments in the landfill could able to treat the leachate, but it did not efficient enough to comply the discharge standard. It is crucial to treat leachate according to its types. SRLS is highly recommended to upgrade its landfill to the sanitary level even though it will be facing some problems such as environmental issues, financial constraints, and residents’ complaints. Installing new types of treatments by according to the types of generated leachate is strongly recommended. Based on the characterization of leachate in SRLS, the landfill is recommended to have an integrated treatments, by combining two or more treatments to treat the leachate. For instance, the biological treatment can be operated by adding respective bacteria at the first stage to eradicate the high inorganic pollutants such as ammonia nitrogen. Next, physical-chemical treatment can be operated such as coagulation-flocculation process by using coagulants to effectively settle down the physical impurities. Therefore leachate can be released safely without violating the environmental regulations. The most benefit after all will goes to the society and residents around the landfill, which are able to live safely while protecting the environment and water resources. World trends now show supportive idea of being green, thus the new types of sustainable treatments are preferred for the time being and in the future. At the same time, sustainable treatments in the landfills can also advocate the country to be the next green nation by 2030.

5. Reference

[1] Budhiarta I, Siwar C, and Basri H 2012 Advanced science information technology current status of municipal solid waste generation in Malaysia. Int. J. on Adv. Sc. Eng. Info. Tech. 2 p 16–21.
[2] Tarmudi Z, Abdullah M L, and Md Tap A O 2009 An overview of municipal solid wastes generation in Malaysia. J. Teknologi 51 p 1–15.
[3] Bhalla B M S and Saini M K J 2014 Assessment of municipal solid waste landfill leachate treatment efficiency by leachate pollution index. Int. J. Inno. Res. in Sc, Eng., Tech. 3 p 8447–54.
[4] Ismail S N S and Manaf L A 2013 The challenge of future landfill: a case study of Malaysia. J. Tox. Env. Health Sc. 5 p 86–96.
[5] Environmental Management Centre (EMC) 2007 Solid waste management: issues and challenges in Asia. Asian Prod. Org. (APO).
[6] Daud Z, Abubakar M H, Kadir A A, Latiff A. A. A, Awang H, Halim A A, and Marto A 2016 Optimization of leachate treatment with granular bioma: feldspar and zeolite. Indian J. Sc. Tech. 9 p 11–5.

[7] Kalanatarifard A and Su Yang G 2012 Identification of the municipal solid waste characteristics and potential of plastic recovery at Bakri Landfill, Muar, Malaysia. J. Sustain. Dev. 5 p 11–7.

[8] Kamaruddin M A, Yusoff M S, Aziz H A and Hung Y T 2015 Sustainable treatment of landfill leachate. App. Wat. Sc. 5 p 113–26.

[9] Agamuthu P and Fauziah S 2011 Challenges and issues in moving towards sustainable landfills in a transitory country - Malaysia. Waste Man. Research. 29 p 13–9.

[10] Idris A, Inanc B and Hassan M N 2004 Overview of waste disposal and landfills/dumps in Asian countries. J. Mat. Cyc. Waste Man. 6 p 1-5.

[11] Fauziah S H and Agamuthu P 2010 Landfills in Malaysia: past, present and future. 1st Int. Conf. Final Sinks, Vienna. (Sept. 23-25) p 1–9.

[12] Yusoff M S and Mohamad Zuki N A 2015 Optimum of treatment condition for artocarpus heterophyllus seeds starch as natural coagulant aid in landfill leachate treatment by RSM. J. Appl. Mech. Mat. 802 p 484–9.

[13] Aziz S Q, Aziz H A, Bashir, M J K and Mojiri A 2015 Assessment of various tropical municipal landfill leachate characteristics and treatment opportunities. Glo. NEST J. 17 p 439–50.

[14] Rusdzial N, Aziz H A and Mohd Omar F 2015 Potential use of polyaluminium chloride and tobacco leaf as coagulant and coagulant aid in post-treatment of landfill leachate. Avicenna J. Health Eng. 2 p 1–5.

[15] Ghosh S and Hasan S E 2010 Sanitary landfill. J. Eng. Geo. Env. 2 p 1-6.

