Poll Res. 28 (2) : 279-285 (2009)

UNTREATED SULLAGE FROM RESIDENTIAL AREAS – A CHALLENGE AGAINST INLAND WATER POLICY IN MALAYSIA

ABDULLAH AL-MAMUN[1]*, MD. ZAHANGIR ALAM[1], AZNI IDRIS[2] AND WAN NOR AZMIN SULAIMAN[3]

[1]*Bioenvironmental Engineering Research Unit (BERU), Faculty of Engineering, International Islamic University Malaysia (IIUM), Jalan Gombak, 53100 Kuala Lumpur, Malaysia.*

[2]*Department of Chemical & Environmental Engineering, Faculty of Engineering, Universiti Putra, Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.*

[3]*Department of Environmental Science, Faculty of Environmental Studies, Universiti Putra, Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.*

ABSTRACT

Malaysian water policy was mainly focusing on the protection of the inland water resources by controlling point pollution from industrial activities and domestic sewage. Contribution of pollution loading from untreated sullage is not determined yet in Malaysia. This study was conducted to evaluate the quantity and quality of sullage discharged from an urban residential area in hot tropical climate. Median concentrations of the physical parameters, e.g. TSS, VSS, TDS, Turbidity and pH were 38, 7, 170, 36 mg L^{-1} and 6.71, respectively. Concentrations of BOD, COD, DO, TKN, AN, OP, TOC, Zn and Oil & Grease were 49, 120, 1.6, 7.08, 4.85, 1.94, 35.43, 0.056 and 13 mg L^{-1}, respectively. Generally, the pollutant concentrations in sullage were higher than the limits stated in the Environmental Quality Act (EQA) of Malaysia. However, the sullage issue is not seriously considered by the relevant authorities due to unavailability of data gathered from detailed study conducted in the country. The information on various parameters provided in this paper would be a reference material for the typical characteristics of sullage discharged from the urban residential areas in Malaysia and most likely for other developing countries.

KEY WORDS: Pollution loading; sullage characteristics; urban residential area; water quality index.

INTRODUCTION

Urban areas contribute various types of pollutant from point and non-point sources (Gray and Becker, 2002), which degrade the water bodies. Recent concerns over long-term river water quality objectives have led to a growing awareness to investigate discharges from all pollution sources. The major point pollution sources are sewage treatment plants, industries, sullage or greywater from commercial and residential premises. Traditionally domestic sewage and industrial wastewaters, in Malaysia and in most of the developing countries, are being addressed by various technical (structural) and institutional (non-structural) strategies. Pollution due to storm runoff (diffuse or nonpoint source pollution) is also being controlled by implementation of various best management practices (BMPs), as proposed in the urban stormwater management manual for Malaysia (DID, 2000).

However, a significant portion of sullage or greywater from domestic and commercial sources ends up into the streams without any sort of treatment (DOE 2003, DOE 2004 and SWMA 2004). Sullage mainly originates from kitchen sinks, washing machines, bathrooms, restaurants, wet markets, car washing centres, etc. Although the quantity and quality of sullage varies from source to source, the pollutant concentration could be high (Christova-Boal, 1996; Nolde, 2000; Eriksson *et. al*., 2002; Al-Jayyousi, 2003) and should not be allowed to enter into the river system without any treatment. The total grey-water fraction has been reported to account for 50% to 80% (Hypes, 1974), 60% to 70% (Friedler and Hadari, 2006) of the total domestic wastewater usage.

A significant portion of the water in urban streams

[1]**Corresponding author :** mamun@iium.edu.my (Abdullah Al-Mamun). Tel: (+6-012) 3650516, Fax: (+6-03) 61964853

is contributed by sullage from the residential settlements (SWMA, 2004). No detailed study is available on the characteristics of sullage in Malaysia. As such, it was necessary to conduct a detailed study to determine the typical quantity and quality of sullage discharged from a residential area. The main objectives of this paper were to report the variation of quantity and quality of sullage from a residential area and to compare the overall quality of sullage with the existing water quality index.

METHODOLOGY

The Study Area

The study area (about 6.14 ha) is located at a residential area of Taman Sri Serdang, Selangor. This is a typical Malaysian housing scheme in urban setting which consists of 283 units of single-story terrace houses, the aerial photo is shown in Fig. 1. The area was developed in 1981 and all sullage from the houses are discharged into a nearby detention pond, which flows into receiving Kuyoh River. Sewage from the houses are conveyed by a separate sewer line and treated in an oxidation pond. All houses are provided with potable water by Selangor Water Management Board Limited. The total population served in the area was calculated at 1448 person equivalent (or 236 PE per ha).

Fig. 1. Aerial photo of the study area.

Field and Laboratory Works

The drainage outlet of the study area was selected for sampling of sullage water. It was verified that sullage from the nearby commercial lots does not enter into the study area. Hence, the sullage can be considered to originate purely from the houses. Sampling was done for one working day, one Saturday and one Sunday to study the possible variation in sullage quantity and quality in a week. Twenty-four samples were collected from the outlet for each day. Four aliquots of 250 mL samples were collected at 15-minute interval to provide an hourly composite sample. Samples for oil and grease (O&G) were collected manually by a glass sampler. The data logger of the auto sampler recorded water levels for every minute. Average hourly water depth was calculated from 1-minute data. Slope of the outlet culvert was determined by level survey to apply Manning formula to calculate discharge rate of sullage. The Manning roughness "n" was calibrated by field measurements of discharge and water depth in the outlet culvert.

