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THE QUANTIFICATION OF URBAN LITTER LOAD AT GROSS POLLUTANT TRAP ALONG SUNGAI BATU, SELANGOR

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Abstract

The massive amount of urban litter in Malaysia is influenced by rapid population growth, development, economic growth and unsustainable lifestyles. Few studies have assessed the amount of urban litter load and its composition at gross pollutant trap (GPT), significantly contributing to lack of historical data. This study is aimed to assess the amount of urban litter load in wet basis condition at individual GPTs along Sungai Batu, Selangor in 2015. The urban litter collection data at each GPT in 2015 were sourced from Department of Irrigation and Drainage (DID). Samples were manually collected once a month, stored in plastic bag and immediately weighed and recorded by following the ASCE standard method. The result shows that the total amount of urban litter load in 2015 was 3761.72 kg/year (Mean ± SD; 313.4767 ± 141.9105 kg/year). In such situations, further study on urban litter load and its composition trapped at GPTs is urgently required as it is crucial to establish baseline data information during the decision making process, holistically improving stormwater management and urban litter management in Malaysia.

***Keywords*: Downstream defender; drainage; gross pollutant traps; quantification; urban litter**

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INTRODUCTION

Urban litter is commonly known as the trash, debris, flotsam, jetsam, floatables, gross pollutants, rubbish or solid waste (Armitage, 2007). The technical definition of urban litter is a visible solid waste arising from urban environment (Armitage, Rooseboom, Nel, & Townshend, 1998). In fact, the rising levels of urban litter composition and quantity load are the most challenging environmental issues to be addressed due to the various factors such as the growth of the human population, type of development, anthropogenic activities through littering; excessive of packaging; inefficient service of street sweeping; lack of disposal facilities and lack of enforcement from authorities (Hall, 1996). The high population and the areas with high levels of commercial activity produced massive amount of urban litter in terms of quantity (Purcell & Magette, 2009). The abundance of urban litter derived from residential and commercial areas have a high tendency to be visible at the drainage and river that might be due to lack number of disposal bins or individual behaviour in managing the waste. Ab Ghani et al. (2011) stated that the rising urban population and developed areas also can influence hydrological processes through stormwater runoff and characteristics of peak flow. Impervious surfaces increase due to rapid development in urban areas, which subsequently can generate more surface runoff which conveys urban litter into receiving water bodies such as rivers.

Furthermore, the rising urban litter composition and quantity load at GPT is also derived from the characteristics of catchment, management practices including law enforcement and services, the efficiency and effectiveness of litter removal by local authority (Marais, Armitage, & Pithey, 2001); environmental awareness among the communities (Sidek, Basri, Lee, & Foo, 2016); types of land use (Lariyah, Norazli, Nasir, Hidayah, & Zuleika, 2011); and climate conditions and rainfall patterns (Mohd Shah et al., 2016; Alam, Anwar, Sarker, Heitz, & Rothleitner, 2017). Therefore, in such a situation, the factors described above contribute to the various types of litter composition in the stormwater system, which encompasses plastic, paper, metal, glass, metal, vegetation, sediment and others (Marais et al., 2001) illegally dumped nearby or directly into the drainage system through the littering activities or transported by wind or surface runoff.

GPT IN STORMWATER MANAGEMENT PRACTICES IN MALAYSIA

There are several types of GPTs available for urban stormwater management and treatment applications in Malaysia, such as Type 1 (floating debris trap; trash racks and litter control devices); Type 2 (sediment basin and trash rack (SBTR) traps); and Type 3 (oil and grease interceptor) (Jabatan Pengairan dan Saliran, 2012).

In this study, the Department of Irrigation and Drainage (DID) has introduced the GPTs with a downstream defender as a hydrodynamic deflective separation device (Fitzgerald & Bird, 2011) with hydrodynamic vortex separator system for stormwater treatment applications (Faram, Lecornu, & Andoh, 2000) to trap litter at the drainage conveyance along Sungai Batu, Selangor. The mechanism of this device can be described as diverting the incoming flow and associated pollutants away from the main flow stream of the pipe or waterway into a pollutant separation and containment chamber. Generally, GPTs are vital in stormwater management practices where GPTs act as devices to control water quality by trapping and removing gross pollutants which commonly greater than five millimetres (>5mm) such as urban litter washed into stormwater system and reduce the effect of pollutants loads from entering the receiving water bodies (Madhani & Brown, 2015). However, Alam et al. (2017) stated that the periodic cleaning process of GPTs is challenging and ineffective for removal of pollutants less than 5 millimetres (<5mm). The estimation performance of GPTs efficiency to remove the urban litter is about 10% to 30% (Fletcher, Duncan, Poelsma, & Lloyd, 2004). High proportions of pollutants including gross pollutants, sediments, and nutrients will be transported from the contributing catchment area to the receiving water bodies during the higher runoff volume.

