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Gross Pollutants Study in Urban Areas under Tropical Climates

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Abstract: Gross pollutants are the primary targeted pollutants in urban catchment management for urban water quality improvement as well as mitigation of flood. Apart from aesthetically unattractive because of its visibility, gross pollutants also contributes to degradation of river water quality and loss of aquatic habitat as it carries harmful pollutants such as oxygen demanding material, hydrocarbons and heavy metals. This study analyzed trend of gross pollutant generated from two urban residential areas located in Selangor, Malaysia. The median value of gross pollutant load obtained from the Amanah Apartment and Bandar Botanic are 347.41 kg/ha/year and 32.46 kg/ha/year, respectively. Relationship between gross pollutant wet load with rainfall depths was derived using regression equation. A significant trend of increasing gross pollutant wet load into drainage system with increasing rainfall depth was observed. The behavior of pollutant load is related to the one observed in Australia.

Key words: Gross pollutant load, urban stormwater quality, urban stormwater management.

1. Introduction

Gross pollutants are the primary targeted pollutants in urban catchment management for water quality improvement. Various definitions of gross pollutants have been made in many previous studies around the world. It is important to understand the definition of gross pollutants in order to propose suitable treatment facilities to treat gross pollutants in urban waterways. Allison et al. [1] defines gross pollutants as large piece of debris flushed through urban catchments and stormwater system. Further definition has been made by Rushton et al. [2], where gross solids are defined as litter, trash, leaves and coarse sediments either as floating debris or as bed loads in urban runoff conveyance system. Study by Allison et al. [3] and Sullivan [4] found out that gross pollutants in urban waterways as material that are captured by 5 mm mesh debris larger than 5 mm. The size of 5 mm is consistent with previous study by Essery [5] that used 5 mm aperture size of sampler to measure gross pollutants.

Gross pollutants in urban waterways have adverse impact towards water quality and environment. Gross pollutants in urban waterways also reflect the unhygienic behavior of local community. Litter can be unsightly, environmentally damaging and impede hydraulic performance of urban drainage system by causing blockages [6]. Furthermore, accumulated litter not only aesthetically unattractive, it also increased the possibilities in spreading disease [7].

Increasing concerns about degradation of river water quality caused by uncontrolled gross pollutants in urban waterways has resulted in implementation of gross pollutant management strategies as an approach

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to reduce gross pollutants from entering stormwater drainage system [8]. Gross pollutant management strategies integrate both non-structural and structural measures as an approach to reduce the amount of gross pollutant transported in waterways. Non-structural BMPs (best management practices), which may be used independently or in conjunction with structural BMPs, rely on a much wider breadth of mechanisms to reduce the amount of gross pollutants transported into the drainage system. Therefore, this study focus on the analysis of gross pollutants captured in the structural devices known as GPTs (gross pollutant traps) which will able to give direct quantitative result that can contribute to local data and increase understanding on the amount, types and trend of gross pollutants transportation under Malaysian condition .

Structural measures are constructed in-transit treatments that separate and contain pollutants. Installation of trapping devices to trap and contain gross pollutant is a structural method to address gross pollutants problem in urban waterways. This structural measure or urban stormwater management is based on the concept of "control-at-source" with the objective to control stormwater quantity and quality [9]. The DID (Department of Irrigation and Drainage) Malaysia has introduced a new MSMA (Urban Stormwater Management Manual) that addresses the methods to control gross pollutants (in Chapter 34) using GPTs located at the downstream end of drains or engineered waterways [10]. Selection of suitable devices depends on many factors including catchment size, pollutant load, type of drainage system and cost.

However, the performance of GPTs is not fully understood under the influence of tropical climate where high rainfall intensity in short duration prevails [9]. In order to get the best performance of GPTs in Malaysia, it is essential to study the gross pollutant characteristics generated from different type of land use. The study aims to improve existing knowledge about the source, type and amount of gross pollutant generated from different types of urban land uses. It will eventually assist in arriving at of the appropriate catchment management strategies as well as the design of suitable gross pollutant traps to remove the balance. However, this paper will discuss on load of gross pollutants and the trend of gross pollutants transportation during storm event in the study area.

