Assessment of water quality of Sembilang River receiving effluent from controlled municipal solid waste (MSW) landfill in Selangor

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Abstract. Most of the landfills in Malaysia are situated near to the main river basin that supplies almost 90% of water requirement. This includes landfills in Selangor where a total of 20 landfill sites are situated in 5 main river basins and the highest number of operating landfills (three) are at the Selangor River Basin (Jeram, Bukit Tagar and Kuang Inert landfills). This situation has caused wide concern over the water safety, even the leachate has been treated. The leachate itself still contains contaminants that are difficult to treat. The main objective of this study is to investigate the effect on water quality of Sembilang River that receives effluent from the nearby landfill. In this study, we analyzed samples of water from ten sampling stations starting from the upstream to downstream of Sembilang River. The water quality was evaluated by the Water Quality Index (WQI) depending on in-situ and laboratory analysis. 11 water quality variables are selected for the quality assessment; temperature, pH, turbidity, salinity, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total suspended solid, ammoniacal nitrogen, phosphate and nitrate. The result indicated that, when the effluent mixed with the river water, the water quality decreased gradually and was found to be lower at a few stations. The water quality of Sembilang River falls under Class III of Water Quality Index with ranges between 68.03 to 43.46 mg/L. It is revealed that the present scenario of water quality of Sembilang River is due to the effect of effluent from the landfill.

1. Introduction
Since the last century, landfilling has been the common method for the disposal of solid waste in many cities in developing Asian countries. Despite all the issues related to existing landfill sites and the increasing volume of waste generation, landfills remain the integral part of solid waste management plans [1-4]. Due to its economic advantages, landfills can potentially lead to a wide range of compounds with environmental, wildlife and human health concern. Gases and liquid leachate are the main pollution issues associated with landfill sites where leachate from MSW landfills is a threat to the quality of groundwater and surface water [5-7]. Liquid waste or leachate is produced during the stabilization in a landfill with a mixture of liquid from layers of waste and undergoes several hydrological and biogeochemical reactions. The characteristic of the landfill leachate can be varied depending on landfills characteristics, such as; the type of waste and its decomposition degree, the climatic variation during the waste disposal, the waste compaction, landfill cover, height of landfill layers, as well as the landfill environment: waste degradation phase, humidity, precipitation,
temperature, etc. All these factors represent the characteristics of the landfill leachate which normally contain high Chemical Oxygen Demand (COD), total organic carbon (TOC), biochemical oxygen demand (BOD), pH, ammonical nitrogen (NH$_3$-N) and heavy metals content [8,9]. Landfill can be classified as young (less than 5 years) which is in acidogenic phase and has large amounts of degradable organic substances and heavy metals. While old leachate (more than 10 years) is highly contaminated with NH$_3$-N and has a lower BOD/COD ratio lower than 0.1. Study shows that unionized ammonia and high concentration of nitrate and nitrite can cause fatalities in several species of fish and serious methemoglobinemia in young children [9, 12, 13]. This has become worldwide concern since most of the landfill sites are located near to the river with no facilities for collection and/or treatment of leachate and landfill gas. There are about 251 landfills with different sizes and ages in Malaysia and it is estimated that landfills in Malaysia can generated 3.0 million liters leachate per day [14]. Leachate then is released into the river after full or partial treatment. Selangor itself have 20 landfills that are situated at 5 main river basins and Selangor River Basin has the highest number of operating landfills, which are a major source of agriculture and productivity, industrial and domestic water supply [10, 11]. The list of landfill sites in Selangor is shown in Table 1. However, to ensure no watercourses is affected by the disposal of pollutants especially to the aquatic ecosystem, economic resource potential, public health and welfare, Malaysia have its very own wastewater discharge standard and the receiving water quality standard. Objective of this study is to assess the Sembilang River water quality for the disposal of effluent generated from the Jeram Sanitary Landfill.