In such situations, the size of catchment, pollutant load, type of drainage system and cost are the main factors in operating the gross pollutant devices (Sidek et al., 2016) prior to installation of GPT at the selected site. The installation and maintenance costs, and costs of gross pollutant disposal can also affect the efficiency of GPTs indirectly through the budget and capacity of the management, as the conditions of gross pollutant vary during the different season in terms of load and its composition. Generally, a trap with a dry load condition is easier to operate and deliver to the landfill as compared to traps with wet load, which are more expensive to operate due to difficulty in the cleaning process (Fitzgerald & Bird, 2011).

There are limited studies in assessing the amount of urban litter load and its composition at GPTs, and this significantly contributes to the lack of historical data. Thus, this study is aimed to assess the amount (quantity) of urban litter load on a wet basis condition at individual GPTs along Sungai Batu, Selangor in 2015. The types of urban litter composition data were not tested and analysed in this study. Further investigation on urban litter composition trapped at GPTs is strongly required as it is crucial to providing baseline data and information for stakeholder agencies. These data are one of the main environmental indicators for improving the GPT performance and maintenance, which subsequently gives informative input during the decision-making process and make a better improvement in stormwater management practices.

RESEARCH METHODOLOGY

Study Area

The total area of Sungai Batu catchment is about 103.50 km^2 and covers a small part of south area in Selangor State (upstream) to Federal Territory of Kuala Lumpur (downstream) before entering Sungai Klang. The Sungai Batu catchment in Selangor was selected as a study area due to the dense population and developing areas, including both residential and industrial areas. The DID has installed 18 GPTs (K1 to K18) with downstream defenders at upstream area of Sungai Batu (Figure 1) in order to trap the urban litter in drainage, subsequently minimises the amount of urban litter from being transported into water bodies.

Selection of installation sites was based on several factors such as topography, soil and geology, groundwater, space availability and road accessibility. Other social factors, such as odour, health and safety, visual/aesthetics and vermin, were also considered as the GPT sites are usually in close proximity to residential area.

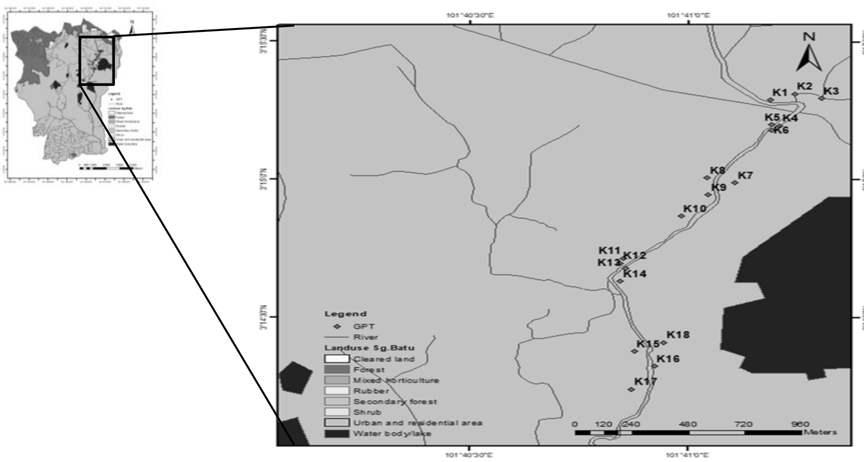

Figure 1 The location of GPTs along Sungai Batu, Selangor

Field Sampling and Data Collection

The downstream defender (Figure 2) components and functions can be described in terms of general operation of this unit. The tangential inlet pipe will receive water and enter the treatment chamber which subsequently induces a rotating fluid field. As the water initially flows around the outer annular space between the dip plate cylinder and manhole wall, the floatable contaminant and oil will accumulate on the water surface at the outer annular space. The sediment will be deposited in the bottom centre of the unit, known as isolated sediment storage zone, as the water continues to flow downward. Then, the water exits the unit by passing under the dip plate and moving upward through the inner annular space and subsequently to the outlet pipe. The function of the centre cone is to direct flow into the inner annular space and protect the accumulated sediment from being incorporated and swept along in its flow.