2. Study Area

Two residential areas have been selected, i.e., Amanah Apartment in Universiti Tenaga Nasional (UNITEN) and Bandar Botanic in Klang Selangor. The annual average rainfall over these areas is about 2,285 mm [11].

2.1 Study Area 1—Amanah Apartment, UNITEN

Amanah Apartment, located in UNITEN Putrajaya Campus is a residential area mainly occupied by UNITEN students. In year 2004, two units of model P1015 of CDS (continuous deflective separator) were installed at Amanah Apartment in UNITEN. These two CDS units were built by Ecoclean Technology Sdn. Bhd. for UNITEN. Contribution of catchment area for each GPT is 1.8 hectares. Fig. 1 shows the location of CDS units installed in Amanah Apartment, UNITEN.

Fig. 1 Location for CDS 1 and CDS 2 at Amanah Apartment, UNITEN.

2.2 Study Area 2—Bandar Botanic, Klang

Bandar Botanic is the only lifestyle township in Klang which offers value added quality and unique lifestyle. Spanning a total of 505 hectares of freehold township, Bandar Botanic is a mixed development of quality designed bungalow homes, semi-Ds, super link homes, double storey terrace homes and apartments. Designed in two parcels-Parcel A and Parcel B, each has its own distinct characteristics and its own parkland environment, amenities and facilities for a complete lifestyle. There are a total of 18 units of CDS installed in Phase I of Bandar Botanic. Fig. 2 shows one of the CDS located in the Bandar Botanic Phase 1 residential area.

3. Gross Pollutant Monitoring

The monitoring process involved collection of gross pollutants during maintenance of gross pollutant traps at study locations. A detail analysis on gross pollutant classification of trapped gross pollutants will be done during the monitoring process. As gross pollutants cannot be sampled by automatic sampler, this study adopted the gross pollutant monitoring guideline developed by ASCE [12]. The only data that can be measured for gross pollutants are volume and mass. Since the cleaning method of all GPTs is by using crane, it is more convenient to get the mass of the gross pollutants instead of volume. Therefore, data

Fig. 2 Location of one CDS in Bandar Botanic Phase 1 residential area.

collected during the monitoring process for this study are wet load of gross pollutants. These collected gross pollutants are transferred to Civil Engineering Laboratory in UNITEN to be dried and classified into different types of gross pollutants.

The main categories have been selected based in research experience elsewhere. This study adopted the gross pollutant characterization based on previous study [13]. Dried gross pollutants are further classified into plastic, paper, metal, glass, vegetation, sediment and miscellaneous.

4. Analysis of Gross Pollutant Load

The collected data of litter characteristic in Amanah apartment was analyzed using the same method as suggested in ASCE Guideline for Monitoring Stormwater Gross Pollutant [2]. The wet load samples acquired from CDS 1 and CDS 2 are scattered onto impermeable membrane (large plastic) and dried under the hot sun. The dried pollutants were characterized into seven respective gross pollutant classifications. Gross pollutant load was measured in terms of weight per area per duration. The obtained result indicated the load of gross pollutants generated from the study areas. It is important to observe the load of gross pollutant in order to determine the required size of pollutant storage and also maintenance frequency (South Australia Department of Planning and Local Government, 2009). Therefore, the gross pollutant load obtained in this study area will be representative of the amount of gross pollutant generated from a typical residential area in Malaysia. Fig. 1 shows the gross pollutant wet load for CDS 1 and CDS 2 at Amanah Apartment, UNITEN.

The highest gross pollutant load was obtained during the first cleaning of the trapping devices. Referring to Fig. 3, CDS 1 captured more load compared to CDS 2 at most of the time. Although the catchment areas are similar, there are many factors that contributed to the pollutant load in the catchment. Marais et al. [14] and RBF Consulting [15] described