Table 1. List of landfills sites a long Selangor River Basin

| Landfill     | River Basin | Nearest River     | Year         | Type of Landfill | Operator                                      |
|--------------|-------------|-------------------|--------------|------------------|-----------------------------------------------|
| Kuang Inert  | Selangor    | Dungon River      | June 2007-Present | Non-sanitary     | Worldwide Landfill Sdn. Bhd                   |
|              |             |                   |              | Active           |                                               |
| Jeram        | Selangor    | Sembilang River   | Jan 2007-Present  | Sanitary         | Worldwide Landfill Sdn. Bhd                   |
|              |             |                   |              | Active           |                                               |
| Bukit Tagar  | Selangor    | Bangkar River     | 2005-Present | Sanitary         | KUB-Berjaya Enviro Sdn. Bhd                   |
|              |             |                   |              | Active           |                                               |
| Kundang      | Selangor    | Kuang River       | 2002-April 2006 | Non-sanitary     | Alam Flora Sdn. Bhd                          |
|              |             |                   |              | Closed           | Worldwide Landfill Sdn. Bhd                   |
| Kubang Badak | Selangor    | Kubang Badak River| 1985-March 2007 | Sanitary         | Majlis Daerah Hulu Selangor                   |
|              |             |                   |              | Closed           |                                               |
| Bukit Beruntung | Selangor  | Sabai River       | NA           | Non-sanitary     | Majlis Daerah Hulu Selangor                   |
|              |             |                   |              |                  |                                               |
| Sungai Sabai | Selangor    | Beletak River     | 2000-present |                  |                                               |
|              |             |                   |              |                  |                                               |
| Ulu Yam Bharu | Selangor   | Liam River        | 1997-April 2007 | Non-sanitary     | Majlis Daerah Hulu Selangor                   |
|              |             |                   |              | Closed           |                                               |

2. Materials and Method

2.1. Description of the study area
The study was carried out at Sembilang River near Jeram Town, Kuala Selangor, Malaysia. The main usage of land along the Sembilang River is for palm oil plantation and heading downstream there are industrial areas such as plastic factory and timber factory. 20 km to the north there is Pantai Remis which is a popular tourist attraction especially seafood. Sembilang River has also received attention
When the prime minister has allocated RM3.8 million to rebranded fishing activity centre to serve the local fisherman. Another land usage near to Sembilang River is for Jeram Sanitary Landfill which is located at Lot No. 1595, 2598, 2959 with approximate area of 160 acres. Jeram Sanitary Landfill is operating under Worldwide Landfills Sdn. Bhd. since 1st of January 2007. This landfill has received 2,100 tonnes of waste per day with dominating waste type are domestic (95%), bulky waste and garden waste.

Figure 1. Study area: Sembilang River

2.2. Data collection
Figure 1 shows the sampling station of Sembilang River water quality. 2 stations were located upstream of Sembilang River and before the Jeram Sanitary Landfill. 8 other sampling stations were located downstream of Sembilang River and located at landfill effluent discharge, palm oil plantation, industrial zone and near to Pantai Remis on a monthly basis from September 2015 to September 2016 (Table 2). Water samples were then frozen to keep the temperature at 4°C for transportation for further analysis in laboratory. 11 water quality variables were selected for the quality assessment; temperature, pH, turbidity, salinity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS), ammonia nitrogen, phosphate and nitrate. Standard Methods of Water and Wastewater (APHA 2005) were followed for water samples collection and water samples analysis.

2.3. Data analysis
To obtain the results, Water Quality Index (WQI) were used by entering the average of six water quality parameters including DO, BOD, COD, pH, ammonia (NH₃-N) and total suspended solid (TSS) into the WQI formula (DOE):
WQI = [0.22*SIDO] + [0.19*SIBOD] + [0.16*SICOD] + [0.15*SIAN] + [0.16*SISS] + [0.12*SIpH]

where:
SIDO = Subindex DO
SIBOD = SubIndex BOD
SICOD = SubIndex COD
SIAN = SubIndex NH3-N
SISS = SubIndex SS
SIpH = Subindex pH

### Table 2. Sampling points along the Sembilang River

| Location Point | Status     | Coordinate       | Remarks                           |
|----------------|------------|------------------|-----------------------------------|
| J01            | Upstream   | Latitude (Deg.)  | Longitude (Deg.)                  |
|                |            | 3.196            | 101.373                           |
| J02            | Upstream   | 3.194            | 101.370                           |
| J03            | Upstream   | 3.194            | 101.367                           |
| J04            | Upstream   | 3.194            | 101.360                           |
| J05            | Downstream | 3.194            | 101.353                           |
| J06            | Downstream | 3.195            | 101.330                           |
| J07            | Downstream | 3.195            | 101.326                           |
| J08            | Downstream | 3.195            | 101.320                           |
| J09            | Downstream | 3.195            | 101.315                           |
| J10            | Downstream | 3.195            | 101.311                           |

### 3. Results and discussion
The acidity and alkalinity of water can be measured by pH parameters, which is simple but important where most chemical processes in aquatic environments are controlled by any change in its value [11]. All the water samples at Sembilang River showed slightly acidic pH with pH values varied from 3.98 to 6.45. pH value is less than 5 at upstream stations (J01 and J02) for all samples indicating the
Figure 2. Average value of water quality measurement along the Sembilang River

Acidic conditions is under Class III of DOE Water Quality Index Classification. This shows that the pH level was influenced by the leachate, where after point J01 and J02 the pH values increased to 6.45 at station J10. The mean pH value for Sembilang River was found to be 5.34 (Figure 2). Past studies had equally revealed the acidic nature of Sembilang River due to oxidation of pyrite (FeS$_2$) from the river soil which is common characteristic reported for acidic sulfate soil and could increase the
mobility of heavy metals from young leachate. The higher reading of pH at the downstream of Sembilang River was caused by the palm oil plantation near the landfill where NPK fertilizer was used [12].

