Life Cost Analysis and Cost Effectiveness Ratio Determination of Gross Pollutant Trap for Urban River Catchment

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The growing population and migration towards built areas are driving land use change in the form of urbanisation across the globe. By 2050, some 70% of the world's population are expected to live in urban areas. Although this process leads to improvement of socio economic life in one area, urbanisation also brings along a wide range of challenges to the environment. As urbanisation often relates to deterioration of stormwater quality due to factors such as uncontrolled pollution and waste disposal, the management of water quality impacts in urban areas must be addressed in order to protect our environment.

Pollutants carried by urban stormwater runoff are considered a significant contributor to the degradation of receiving waters. In Malaysia, gross pollutants such as litter, debris and sediments are some of the main causes of river pollution and flooding. As a result, there is widespread degradation of rivers, which is often the source of the flooding problems (Lariyah, 2011). Accumulation of gross pollutants results in the blockage of drainage systems which also leads to degradation of receiving water quality despite the flooding problem. Accumulated pollutants are not only aesthetically unattractive but they also demonstrate environmentally threatening and devastating effects to the natural equilibrium as well as impede the hydraulic performance of the urban drainage system (Ghani, 2011).

According to statistics from Dewan Bandaraya Kuala Lumpur (DBKL), the government paid RM80 per tonne of rubbish for cleaning and dumping at Bukit Tagar landfill area (Bernama, 2013). However, the cost of cleaning up rubbish in water bodies is more costly as this involves trapping mechanisms (The Star Online, 2017).

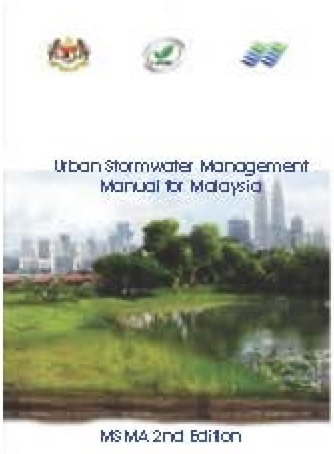
INITIATIVE TO REDUCE GROSS POLLUTANTS IN URBAN WATERWAYS

The Department of Irrigation & Drainage (2012) addressed the treatment methods to control gross pollutants in Chapter 10 MSMA 2nd Edition by installing Gross Pollutant Traps (GPT) at the downstream end of drains or engineered waterways. The introduction of GPT as a pre-treatment for stormwater flow is an excellent method to reduce and handle gross pollutants before the water enters ponds, wetlands and rivers.

Rubbish trapped at a log boom in Batu River, Selangor (Source: The Star Online, 2017)

GPTs are designed to remove litter, debris and sediment from stormwater. Some are even designed to filter oil and to remove chemical from the water flow. Today, there are a number of devices, including conventional and proprietary GPTs, for trapping gross pollutants, which are based on initially diverting stormwater to a separation and retention chamber in which these pollutants are subjected to the mechanisms of interception and sedimentation (Wong & Wootton, 1995; Allison *et al.*, (1998); Walker *et al.*, (1999)). The diversion device allows stormwater to by-pass the separation chamber in the event of blockage due to excessive accumulation of gross pollutants in the chamber during the designed events.

There are now various devices with different trapping mechanisms available in the market. The authorities have made efforts to install GPTs to trap gross pollutants before the water enters the river system. It has been proven in many studies that these devices are able to significantly reduce the amount of gross pollutants. It is also important to note that, with periodic and proper maintenance, these devices will function well (DID, 2012).



Chapter 10 of Urban Stormwater Management Manual (MSMA) on GPT

RIVER OF LIFE PROJECT

In the effort to solve river pollution issues, major investments have been made through the River of Life (ROL) project to improve river water quality. Structural and non-structural measures include the construction of new sewage treatment plants, refurbishment of old ones, installation of gross pollutant traps and construction of river water treatment plants and detention ponds as suggested in Integrated River Basin Management (IRBM).