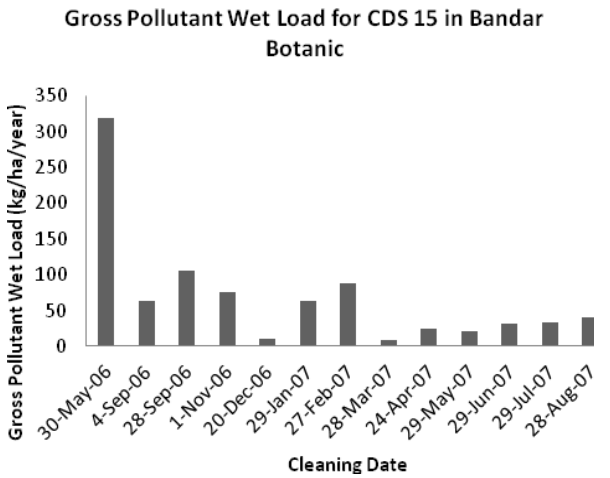

Fig. 3 The gross pollutant wet load for CDS 1 and CDS 2 at Amanah Apartment, UNITEN.

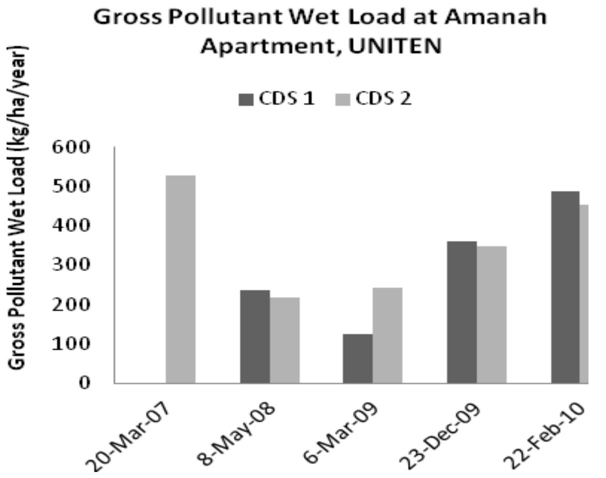

Fig. 4 The gross pollutant wet load obtained during maintenance of one unit of GPTs at Bandar Botanic.

that factor that contributed to the amount of gross pollutant is physical catchment characteristics. Therefore, size, slope, surface characteristics, type of vegetation and percentage of impervious area determine the amounts of pollutant load. In this case, CDS 1's catchment is covered with more impervious surface compared to CDS 2's. Therefore, sediments from road surface runoff are transported into the trapping device, resulting in higher loading of gross pollutants for CDS 1.

The same trend of gross pollutant load has been obtained in Bandar Botanic, where most of the highest gross pollutant load has been obtained during the first cleaning of the CDS unit. Fig. 4 shows the gross pollutant wet load obtained during maintenance of one unit of GPTs at study area. On average, the highest gross pollutant load was obtained from the first cleaning of the CDS. This may have resulted from accumulated rubbish in the drainage system before the installation of the CDS.

In summary, average gross pollutant load obtained from the Amanah Apartment, UNITEN and residential area in Bandar Botanic, Klang indicate the median value of gross pollutant load generated by both study areas. The median value obtained for Amanah Apartment is 347.41 kg/ha/year, while, Bandar Botanic median gross pollutant load is 32.46 kg/ha/year. The relatively different median value obtained from both study areas is due to the frequency of cleaning and quantity of samples obtained. Whereas, Amanah Apartment produces a higher pollutant load due to inconsistent gap compared to Bandar Botanic, which has a more consistent maintenance frequency. The results were compared with findings obtained in previous study by Allison et al. [3], Cornelius et al. [16], Armitage and Rooseboom [17]. The value obtained at Amanah Apartment seems to be higher compared to studies carried out. Other than higher amount of rainfall received in Malaysia, RBF Consulting [15] and Marais et al. [14] suggested that among other factors that contribute toward the volume of gross pollutants load include development density, population, management practice, community behavior and seasonal variation. Hence, the lower median value for Bandar Botanic compared to other countries is explained by the above factors. Table 1 shows the comparison of gross pollutants load obtained in this study and other studies from overseas. The results indicate the gross pollutant load (kg/ha/year) for Malaysia is higher than Australia

Table 1 Comparison of gross pollutant load.

Place	Gross pollutant load (kg/ha/year)
Malaysia	80.26
Australia	71.00
New Zealand	0.54
South Africa	96.00

and New Zealand but slightly lower than South Africa as these values were affected by the public behavior and culture.

