Gross Pollutants Analysis in Urban Residential Area for a Tropical Climate Country

Lariyah M.S.[1*], Mohd Nor M.D.[1], Norazli O.[1], Md. Nasir M.N.[2], Hidayah B.[1] and Zuleika Z.[1]

[1] *Centre for Stormwater and Geohazard Management, College of Engineering, Universiti Tenaga Nasional, KM 7, Jalan Ikram-Uniten, 43000 Kajang, Selangor, Malaysia*
[2] *Department of Irrigation and Drainage Malaysia, Jalan Sultan Salahuddin, 50626 Kuala Lumpur, Malaysia*
**Corresponding author, e-mail lariyah@uniten.edu.my*

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 pollutants wet load with rainfall depths was established. A non linear trend of increasing gross pollutant wet load into drainage system with cumulative rainfall depth was observed.

KEYWORDS
Gross pollutant load; urban stormwater quality; urban stormwater management

INTRODUCTION
Gross pollutants are the primary targeted pollutants in urban catchment management for water quality improvement. Various definition of gross pollutants has been mentioned in many literatures. In spite of that, it is important to understand the definition of gross pollutants in order to propose a suitable treatment facilities to treat them in urban waterways. Allison et al. (1997) defines gross pollutants as large piece of debris flushed through urban catchments and stormwater system. Further definition has been made by Rushton et al. (2007), 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. (1998a) and Sullivan (2005) found out that gross pollutants in urban waterways as material that are captured by 5mm mesh debris larger than 5mm. The size of 5mm is consistent with previous study by Essery (1994) that used 5mm aperture size of sampler to measure gross pollutants.

Gross pollutants in urban waterways have adverse impact toward 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 (Allison et al., 1998a). Furthermore, accumulated litter not only aesthetically unattractive, it also increased the possibilities in spreading disease (Mc Kay and Marshall, 1993).

Amount of gross pollutants generated from different type of land use may differ from one location with other location. It is important to understand the factors causing accumulation of gross pollutants in order to manage them effectively, especially in urban waterways. Marais et al. (2001) and RBF Consulting (2003) conclude various factors affecting gross pollutants deposition into waterways as listed in Table 1 below.

Table 1. Factors Affecting Amount of Gross Pollutant (Marais et al., 2001 and RBF Consulting, 2003).

Factors	Description
Type of Development	Generally commercial and industrial areas produce higher amount of gross pollutant
Population	Permanent of transient residences
Rainfall Pattern	Intensity, stormwater runoff
Management Practices	Enforcement of street sweeping, garbage collection service, law enforcement on littering
Community Profile and Behavior	Income level, environmental awareness
Seasonal Variation	Longer dry periods may accumulate more pollutants
Physical catchment characteristic	Size, slope, surface characteristic, type of vegetation
Drainage system	Size and geometry of inlet and pipe networks

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 to reduce gross pollutants from entering stormwater drainage system (Wong and Walker, 2002). Integration of both non-structural and structural measures is important to ensure the effectiveness of gross pollutant management.

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 (Lariyah et al., 2006). The Department of Irrigation and Drainage Malaysia (DID) (2001) has introduced a new Urban Stormwater Management Manual (MSMA) that addresses the methods to control gross pollutants (in Chapter 34) using GPTs located at the downstream end of drains or engineered waterways. 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 largely misunderstood especially in the tropical region where high rainfall intensity in short duration prevails (Lariyah et al., 2006). In order to get a better insight of GPTs in Malaysia, it is essential first to study the gross pollutant characteristics generated from different type of land use. Hence this study aims to improve existing knowledge about the source, type and amount of gross pollutants generated from different types of urban land use. It will eventually assist in arriving at of the appropriate catchment management strategies as well as the design of suitable gross pollutant traps to totally remove the remaining gross pollutants.

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 2285 mm (Desa and Daud, 1999).

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, 2 units of model P1015 of Continuous Deflective Separator (CDS) 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. Figure 1 shows the location of CDS installed at Amanah Apartment.

Figure 1. Location of Installed CDS at Amanah Apartment, UNITEN.

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.

GROSS POLLUTANT LOAD

Gross pollutant load has been obtained from the mass of captured material in the CDS system during maintenance activity. Gross pollutant load was measured in terms of weight per area per duration. The result obtained 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. Table 2 shows tabulated gross pollutant load obtained from CDS 1 and CDS 2 during a maintenance.

Table 2. Gross Pollutant Load Obtained from Amanah Apartment, UNITEN.