In total, seventy-two samples were collected from the drainage outlet (Fig. 1) within three days and sent to laboratory for analyses. Ice was placed inside the auto sampler in order to keep samples below 4^{o} C which will minimise the degradation of sample properties. Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Organic Carbon (TOC) and Ammoniacal Nitrogen (AN) were tested using standard methods (Hypes, 1974). Dissolved Oxygen (DO), pH, Turbidity and Total Dissolved Solids (TDS) were measured with calibrated sensors and instruments.

Analytical Method

Pollutant concentrations and the value of water quality index were compared to the limits or classes given in the Interim National Water Quality Standards-INWQS (DOE, 1994). The overall quality of sullage was assessed based on Malaysian Environmental Quality Act – EQA (DOE, 1979) and INWQS.

Six parameters were used to determine the overall quality of sullage. The procedure was same as the water quality index (WQI) used by the DOE Malaysia. The higher value of WQI indicates better quality of river water. The parameters used for WQI are; pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and ammonia nitrogen (AN). Pollutant concentrations in the WQI equations are in mg L^{-1} for all parameters except for pH (which is in number). Detailed procedure to calculate WQI, according the Department of Environment Malaysia guideline, discussed by Idris *et al.* (2003).

The compounded WQI equation applied in Malaysia is:

WQI= 0.22SIDO + 0.19SIBOD + 0.16SICOD + 0.15SIAN + 0.16SITSS + 0.12SIpH (1)

Where, WQI= Water quality index, SIDO= Sub-index of DO, SIBOD= Sub-index of BOD, SICOD= Sub-index of COD, SIAN= Sub-index of AN, SITSS= Sub-index of TSS and SIpH= Sub-index of pH.

RESULTS AND DISCUSSION

Flow Pattern of Sullage

It was found that the discharge of sullage was not constant throughout the day. Hourly average flow hydrographs of seven days are shown in Fig. 2. It was observed that generally there were three peaks in sullage flow during the working days. Two mild peaks were noticed during the working days, one in the morning (within 6 am and 9 am) and one in the evening (within 6 pm and 9 pm), as shown in Figure 2. The lowest flow was observed at about 4 am. The high peak occurred at about noon (1 pm) of the working and non-working days when the household washing activities are also at their peak condition. The average hourly minimum & maximum sullage flow from the study area during working and non-working days were 2.07 and 4.05 L s^{-1} and 1.93 and 5.53 L s^{-1}, respectively. It was observed that the sullage flow was high in the weekends, which recorded 40% higher values than the highest flow during week days.

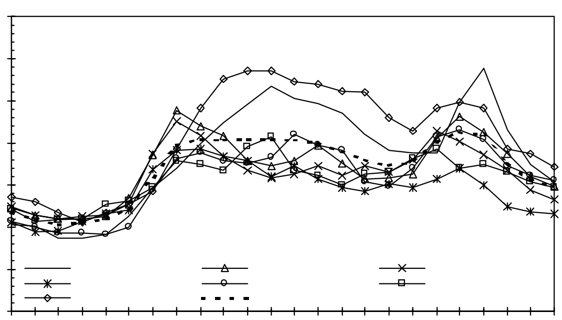

Fig. 2. Mean hourly flow rate of sullage on various days of the week.

Characteristics of Sullage

Summary of the sullage quality for working and non-working days is given in Table 1. The table shows the statistical parameters of pollutant concentrations for different days, including the effluent standard to be compared with the quality of the sullage. It was observed that the median concentrations of BOD, COD and O&G exceeded the limits stipulated in the effluent discharge standard set by Environmental Quality Act - EQA (DOE, 1979). Although there is no limit mentioned in the EQA for the ammoniacal nitrogen (AN) and orthophosphate (OP), looking at the concentration in sullage (Table 1), it can be considered that the sullage from the study area contributes significant amount of nutrients into the river system.

A pollutograph is the graphical presentation of the variation of pollutant concentration with time. Diurnal variations of the selected pollutants for a working day (Wednesday), a Saturday and a Sunday are shown in Figures 3 and 4. Fluctuations were observed in the concentrations of the pollutants during the days. Generally, the pollutant concentrations were high during the high flow periods. It was observed that pollutant concentrations were, generally, high during the peak sullage flows of the days. No specific trend was observed in the cases of metals monitored in the study and, therefore, not shown in the figures.

The pollutographs for the same parameters were plotted in the same graph to compare the pollutant concentrations in different days (Figs. 3 and 4). It was observed that the median concentrations of BOD, TKN, AN, OP and ON were slightly higher during the non-working days due to more household activities. The ANOVA analysis indicated that there were significant differences (at 95% confidence level) among many of the average pollutant concentrations in working days and non-working days. However, no significant difference were observed among the average concentrations of DO, BOD, COD, VSS, OP, TC, TOC and O&G in the working and non-working days.