ROL is a long-term programme to rehabilitate and provide an adequate level of flood protection in the Klang River catchment. It involves improving water quality, beautifying the river and creating conducive working/ living conditions along its banks. ROL is a key component of the Economic Transformation Programme (ETP) initiated by the government to transform the Klang River into a vibrant and liveable waterfront with high economic value.

Construction of detention ponds to trap sediments

River bank stabilisation and beautification

Construction and refurbishment of sewage treatment plants

Installation of GPT

Beefing up enforcement

Education & Public Outreach

Structural and non-structural measure for River Cleaning Components

The ROL project area is located at the Sg. Klang catchment area. Main tributaries in the catchment are Sungai Klang (upper catchment), Sungai Gombak, Sungai Batu, Sungai Jinjang, Sungai Keroh, Sungai Bunus, Sungai Ampang and Sungai Kerayong.

ROL Project Area

GROSS POLLUTANT TRAP

When used in connection with stormwater drainage systems, the term "gross pollutant" may include litter, debris and coarse sediments (Fitzgerald, 2010). Studies and rationality of daily activities indicate that a significant proportion of gross pollutants discharged into waterways are generated from residential land, as this type of development constitutes a significant proportion of the land use in most catchments (Land Development Guidelines, 2007).

Each type of GPT has a control mechanism for the flow rate that passes through, by filtering and capturing gross pollutants such as silt and sediment which have been transported from upstream to downstream. The selection number of GPTs for each catchment area is essential to ensure that flow rates are under control and treatable, especially during high rainfall intensity. An inadequate number of GPTs or unsuitable types of GPT installed will result in inefficiency when treating the flow.

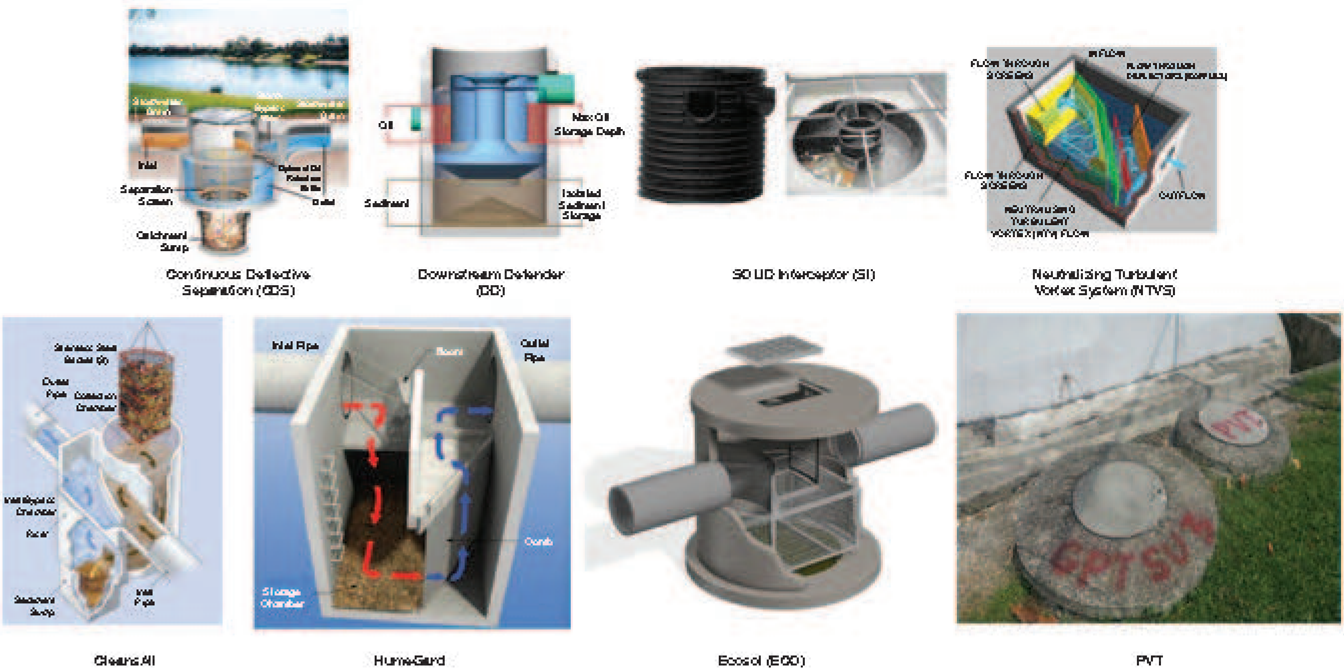
The important role of GPTs in stormwater management also depends on land usage. A study by Allison and Chiew (1995) of a fully urbanised area in Coburg catchment shows variability of the composition of gross pollutants with different types of land use.