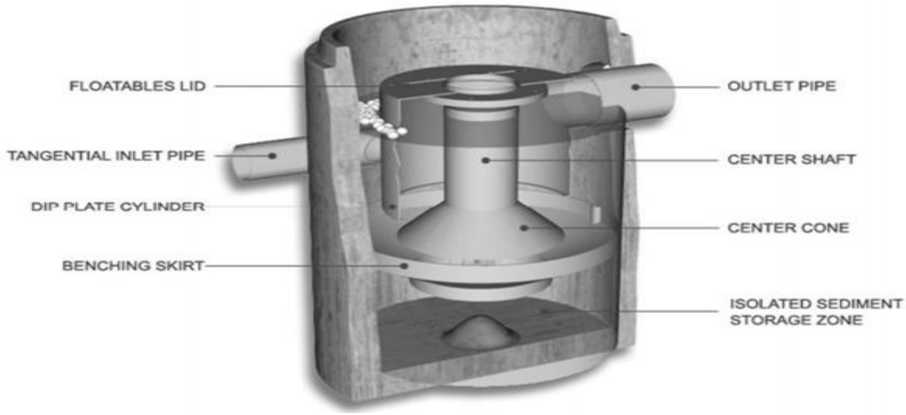

Figure 2 The illustration of downstream defender components
Source: Osei, Faram, & Iwugo (2007)

In this study, the amount of urban litter collection data at each GPT along Sungai Batu in 2015 was sourced from DID and used in the analysis. Field sampling was performed once in a month during cleaning operation at each GPT along Sungai Batu. However, there is no recorded data on the amount of urban litter collection in February due to the absence of cleaning operation during that month. As litter was left some days with monthly interval in an area until the day of cleaning operation, field sampling for urban litter collections at GPT under wet basis conditions was performed accordingly to American Society of Civil Engineers guidelines under the litter section for Wet Best Management Practices (BMPs) (ASCE, 2007). In order to obtain the precise weight of litter in wet basis condition at each GPT, litter was manually collected using nets to filter the excess water content prior to storage in plastic bags. Each bag was immediately weighed and recorded (Alam et al., 2017).

Statistical Data Analysis

Descriptive statistical analysis has been performed in this study in order to obtain and describe the urban litter load trapped at GPTs along Sungai Batu. Since the sample size was only 18, the Shapiro-Wilk test was used in this study for normal distribution test, as it is generally sensitive and recommended by Ghasemi and Zahediasl (2012) for a sample size of less than 50. However, the small sample size of data applied in this study was not strong enough to be used in parametric statistical analysis. Therefore, as a decision for normality test, the null hypothesis was rejected as the data was not normally distributed. The Kruskal-Wallis test was applied in this study in order to test the significance differences in total urban litter load between individual GPT along Sungai Batu and months in 2015.

RESULTS AND DISCUSSION

Quantification of Urban Litter Load Trapped at Individual GPT

Based on Table 1 and Figure 3, the results show that the urban litter collection in August contributed to the highest amount of urban litter load with 510.00 kg/month (Mean ± SD; 28.3333 ± 18.9426 kg/month), followed May with 435.00 kg/month (Mean ± SD; 24.1667 ± 14.9755 kg/month). Meanwhile, urban litter collection in March was the lowest with 121.00 kg/month (Mean ± SD; 6.7222 ± 11.9029 kg/month). There is no recorded data on the amount of urban litter load in February due to the absence of cleaning operations during the month. The amount of urban litter load trapped at GPTs generally derived from several factors including the growth of human population; type of development; characteristics of the catchment area; management practices including law enforcement and services; environmental awareness among the communities (Sidek et al., 2016); types of land use (Lariyah et al., 2011); and climate conditions and rainfall patterns (Mohd Shah et al., 2016; Alam et al., 2017).