[16] Shaylinda M Z, Abdul Aziz H, Adlan M N and Arifin A 2012 Characterization of leachate at Matang landfill. Acad. J. Sc. 1 p 317–22.

[17] Zailani L W M, Amdan N S M and Shaylinda M Z N 2018 Characterization of leachate at simpang renggam landfill site, Johor, Malaysia. IOP Conf. Series: Earth Env. Sc. 140 012053.

[18] Daud Z, Muhamad Hanafi N F and Awang H 2013 Optimization of COD and colour removal from landfill leachate by electro-fenton method. Aus. J. Basic App. Sc. 7 p 263–8.

[19] Fatifah M H 2015 Landfill leachate treatment by combination of electro-fenton and sequencing batch reactor method. Master Thesis, (June). Universiti Tun Hussien Onn Malaysia.

[20] Abd. Kadir A, Al Bakri Abdullah M M, Sandu A V, Noor, N M, Abd. Latif A L and Hussin K 2014 Usage of palm shell activated carbon to treat landfill leachate. Int. J. Cons. Sc. 5 p 117–26.

[21] Mat-Salleh N F D and Ku-Hamid K H 2013 Leachate characterization from a closed landfill in Air Hitam, Puchong, Malaysia. Malaysian J. Anal. Sc. 17 p 24–9.

[22] Emenike C U, Fauziah S H and Agamuthu P 2012 Characterization and toxicological evaluation of leachate from closed sanitary landfill. J. Waste Man. Research, 30 p 888–97.

[23] Naveen B P, Puvvadi S and Sitharam T G 2014 Characteristics of a municipal solid waste landfill. Pro. Indian Geotech. Conf. IGC-2014. (Dec. 18-20) p 1–7.

[24] Al-Hamadani Y A J, Yusoff M S, Umar M, Bashir M J K and Adlan M N 2011 Application of psyllium husk as coagulant and coagulant aid in semi-aerobic landfill leachate treatment. J. Haz. Mat. 190 p 582–7.

[25] Verma M and Naresh Kumar R 2016 Can coagulation–floculation be an effective pre-treatment option for landfill leachate and municipal wastewater co-treatment? Perspectives in Sci. 8 p 492–4.

[26] Shaylinda M Z, Abdul Aziz H, Adlan M N, Arifin A, Yusoff M S and Dahanl I 2015 A comparative study of floc and sludge of leachate under different types of coagulants. J. App. Mech. Mat. 802 p 406–11.

[27] El-Gohary F A and Kamel G 2016 Characterization and biological treatment of pre-treated landfill leachate. J. Eco. Eng. 94 p 268–74.

[28] Kargi F and Pamukoglu M Y 2004 Adsorbent supplemented biological treatment of pre-treated landfill leachate by fed-batch operation. Bioresource Tech. 94 p 285–91.

[29] Lee A H and Nikraz H 2014 BOD:COD ratio as an indicator for pollutants leaching from landfill. J. Clean Energy Tech. 2 p 263–6.
[30] Dadrasnia A, Azirun M S and Ismail S 2017 Optimal reduction of chemical oxygen demand and NH3-N from landfill leachate using a strongly resistant novel Bacillus salmalaya strain. *BMC Biotech.* **17** p 1–9.

[31] Kylefors K, Ecke H and Lagerkvist A 2003 Accuracy of cod test for landfill leachates. *Water, Air, and Soil Pollution*, **146** p 153–69.

[32] Zainol N A, Aziz H A, Yusoff M S and Umar M 2011 The use of polyaluminum chloride for the treatment of landfill leachate via coagulation and flocculation processes. *Research J. Chem. Sc.* **1** p 34–9.

[33] Baiju A, Gandhimathi R, Ramesh S T and Nidheesh P V 2018 Combined heterogeneous electro-fenton and biological process for the treatment of stabilized landfill leachate. *J. Env. Man.* **210** pp 328–37.

**Acknowledgments**

This work was supported by Universiti Tun Hussein Onn Malaysia under *Geran Penyelidikan Pascasiswazah* (GPPS) Vot H014 and Ministry of Higher Education through Fundamental Research Grant Scheme (FRGS) Vot 1570, respectively. The authors also wish to acknowledge Majlis Perbandaran Kluang, Johor and SWCorp for their permission and assistance during the sampling process.