RESEARCH & DEVELOPMENT TO SUPPORT ROL PROJECT

The implementation of river cleaning component utilises water treatment technologies to improve water quality in the ROL project. Among these are using of river treatment methods to control gross pollutants, as suggested in Chapter 10 MSMA 2nd Edition. Installation of GPTs are among the structural measures under Key Initiatives 4A and 7 to clean and improve a 110km stretch along the Klang River basin, from the current Class III-V to Class IIB by 2020. To date, there are 528 units of GPTs installed in the project area.

The performance of a GPT depends strongly upon the specific site criteria such as land use, hydrological regime and maintenance frequency. As maintenance cost is significant in the life-cycle cost of GPTs, the local authority faces issues of conducting proper maintenance frequency for installed GPTs, resulting in system clogging which, in turn, leads to flooding and contamination of water in the downstream area. In view of this, UNITEN R&D Sdn. Bhd. has been entrusted by DID Malaysia to carry out research on the performance of proprietary Gross Pollutant Trap (GPT) trapping devices versus life-cycle cost and gross pollutant management strategies knowledge database for the ROL project.

The study involves field activities such as sorting gross pollutants, measuring wet loads during GPT maintenance and analysing the performance of GPTs to remove the gross pollutants. The research purpose is to investigate the characteristics of gross pollutants derived from urban drainage, which is obtained from GPT operation and maintenance. It also aims to measure the performance of gross pollutant traps installed in the study in terms of trapping various types of gross pollutants and improving water quality. Finally, the data obtained will assist engineers and local authorities to implement appropriate strategies for trapping gross pollutants in urban areas, expand the sources for managing gross pollutants in order to rehabilitate the river system and preparing budget allocation of using GPTs in terms of installation cost and maintenance cost annually, including the Life-Cycle Cost analysis. The ultimate aim is to provide a management and planning tool for effective management of the gross pollutants in the urban areas, specifically in the River of Life (ROL) project.



Different Types of GPT in ROL Project

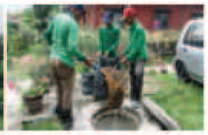
GPT MAINTENANCE & MONITORING

This study consists of monitoring and assessing gross pollutant traps for 5 types of proprietary GPTs from 3 different types of land use (residential, commercial and mixed development) at Sg. Klang, Sg. Gisir, Sg. Sering, Sg. Kemensah and Sg. Kerayong.

The data collection process was divided into desktop data collection and field data collection. Desktop data collection involved gathering of hydrological data, GPT inventory database, GIS mapping as well as operation and maintenance cost data. For field data collection, there were three on-site activities involved: Weighing of gross pollutant wet load trapped in GPT, sorting gross pollutant and sampling water quality at selected locations. All data and information were finally incorporated into the gross pollutant management strategies database.

Maintenance of GPT: Suction Truck

Maintenance of GPT: Crane



Maintenance of GPT: Manual

Data Collection Activities during GPT Maintenance

ESTIMATION OF LIFE-CYCLE COST ANALYSIS AND COST EFFECTIVENESS RATIO

The data on estimated life-cycle cost (LCC) of GPT costing was obtained from PLSK. The data included installation cost, inspection cost and cleaning cost. The LCC for each trap was calculated using the appropriate Australian Standard (AS/NZS 4536, 1999). This process used Excel spreadsheet to calculate the LCC. The life duration of the GPTs was based on 10 years and 40 years, as recommended from a previous study (Brisbane City Council. 2002).