The temperature has a major role in dissolution and precipitation reactions and is major factor in determining water chemistry as well as biological conditions. These can be caused from various environmental processes: natural and anthropogenic [13, 14]. Global climate change, regional land-use, heated effluents from power generation plants, river flow, depth of water, cloud cover and solar radiation are those that can affect the river temperature. Temperature is important parameter for water quality, for example, most chemical and biological activity is a function of temperature because it may affect the river in so many ways such as the geographical distribution, growth rate and reproduction of aquatic life and this is dependent on both natural and anthropogenic energy exchange process [15]. Surface water is usually within the temperature range of 0 °C to 30 °C. For Sembilang River, the surface water temperature varied between 29.56 to 33.62 °C. The mean value of temperature measured along the river of Sembilang River was 31.69 °C (Figure 2). Moreover, most of the time during the ten sampling dates the weather was sunny and dry. These conditions affect the temperature the most.

Natural processes such as weathering rocks and rain takes place where there is ample opportunity for the mineral crystals that constitute rock to oxidize. However, all natural waters contain salts. High level of salts not only affects the ecological health of rivers and estuaries, but also the drinking water and irrigation with serious economic, social and environmental consequences for both rural and urban communities [16]. For Sembilang River, the salinity level is between 160 ppm from the upstream and 646 ppm at the downstream near the Pantai Remis. The mean value for salinity for Sembilang River was found to be 418 ppm (Figure 2). Turbidity plays a relevant role in controlling the penetration of light into the water column where it is one of the water quality parameters that can shape the physical landscape and regulating ecological systems. Turbidity can be caused from suspended particles, either organic or inorganic and dissolved organic matter in coastal and estuarine areas. High level of turbidity can influence underwater light transmission and therefore altering the productivity and the living conditions of aquatic, animal and vegetation. From ten number of sampling at Sembilang River we found that the turbidity level is between 6.92 NTU and 84.70 NTU. The highest turbidity level was found at J07DS where the river is of grass water. The mean value for turbidity of Sembilang River is 37.99 NTU (Figure 2).

TSS is one of the most commonly used indicators of surface water quality problems. This is because TSS has a direct (physical, biological and ecological) and indirect (toxicology) impact on aquatic ecosystems. Thus, TSS is considered a good proxy for current water conditions and is useful to assess the risk of water quality hazard. The TSS level of Sembilang River for station J01US and J02US exhibits <25mg/l indicating the category of Class-I. After the landfill, when effluent is mixed with the river water, suspended solid increases gradually and are found to be higher at station J03DS, J05DS and J11DS. The value is fluctuating at downstream of Sembilang River and most of the value are of Class I-II. Past studies also show a strong correlation between TSS and turbidity. This coloration is also found in water sample at station J09 where both results for turbidity and TSS were high. Location of sampling station can be the factor for high result for TSS at J09 where it is located at the highway culvert, at which the river is mostly filled with garbage and there is no water stagnation. The mean value for TSS of Sembilang River is 25.61 mg/l (Figure 2).