CDS No.	Gross Pollutant Load (kg/ha/year)				
	20/03/07	08/05/08	06/03/09	23/12/09	22/2/10
CDS 1	N/A	235.04	123.83	359.26	488.56
CDS 2	527.78	216.52	241.63	347.41	452.61

The highest gross pollutant load was obtained during the first cleaning of the rapping devices. Referring to Table 1, most of the time, CDS 1 captured more load compared to CDS 2. Although the catchment areas are similar, there are many factors that contributed to the pollutant load in the catchment. Marais et al. (2001) and RBF Consulting (2003) described 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 pollution 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. Table 3 shows the gross pollutant wet load obtained during GPTs cleaning at study area.

Table 3. Gross Pollutant Wet Load for Bandar Botanic, Klang.

No.	Gross Pollutant Load (kg/ha/year)												
	30 May 06	4 Sept. 06	28 Sept. 06	1 Nov. 06	20 Dec. 06	29 Jan. 07	27 Feb. 07	28 Mar. 07	24 Apr. 07	29 May 07	29 Jun 07	29 Jul. 07	28 Aug. 07
1	31.45	18.87	41.93	45.63	15.40	18.87	26.03	35.94	32.46	35.94	0.00	25.16	32.46
1A	94.34	18.87	41.93	37.00	10.27	12.58	26.03	35.94	32.46	35.94	0.00	25.16	32.46
3	193.93	38.79	75.13	53.03	5.13	18.87	26.03	20.97	24.35	28.75	32.46	51.71	40.58
5	94.34	25.16	52.41	37.00	25.67	38.79	53.50	17.97	24.35	28.75	40.58	41.93	16.23
6	319.72	12.58	20.97	14.80	15.40	18.87	26.03	26.96	32.46	28.75	40.58	41.93	40.58
7	125.79	31.45	64.64	53.03	36.80	45.08	62.17	73.38	66.28	65.89	0.00	8.39	0.00
9	319.72	57.66	96.09	75.23	10.27	18.87	26.03	58.40	32.46	35.94	0.00	8.39	0.00
10	125.79	18.87	31.45	29.60	25.67	38.79	62.17	0.00	16.23	28.75	40.58	51.71	50.05
11	125.79	25.16	41.93	37.00	25.67	31.45	53.50	0.00	16.23	21.56	32.46	41.93	0.00
12	193.93	38.79	64.64	45.63	10.27	18.87	34.70	44.93	50.05	51.52	0.00	8.39	0.00
13	31.45	12.58	20.97	14.80	10.27	12.58	17.35	17.97	16.23	21.56	24.35	33.54	32.46
15	319.72	63.94	106.57	75.23	10.27	63.94	88.20	8.99	24.35	21.56	32.46	33.54	40.58
17	94.34	25.16	52.41	45.63	31.66	38.79	53.50	55.41	50.05	44.33	0.00	8.39	16.23

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 the inconsistent gap compared to Bandar Botanic, which has a more consistent maintenance frequency. The value obtained at Amanah Apartment seems to be higher compared to studies carried out elsewhere (Allison et al., 1998; Cornelius et al.; 1994 and Armitage and Rooseboom, 2000). Other than higher amount of rainfall received in Malaysia, RBF Consulting (2003) and Marais et al (2001) 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 4 shows the comparison of gross pollutants load obtained in this study and other reported studies

Table 4. Comparison of Gross Pollutant Load.

Gross Pollutant Load (kg/ha/year)			
Malaysia	Australia	New Zealand	South Africa
347.41	71	0.54	96

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 varies according to CDS unit.

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 8 May 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 1740.5mm. Based on the result obtained, the relationship of average gross pollutant wet load with cumulative rainfall depth is derived using the regression technique and shown in Figure 2. The relationship shows that the average gross pollutants wet load behaves non linearly against with the cumulative rainfall depth for both CDS units.

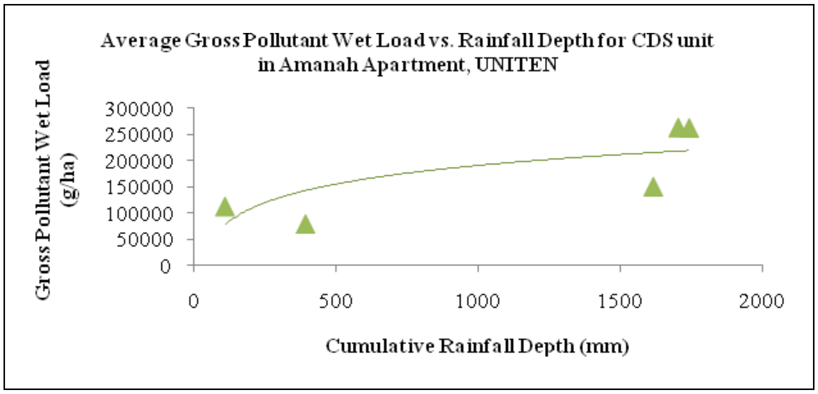

Figure 2. Relationship of Gross Pollutant Wet Load with Cumulative Rainfall Depth for CDS Unit at Amanah Apartment, UNITEN.