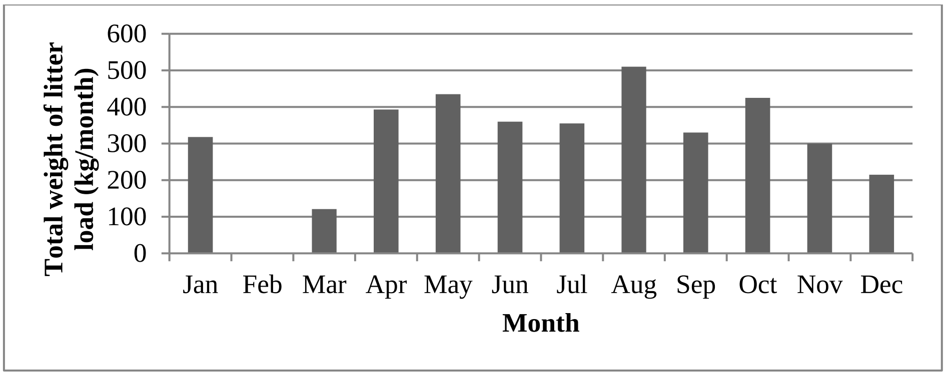

Figure 3 Total litter weight trapped at 18 GPTs along Sungai Batu in Year 2015

Table 1 Descriptive statistics for total urban litter weight (by month) in 2015 for 18 GPTs along Sungai Batu

Month	Min	Max	Sum	Mean ± SD	Skewness	Kurtosis
Jan	0.00	88.66	317.72	17.6511 ± 31.3192	1.6467	1.2779
*Feb	0.00	0.00	0.00	0.0000 ± 0.0000	N/A	N/A
Mar	0.00	37.48	121.00	6.7222 ± 11.9029	1.9665	2.8610
Apr	3.00	85.00	393.00	21.8333 ± 17.8696	2.7934	9.6823
May	5.00	55.00	435.00	24.1667 ± 14.9755	1.0525	0.1796

June	0.00	50.00	360.00	20.0000 ± 12.7187	0.6272	0.6919
July	0.00	45.00	355.00	19.7222 ± 11.3075	1.0384	1.5589
Aug	15.00	95.00	510.00	28.3333 ± 18.9426	2.8389	9.4201
Sept	5.00	30.00	330.00	18.3333 ± 7.0711	-0.4523	-0.3574
Oct	10.00	60.00	425.00	23.6111 ± 11.9811	1.5234	4.0701
Nov	10.00	40.00	300.00	16.6667 ± 7.0711	2.6984	7.5221
Dec	5.00	20.00	215.00	11.9444 ± 3.8877	0.8377	0.5168

Note: *There is no recorded data on the amount of urban litter collection in February due to the lack of cleaning operations during that month

Comparison by Month: Total Urban Litter Load at GPT along Sungai Batu

The Shapiro-Wilk test was applied in this study. The results show that the statistic value for the total urban litter load come as 0.821 corresponds to p-value = 0.000. Since the p-value is 0.000 < 0.05, as a decision for normality test, the null hypothesis was rejected as the data was not normally distributed. The Kruskal-Wallis test was applied in this study in order to test the significance differences in total urban litter load between months in Year 2015. The result revealed a statistically significant difference in total urban litter load between each month at 18 GPT along Sungai Batu, χ^2 (11) = 85.516, p = 0.000. The total urban litter load in May 2015 recorded a highest mean rank at 158.03, corresponding to the highest total weight of urban litter load (Table 2).

The total urban litter load is significantly influenced by the seasonal variation through the rainfall pattern throughout the year. Alam et al. (2017) have proved in their study where the urban litter load during wet season was significantly higher as compared during the dry season due to factors of rainfall-runoff in carrying these pollutant loads through a large volume of stormwater that could convey the gross pollutant into water bodies. Allison, Chiew and McMahon (1997) found that most of the load was conveyed during high flow condition. The types of gross pollutant composition which are able to be captured within a catchment also can be influenced through rainfall and runoff pattern, rate of infiltration, and stormwater system connectivity (Fitzgerald & Bird, 2011).

Lun, Gasim, Toriman, Rahim and Kamaruddin (2011) described the high distribution of rainfalls significantly increased the water level, which caused the higher volume of discharge. Ab Ghani et al. (2011) stated that the floatable gross pollutants are easily transported into the downstream during high flow conditions, as this process is significantly influenced by the efficiency of GPTs. The efficiency of trapping at GPTs can be less effective during the high flow condition and high water depths. Hydrological parameters such as rainfall intensity, depth and discharge were very important indicator to ensure the efficiency of GPTs (Ab. Ghani et al., 2011).