The LCC for all GPTs in the study area was analysed. The analysis included Equivalent Annual Cost (EAC) derived from the life-cycle cost, based on different project durations of 10 and 40 years, based on the literature review. The analysis assumed that maintenance was performed monthly on all GPTs.

From the analysis, the LCC of GPTs in the study area ranged from RM157,750 to RM297,086 for a duration of 10 years. However, for a duration of 40 years, the LCC ranged from RM315,358 to RM616,694. The main factors contributing to the LCC value are maintenance frequency and maintenance method.

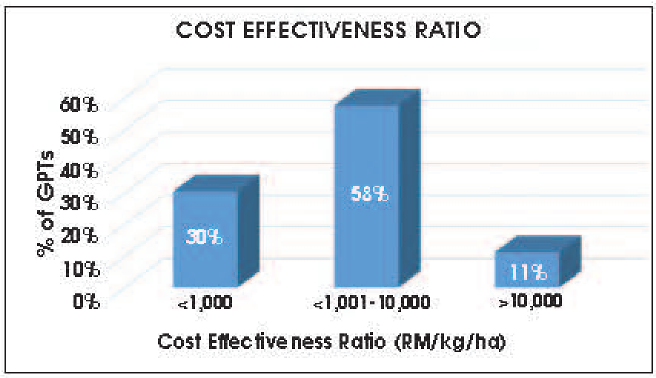
The study shows that manual maintenance (using manpower to remove rubbish from GPT) has the lowest LCC value of RM157,750. The second lowest LCC is using a suction truck, while the highest LCC is using a crane. For this method, at least two vehicles (crane and lorry) are required to transport the gross pollutants to the dumping area. This explains the higher LCC for this type of maintenance. It is also important to note that more frequent maintenance will increase the total life-cycle cost. Therefore, to decide on the maintenance frequency of GPTs, it is important to first identify the total loading from each catchment. Table 1 shows the maintenance method conducted during the maintenance activities in the study areas.

Table 1: LCC and EAC of GPTs for the frequency of Monthly Maintenance

Maintenance Method	LCC (RM)		EAC (RM/year)	
	10 years	40 years	10 years	40 years
Manual	157,750.00	315,358.50	15,775.05	7,883.96
Suction Truck	163,054 to 270,686	387,712 to 511,094	16,305.40 to 27,068.60	9,692.80 to 12,777.35
Crane	297,086	616,694	29,708.60	15,417.35

The important criterion in assessing the performance of GPTs is the cost analysis. The analysis involved is quantifying the value for money for each device, using the "Cost Effectiveness Ratio" analytical technique (9). The Cost Effectiveness Ratio (CER) takes into account the life-cycle cost and pollutant removal efficiency. The important advantage is that CER provides a simple tool for assessing management options for pollution trap operations.

The CER for all 151 GPTs in the study area was calculated and it was found that more than 50% of proprietary GPTs in the study area have a CER of between RM1,001 and RM10,000. Another 30% have a CER value less than RM1,000, while only 11% have a CER of more than RM10,000. In general, a device with the lowest CER is preferred. (10)



Percentage of GPTs with Different Range of Cost Effectiveness Ratio

GPT STRATEGIES KNOWLEDGE DATABASE SYSTEM

The Gross Pollutant Management Strategies Database was developed based on previous and current research and collection of data which would complement the system as a data storage hub. The system provided a database for monitoring data collected and performance analysis results. System architecture was also designed based on a scalable and extensible platform which could be easily extended and configured to meet the progressive needs of supporting delivery of services across multiple platforms, including desktop, server, web and mobile developed by DID & UNITEN.

Mobile-based application solution for data collection, updating and site verification direct from the field to centralised geodatabase

ROL PUBLIC OUTREACH PROGRAMME

Apart from the installation of GPTs as a structural measure to reduce the amount of gross pollutants, there are non-structural methods which basically focus on public attitudes through monitoring and law enforcement. FHWA (2002) describes non-structural Best Management Practices (BMPs) as an "at-source approach" to prevent and remove stormwater constituents load. Stormwater non-structural BMPs may be among the most cost-effective solutions to reduce constituents in stormwater runoff.