5. Relationship of Gross Pollutant Load with Rainfall

Relationship of gross pollutant load with rainfall depth has been derived from CDS monitoring data. The relationship obtained can be used to estimate gross pollutant loads for typical residential areas in Malaysia. Results obtained for this relationship vary according to CDS unit.

5.1 Amanah Apartment, UNITEN

Relationship of gross pollutant load with cumulative rainfall depth for Amanah Apartment has been derived by using the gross pollutant load data from CDS cleaning and cumulative rainfall depth obtained from nearest rainfall station.

The highest gross pollutant load was obtained on May 8, 2008, with the value of 275,000 g/ha and 253,333.3 g/ha, respectively. The cumulative rainfall depth recorded on this date is 1,740.5 mm. Based on the obtained result, the relationship of average gross pollutant wet load with cumulative rainfall depth is derived by using the regression technique and shown in Fig. 5. The relationship shows that the average gross pollutants wet load behaves non-linearly against the cumulative rainfall depth for both CDS units.

5.2 Bandar Botanic, Klang

Analyses of the gross pollutant load captured in the CDS device installed at Bandar Botanic with cumulative rainfall depth have been carried out for 13 units of CDS. Analysis of results shows that average gross pollutant wet load for 13 CDS varies according to cumulative rainfall depth. Variation of gross pollutant load depends on accumulated litter during the dry seasons. During the wet season, pollutants are being transported into the drainage system. Therefore, if only small amounts of gross pollutants accumulate in catchment area, it is expected to have small gross pollutant loads during the rainy seasons despite the amount of rainfall. Allison et al. [11] stated that there is indication from data collected in Australia study showing rainfall are the best explanatory variables for estimating gross pollutant loads.

Although the gross pollutant wet load varies with rainfall depth, an estimation of gross pollutants loads is derived by fitting a non linear graph as shown in Fig. 6 for selected CDS in Bandar Botanic. A similar trend has been observed for the relationship of gross pollutant wet load with cumulative rainfall depth for CDS unit installed in Bandar Botanic, Klang. It can be seen from the figures that the amount of gross

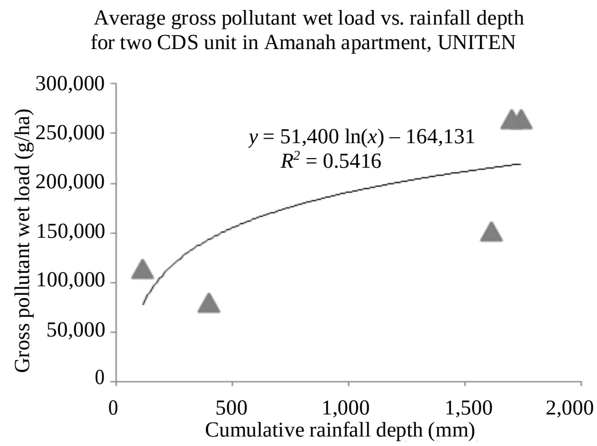

Fig. 5 Relationship of gross pollutant wet load with depth cumulative for CDS 1 in Amanah Apartment, UNITEN.

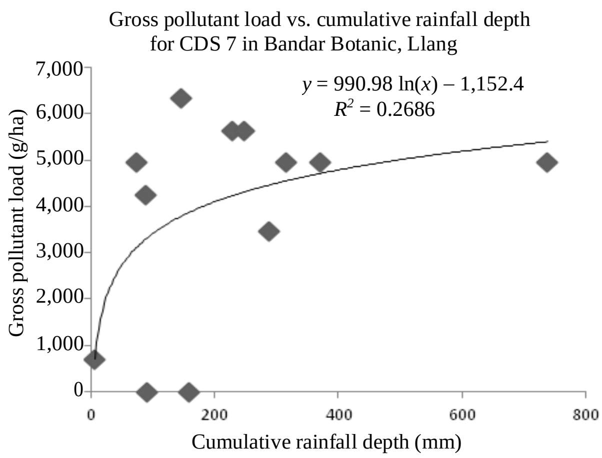

Fig. 6 Relationship of gross pollutant wet rainfall load with cumulative rainfall depth for CDS 7 in Bandar Botanic, Klang.

pollutant transported is also non-linear with the rainfall depth.