Table 2 Kruskal-Wallis test of monthly urban litter load at 18 GPT along Sungai Batu

Month	Mean Rank	df	χ^2	p – value
Jan	73.11			
Feb	19.00			
Mar	62.94			
Apr	127.56			
May	139.39	11	85.516	0.000
June	126.56			
July	127.17			
Aug	158.03			
Sept	128.83			
Oct	144.78			
Nov	111.31			
Dec	83.33			

Comparison by GPT: Total Urban Litter Load at GPT along Sungai Batu

The result derived from Kruskal-Wallis test revealed a statistically significant difference in total urban litter load among individual GPTs along Sungai Batu, χ^2 (17) = 34.255, p = 0.008. The total urban litter load in K2 recorded a highest mean rank with 163.25 than the other GPTs which correspond to the highest total weight of urban litter load (Table 3).

Table 3 Kruskal-Wallis test of urban litter load at individual GPT along Sungai Batu

GPT	Mean Rank	df	χ^2	p – value
K1	69.46			
K2	163.25			
K3	102.33			
K4	85.92			
K5	106.92			
K6	85.88			
K7	111.29			
K8	132.79	17	34.255	0.008
K9	104.58			
K10	83.79			
K11	88.58			
K12	117.92			
K13	92.88			
K14	114.63			
K15	138.75			
K16	113.50			
K17	152.79			
K18	87.75			

The urban litter weight trapped at GPT varied and influenced by the types of urban litter composition which mainly derived from land-based sources. The types of urban litter composition data were not analysed in this study, as there is a lack of historical data on urban litter composition which can be used as baseline data information. However, previous studies conducted by Sidek et al. (2016) and

Alam et al. (2017) on types of urban litter composition found at GPTs in different regions in Klang River catchment and Gosnells Western, Australia, respectively, show that both plastics and vegetation such as leaves are the most commonly found in GPTs during the cleaning operation. The amount of urban litter generation and its composition are fundamental information strongly required for urban litter management systems in terms of planning, operation and optimization (Beigl, Lebersorger, & Salhofer, 2008). The characteristics of litter differ with time and are exaggerated by socio-economic conditions (Buenrostro, Bocco, & Vence, 2001; Gómez, Meneses, Ballinas, & Castells, 2009). In addition to the structural method applied in this study to filter the gross pollutants, including urban litter, from flowing into water bodies, environmental education programs, cleaning operations and law enforcement play crucial roles in mitigating the urban litter management issue, which indirectly affects the stormwater quality.

CONCLUSION

This paper has demonstrated the quantification of urban litter load trapped at 18 GPTs along Sungai Batu, Selangor in 2015. The growing issue of urban litter in drainage systems is mainly influenced by the growth of the human population, lack of environmental awareness in waste disposal, littering, law enforcement and policy, type of development, land use changes, and rainfall patterns. The result shows that the total amount of urban litter load in 2015 was 3761.7200 kg/year (Mean ± SD; 313.4767 ± 141.9105 kg/year). DID has installed GPTs with downstream defender at selected sites along Sungai Batu which are functioning as hydrodynamic vortex separator systems for stormwater treatment to trap litter at drainage conveyances before it enters the main river. A significance difference in total urban litter load between individual GPT along Sungai Batu obtained in this study were mainly influenced by various type of urban litter composition derived from land based sources including the human activities; consumption and production; and types of development. The different types of development and land use will generate different urban litter compositions. However, the urban litter composition at individual GPT was not evaluated in this study due to unavailability of baseline data. Moreover, a significant difference in total urban litter load for each month at 18 GPTs along Sungai Batu also were mainly influenced by seasonal condition through rainfall pattern throughout the year, as the efficiency of trapping at GPTs can be less effective during the extreme storm event and high flow conditions, and tend to be more effective during low-flow conditions.

Due to the high amount of urban litter load in year 2015, this study suggests that environmental education program encompasses the field of knowledge, attitude and practices (KAP) is highly required as it can be a medium to improve and enhance public awareness on how to dispose the urban litter in proper way. Besides, urban litter compositions at GPTs also need to be studied as this information is crucial for GPT efficiency in trapping urban litter and other pollutants. This information will serve as baseline data for knowledge contribution and informative input during the decision-making process, subsequently improving stormwater management and urban litter management in a comprehensive way.

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