Bandar Botanic, Klang

Analyses of the gross pollutant load captured in the 13 units of CDS devices installed at Bandar Botanic with cumulative rainfall depth have been carried out. Analysis of data obtained shows that average gross pollutant wet load for varies according to cumulative rainfall depth. Variation of gross pollutant load much depends on accumulated litter during the dry seasons as opposed to the wet season when pollutants are usually transported into the drainage system. Therefore, if only small amounts of gross pollutants accumulate in the catchment area, it is expected to have small gross pollutant loads during the rainy seasons despite the amount of rainfall. However, rainfall still can be taken as explanatory variable for gross pollutant load due compared to runoff data (Allison et al., 1998b).

As can be seen in Figure 3, attempt is made to fit a non linear equation for CDS no 7 in Bandar Botanic. The obtained equation is $Y = 59.1 \ln(x) + 391.52$ with $r^2=0.0916$. The coefficient of determination is very low due to big scatter in the plotted data.

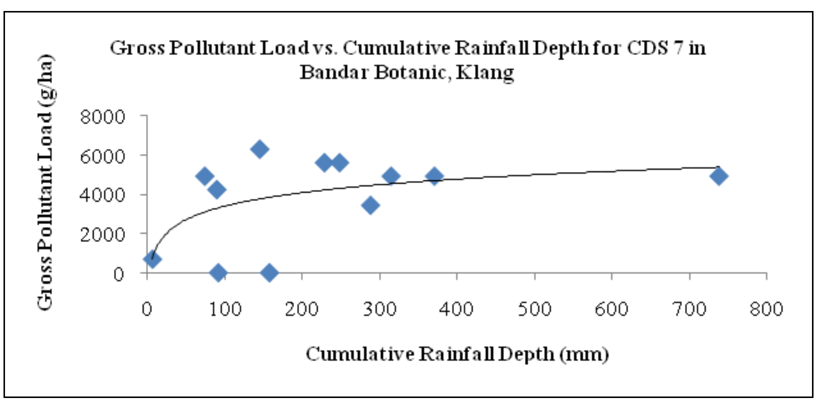

Figure 3. Relationship of Gross Pollutant Wet Load with Cumulative Rainfall Depth. for CDS 7 in Bandar Botanic, Klang.

It must be noted however, the number of samples for both cases is rather small to produce an accurate picture of the characteristics. Hence it requires more in depth study to be carried out in the future.

The fitted relationships in Figures 2 and 3 however indicate that the threshold value of cumulative rainfall that can trigger movement of gross pollutants is about 6.5mm. It has also been observed in the field that apart for rainfall, the runoff rates and velocities are influencing the movement and transport of these pollutants. In spite of that, gross pollutants can also be transported during dry weather period by wind or direct dumping (Hall and Philips, 1997). Comparison has been made from data collected in this study with a study done in Coburg catchment in Melbourne by Allison et al. (1998a). It can be seen that a similar behavior exists between gross pollutants wet load and rainfall depth.

It is also observed that transportation of gross pollutant into drainage system is significant when rainfall depth is 6.5mm, compared to 3.7mm for Australian condition. Figure 4 shows a comparison between Malaysia and Australia. It can also be said that, street sweeping activities contribute toward the reduction of gross pollutant load. Walker and Wong (1999) however expected that the reduction of street sweeping efforts may increase the gross pollutant loads, initially for those events with high rainfall depth.

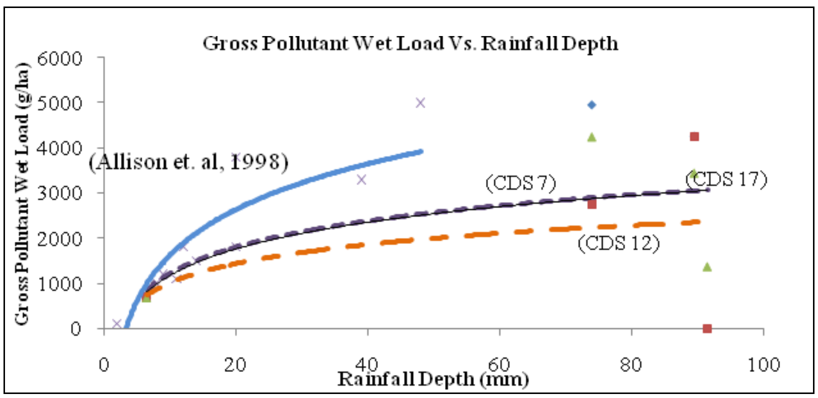

Figure 4. Comparison of Malaysia Condition and Australian Condition for Relationship of Gross Pollutant Wet Load against Rainfall Depth.

CONCLUSIONS AND RECOMMENDATION

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 loads obtained is higher compared to the ones obtained in Australia, New Zealand and South Africa. This is attributed to higher annual rainfall received in Malaysia. Other contributing factors such as development density, management practice employed, community behavior have been reported to influence the amount of gross pollutants transported in urban waterways.