5.3 Comparison with Other Studies

The fitted relationship between the wet gross pollutant load generated and the depth of rainfall indicate that rainfall events of less that 6.5 mm may be considered to be insufficient for remobilization and transport of deposited street surface loads. The graph also indicates the limiting mechanism for stormwater gross pollutant transport, whereby, in majority cases, the stormwater runoff rates and velocities are influencing the mobilization and transport these pollutants rather than the supply of gross pollutants itself.

In summary, data analyses on gross pollutant load and rainfall depth for the two study areas indicate a correlation of gross pollutant wet load with cumulative rainfall depth. The relationship shows significant trend of increasing gross pollutant wet load to the stormwater conveyance system with increasing rainfall depth. Apart from that, the relationship also enables the interpretation that stormwater runoff rats and velocities are limiting mechanism for stormwater gross pollutant transport, rather that the contribution of gross pollutants itself.

Despite the understanding that rainfall runoff is the major factor that transports gross pollutants from street surface into drainage system, gross pollutant can also reach the drainage system during dry weather period by other factors such as wind or direct dumping [17]. Comparison has been made from data collected in this study with a study done in Coburg catchment in Melbourne by Allison et al. [3]. It can be seen the similar trend has been observed for the relationship of gross pollutants wet load with rainfall depth. The only difference is the rainfall amount in Malaysia is higher compared to the rainfall amount in Australia.

It is also observed that transportation of gross pollutant into drainage system is significant when

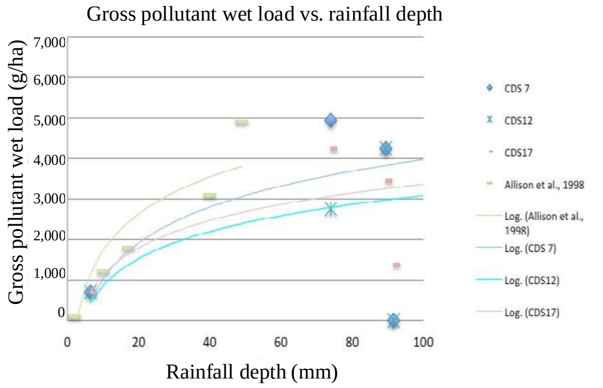

Fig. 7 Comparison of relationship between gross pollutant wet load with rainfall depth under Malaysia Condition and Australian Condition.

rainfall depth is 6.5 mm, compared to 3.7 mm for Australian condition. Fig. 7 summarizes the trend of gross pollutant load transportation with respect to rainfall depth for Malaysian and Australian conditions. Apart from that, street sweeping activities may contribute towards the reduction of gross pollutant load. Walker and Wong [18] expected that reduction of street sweeping efforts may increase the gross pollutant loads, initially for those events with high rainfall depth.

6. Conclusions

This paper focuses on the gross pollutant load emanated from residential area and its relationship with rainfall depth in two residential areas in Malaysia. This study provides analysis of gross pollutant load generated from urban residential area. Estimation on amount of gross pollutant load enables the determination of required size of pollutant storage and maintenance frequency. The value of gross pollutant load obtained is higher compared to the ones obtained in Australia, New Zealand and South Africa as shown in Table 1 [1, 3]. This is attributed to higher annual rainfall received in Malaysia compared to those countries. Other contributing factors such as development density, management practice employed, community behavior and seasonal event such as new year celebration may also affect the amount of gross pollutant transported in urban waterways.

Analysis of gross pollutant load with rainfall depth indicates non linear relation between gross pollutant wet load and cumulative rainfall depth. Significant trend of increasing gross pollutant wet load with rainfall depth was observed, in line with Australian study for similar relationship. The relationship obtained also shows that significant amounts of gross pollutant are being transported into the drainage system when rainfall depth is greater than 6.5 mm.

This research finding will be able to contribute as local data in term of gross pollutant loading emanated from two residential area. It is also can be considered as preliminary finding for estimation of gross pollutant load based on rainfall depth from the developed relationship as shown in Fig. 7. Finally, all the collected data will be incorporated to the development of decision support system that will assist engineers and local authority to choose the most suitable GPTs according to specific site characteristic. In the long term, it will support the aspiration on Malaysian Government to promote the green technology in Malaysia.

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