The River of Life Public Outreach Programme (ROL-POP) is an initiative under the National Key Economic Area (NKEA) and undertaken by the Department of Irrigation and Drainage (DID) Malaysia. The programme was initially started at the Upper Sg. Klang catchment. ROL-POP is a non-structural measure to foster partnerships and to improve the attitude and behaviour of target groups so as to reduce pollution.

It aims to formulate an effective public awareness programme to inculcate and raise general public awareness and understanding of Greater KL as well as to formulate a suitable public participation mechanism and platform to encourage and ensure effective public stakeholders' participation. An outreach programme is not an isolated set of activities. The ROL-POP is an on-going cumulative process, starting at the roots of awareness, participation, action and ownership. It involves different water user groups including communities, NGOs, private sectors, polluters and water-sector service providers.

The cumulative process of Public Outreach Programme

Many ROL-POP activities involve universities and institutions of higher learning, either through awareness creation, public engagement or voluntary participation in events and river care programmes. This key group is seen as agents of change and important stakeholders to ensure that ROL programmes are sustainable and will continue to benefit society as a whole, through continued activism by those who have benefited from it.

The increase in population density, built-up areas, industrialisation and seasonal variation can directly or indirectly affect the hydrological processes through the alteration of flow characteristics, stream-flow regime and changes in river amenities (Y. Liu, 2014).

Education will increase public awareness of the impact of pollution on the environment. Law enforcement on littering also promotes the reduction of gross pollutants. Fundamental elements towards the successful implementation of non-structural methods are positive participation and the involvement of individuals, communities and government/private agencies.

The ROL-POP programme was initially started at the Upper Sg. Klang catchment. In this study, the annual gross pollutant load captured here was compared with that from the Sg. Kerayong catchment (Table 2). The result indicates a 60% difference for the annual gross pollutant load between Upper Sg. Klang and Sg. Kerayong catchments. This shows the success of the Public Outreach Programme conducted at Sg. Klang.

Table 2: Reduction of Annual Average Wet Load at POP project area located at Upper Sg. Klang

Maintenance Method	Total Wet Load (kg/ha/year/GPT)
Upper Sg. Klang (with POP) (Sg. Klang, Sg. Kemensah, Sg. Sering, Sg. Gisir)	143.19
Sg. Kerayong (without POP) (Sg. Kerayong 1, Sg. Kerayong 2)	397.585

OUTCOME R&D PROJECT FOR GROSS POLLUTANT TRAPS (GPT) UNDER ROL PROJECT

1. Gross pollutant generation rate based on different type of land use and population.
2. Estimation of gross pollutant load for different catchment characteristic.
3. Optimum number of gross pollutant traps in each catchment.
4. Provide GPT performance in monitoring gross pollutant to contribute and featured in the next updated MSMA Manual.
5. Updated Gross Pollutant Management Strategies Knowledge Database.
6. GPT knowledge database system that will assist the DID and designers to monitor GPT's and provides complete inventory database of Proprietary GPTs in study area.
7. Estimation of LCC and EAC which is helpful for the DID to allocate sufficient budget for future operation and maintenance of GPTs.

CONCLUSION

From this study, the calculated life-cycle cost and cost effectiveness ratio will be used for the selection of trapping mechanisms to ensure the sustainability of the environment. Continuous research and development activities by the implementing agencies and university will contribute to the success of the ROL project. To ensure the effective management of gross pollutants, the following suggestions are recommended:

- Implementation of the non-structural method (as recommended by MSMA) through public awareness regarding the importance of preserving nature and avoiding pollutants shall be actively done by all parties involved, to reduce the amount of debris produced.
- Education through the mass media, seminars and courses for the young generation to preserve nature and environment.
- Local authorities should be more proactive in implementing the necessary acts and regulations to sustain the quality of environment.

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15-16 May 2017

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