Analysis of gross pollutants load with rainfall depth indicates non linear relation between gross pollutant wet load and cumulative rainfall depth as found in Australia. The relationship obtained also shows that significant amounts of gross pollutant are being transported into the drainage system when cumulative rainfall depth is greater than 6.5 mm.

Finally, all the data collected will be used in the future to develop a decision support system that can assist engineers and local authority to choose the most suitable GPTs according to specific site characteristics.

ACKNOWLEDGEMENT

This study is funded by E-Science Research Grant under the Ministry of Science, Technology & Innovation and UNITEN Seeding Fund. The authors also would like to express their sincere appreciation to Drainage and Irrigation Department, Malaysia for providing rainfall data.

REFERENCE

Allison, R., Chiew, F. and Mcmahon, T. (1997a). *Stormwater Gross Pollutants Industry Report 97/11*, Cooperative Research Centre For Catchment Hydrology, Monash University, Australia.

Allison, R.A., Chiew, F. and Mcmahon, T. (1998a). *A Decision Support System For Determining Effective Trapping Strategies For Gross Pollutants*, Technical Report 98/3, Cooperative Research Centre For Catchment Hydrology, Monash University, Australia.

Allison, R.A., Walker, T.A., Chiew, F.H.S., O'Neill, I.C., And Mcmahon, T.A. (1998b). *From Roads To Rivers: Gross Pollutant Removal From Urban Waterways*, Report 98/6, Cooperative Research Centre For Catchment Hydrology, Monash University, Australia.

Armitage, N.P. and Rooseboom, A. (2000). *The Removal Of Urban Litter From Stormwater Conduits And Streams: Paper 1 - The Quantities Involved And Catchment Litter Management Options*, Water SA, Vol. 26, No. 2, Pp 181-187, ISSN 0378-4738, Water Research Commission.

Cornelius, M., Clayton, T., Lewis, G., Arnold, G. And Craig, J. (1994). *Litter Associated With Stormwater Discharge in Auckland City New Zealand*, Auckland

Department Of Irrigation and Drainage (2000). *Urban Stormwater Management Manual*, Volume 13, Chapter 34, Malaysia.

Desa M. And Z. Daud, (1999). *Interpretation Of Spatial And Temporal Rainfall Properties Of Annual And Monthly Rainfall In Selangor, Malaysia*, in the proceeding of 2nd International Colloquium on Hydrology and Water Management In The Humid Tropics, Panama City.

Essery, C.I. (1994). *Gross Pollutant Water Quality – Its Measurement And The Performance Of Remediation Technologies/Management Practices*, Stormwater Industry Association, Best Stormwater Management Practice, NSW.

Hall, M.D. and Philips, D.J. (1997). *Litter Generation and Distribution in Commercial Strip Shopping Catchments*, Future Directions for Australian Soil and Water Management, Stormwater and Soil Erosion Conference, Brisbane, p. 501-508.

Lariyah, M. S., Mohd Nor, M.D., Mohamad Khairudin, K., Chua, K.H., Norazli, O., and Leong, W. K. (2006). *Development of Stormwater Gross Pollutant Traps (GPT's) Decision Support System For River Rehabilitation*, National Conference – Water For Sustainable Development Towards A Developed Nation By 2020, Guoman Resort, Port Dickson.

Marais, M., Armitage, N. and Pithey,S. (2001). *A Study Of The Litter Loadings In Urban Drainage Systems – Methodology And Objectives*, Water Science Technology Vol. 44 No. 6, IWA Publishing, p. 99-108

Mckay, O. & Marshall, M., (1993). *Backyard to Bay: Tagged Litter Report*, Melbourne Water, ISBN 0 7306 3518 X, p. 36.

RBF Consulting (2003). *Trash and Debris – Best Management Practice (BMP) Evaluation*, Appendix E2, Orange County Stormwater Program, Irvine, CA9261.

Rushton, B., England, G. and Smith, D. (2007). *ASCE Guideline for Monitoring Stormwater Gross Pollutants,* Draft.

Sullivan, J, Mcmasters, F. and Sobelman, T. (2005). *LA River Cleanup*, http://www.gradingandexcavation.com/sw_0511_great.html Accessed on 2 March 2009.

Walker, T.A and Wong, T.H.F. (1999). *Effectiveness Of Street Sweeping For Stormwater Pollution Control Technical*, Report 99/8 Cooperative Research Centre For Catchment Hydrology, Monash University, Australia.

Wong, T.H.F. & Walker Tracey (2002). *Peer Review and Development of A Stormwater Gross Pollutant Treatment Technology Assessment Methodology*, Department of Civil and Cooperative Research Centre for Catchment Hydrology, Monash University, Australia