Dissolved oxygen (DO) is frequently used to evaluate the water quality as the effect of industrial and municipal effluents as well as indicators of the environmental quality of watersheds. By the combination of physical, chemical and biological characteristics of the streams, the oxygen demand substances including algal biomass dissolved organic matter, ammonia, volatile suspended solids and sediment oxygen demand [17, 18]. Sembilang River recorded the level of DO in range of 3.27 mg/l to 4.77 mg/l (Figure 2). The average levels of DO were 3.98 mg/l where at sampling station J09DS the value is slightly low with 3.27 mg/l, which may be affected by the effluent from the landfill and the land usage around that area which is near to the industrial zone. Excessive algae growth exists at station J01US for the third and fourth sampling (Figure 2).
5-day BOD (BOD₅) is the most widely used parameter of organic pollution applied to both wastewater and surface water. BOD involves the measurement of the dissolved oxygen (DO) used by microorganisms in the biological oxidation of organic matter. BOD test is used to determine the quantity of oxygen that is required to biologically stabilize the organic matter present. The level of BOD at station J01US (0.43 mg/l) and J02US (2.27 mg/l) show the lower concentration of BOD compared to other stations (Figure 2). As the landfill effluent is disposed at station J03DS, the BOD value exhibits higher value, which is 22.46 mg/l. From station J04DS to J10DS, it shows that the range of BOD value is between 3.72 mg/l and 6.00 mg/l (Figure 2). The mean value of BOD for Sembilang River is 6.20 and it is classified in Class III of DOE Water Quality Index Classification. COD represents the organic pollution level in water, and it is therefore one of the most commonly utilized parameters for monitoring water quality. It is defined as a number of oxygen equivalence consumed in the oxidation of organic compounds using strong oxidizing agents. The landfill effluent is disposed at station J03DS and the COD value is higher among other sampling points with 135.64 mg/l. The COD value ranges from 28.29 mg/l to 135.64 mg/l. For station J05DS to J11DS, most of the value are greater than 60 mg/l due to higher rate of oxygen consumption from water which is represented the Class IV, indicating unsuitability for any purposes. These phenomena may be the consequences resulted from the organic and inorganic suspended materials runoff from agricultural lands, in this case, is palm oil plantation where, in past studies there is a direct correlation of COD and agricultural discharges [19]. The mean value of COD for Sembilang River is 73.98 mg/l (Figure 2).

The microbial degradation of nitrogenous organic material is one of the most important sources for producing NH₃-N in a river. These compounds are transferred into the environment through different sources including byproduct of sewage decomposition. The aqueous ammonia concentration above 0.2 mg/l may be hazardous to many aquatic organisms [20]. Before the landfill, the level of NH₃-N at two stations J01US and J02US show low concentration and the values range from 2.01 to 4.42 mg/l. Whereas after the landfill, all stations show higher value (>2.7 mg/l) which is in ranges of 6.48 to 11.01 mg/l. This is indicate that the river pollute by ammonia from the fertilizers which is from the palm oil plantation at stations located downstream of the river. The concentration greater than 2.7 mg/l, indicates Class-V categorization. The mean value of NH₃-N for Sembilang River is 7.94 mg/l (Figure 2). Phosphorus (P) and nitrogen (N) are the primary nutrients that in excessive amounts pollute the lakes, streams and wetlands. Phosphate and Nitrate are compound containing nitrogen and phosphorus at elevated levels, can have harmful effects on humans and animals. Nitrates in water can cause severe illness in infants and domestic animals. In inorganic form, phosphate is preferred for plant growth but other forms can be used when phosphate is unavailable. Excess nitrate in water can cause the low concentration of DO [21]. Station J08 recorded the highest level of phosphate that is 10.33 mg/l. The range of phosphate for all 10 stations is between 0.15 to 10.33 mg/l. While for nitrate, the values fluctuated from station to station. The range is between 8.66 to 99.36 mg/l. The increase of NO₃ and PO₄ will also increase BOD and COD where the result for all the parameters shows the same results for all sampling stations. The mean value for both phosphate and nitrate are 2.65 mg/l and 46.45 mg/l (Figure 2).

3.1. Water Quality Index

Water quality index (WQI) combines the measures of several water quality variables in such way as to produce a single score that is representative of quality impairments or suitability of use. Overall WQI for Sembilang River was calculated by averaging WQI from all sampling dates in each station. On the basis of six parameters such as DO, pH, COD, BOD, NH₃-N and suspended solid the WQI value ranges from 68.03 to 43.46 mg/L. Most of the value of the data set is classified under Class III. From pollution index, it reveals that most of the stations show that water quality parameters level in station J03 is more polluted as compared to other stations (Figure 3). Discharged effluent from the landfill was the point source of water pollution and have higher pollution rate.
Figure 3. Average value of water quality of Sembilang River based on DOE Water Quality Index classification

4. Conclusion
Systematic study conducted to determine the impact of municipal solid waste disposal at Jeram Sanitary Landfill has revealed that Sembilang River is being contaminated by the effluent from the landfill. The data indicates the landfill as the point source for all the contaminants because the concentration of pollutants increases radically from upstream to downstream. As can be seen from the result, the WQI for Sembilang River was categorized under Class III of Malaysian Water Quality Standards, indicating the water is not suitable to be used as water supply and in need of extensive treatment. The results show that the effluent discharge from the landfill was lower as compared to raw leachate but still exceeded the standard, as can be seen in Sembilang River water quality. Thus, in general, the overall observation made in this study is that Sembilang River quality is affected by landfill operation.

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