Median concentrations of the physical parameters, e.g. TSS, VSS, TDS, Turbidity and pH were 38, 7, 170, 36 mg L^{-1} and 6.71, respectively (Table 1). Concentrations of BOD, COD, DO, TKN, AN, OP, TOC, Zn and Oil & Grease were 49, 120, 1.6, 7.08, 4.85, 1.94, 35.43, 0.056 and 13 mg L^{-1}, respectively. The EQA and INWQS do not show limits for all the water quality parameters. Therefore, it was difficult to compare the median concentration of sullage with the DOE guidelines. Generally, the median concentrations of DO, BOD, COD and AN were unsuitable for the general purpose of the water usages as stipulated in the Interim National Water Quality Standard (DOE, 1994).

The mean concentrations of the common pollutants studied in this project were compared to

Table 1 Statistical summary of the sullage characteristics at the drainage outlet.

Parameter	Flow ($L s^{-1}$)	TDS ($mg L^{-1}$)	BOD ($mg L^{-1}$)	DO ($mg L^{-1}$)	TSS ($mg L^{-1}$)	COD ($mg L^{-1}$)	TKN ($mg L^{-1}$)	AN ($mg L^{-1}$)	Turbidity (NTU)	OP ($mg L^{-1}$)	ON ($mg L^{-1}$)	TOC ($mg L^{-1}$)	O&G ($mg L^{-1}$)	Zn ($mg L^{-1}$)	Cu ($mg L^{-1}$)
							Wednesday								
Minimum	1.87	138.79	9.00	1.20	11.00	40	5.60	3.60	11.00	0.34	1.30	7.59	10.00	0.018	0.002
Maximum	4.83	188.60	76.50	2.00	95.00	200	10.00	7.50	62.30	4.13	3.90	79.89	22.00	0.124	0.022
CV	0.34	0.08	0.42	0.21	0.58	0.43	0.18	0.21	0.45	0.59	0.31	0.63	0.27	0.463	0.417
90%tile	4.66	184.69	76.05	2.00	62.80	174	9.39	6.66	59.10	3.61	3.10	61.33	20.80	0.089	0.018
50%tile	2.74	166.96	50.25	1.60	32.00	110	7.20	4.93	36.30	2.08	2.28	31.71	14.00	0.054	0.013
10%tile	1.96	147.92	27.00	1.20	16.00	50	5.90	3.96	13.76	0.48	1.50	9.22	10.20	0.026	0.005
Skewness	0.46	-0.42	-0.19	0.16	1.41	0.17	0.48	0.54	-0.01	0.22	0.46	0.53	0.42	0.847	-0.399
							Sunday								
Minimum	1.64	157.73	28.50	1.20	21.00	40	5.60	3.30	10.80	0.77	0.75	25.44	9.00	0.037	0.000
Maximum	7.23	199.76	78.00	2.00	120.00	200	12.15	9.20	59.10	3.30	4.50	54.20	23.00	0.211	0.008
CV	0.43	0.07	0.23	0.16	0.49	0.42	0.22	0.27	0.42	0.37	0.33	0.19	0.31	0.563	0.784
90%tile	6.73	198.11	64.65	1.60	101.80	180	10.94	7.82	40.73	2.97	3.87	49.25	21.70	0.161	0.008
50%tile	4.43	183.60	48.00	1.60	48.00	160	8.22	5.15	32.80	1.76	2.80	37.83	16.50	0.066	0.002
10%tile	1.91	165.25	37.95	1.20	30.60	40	6.30	3.90	14.71	1.19	1.67	31.88	10.00	0.043	0.001
Skewness	-0.04	-0.43	0.40	0.16	1.29	-0.63	0.52	0.64	0.19	0.31	-0.12	0.10	0.20	1.320	0.748
							Saturday								
Minimum	2.02	149.90	37.00	1.20	20.00	40	2.40	1.80	18.30	0.92	0.40	10.84	4.00	0.011	0.002
Maximum	7.49	187.97	64.50	2.40	86.00	160	10.25	6.95	66.50	3.70	3.30	52.76	21.00	0.120	0.015
CV	0.38	0.05	0.14	0.24	0.42	0.36	0.44	0.45	0.32	0.37	0.62	0.34	0.36	0.546	0.354
90%tile	7.07	175.09	59.10	2.00	60.40	150	8.21	6.49	60.91	3.32	2.24	42.19	14.90	0.089	0.014
50%tile	5.20	165.34	50.25	1.55	35.50	115	4.31	3.35	37.75	1.96	0.90	30.79	12.00	0.046	0.011
10%tile	2.62	157.00	41.95	1.20	21.90	50	2.85	1.99	27.33	1.29	0.60	17.70	8.10	0.024	0.007
Skewness	-0.15	0.51	0.07	0.80	1.37	-0.27	0.79	0.43	0.62	0.48	1.58	0.06	0.51	1.185	-1.568
							Effluent Quality Standards and INWQS Limit								
EQA Std. A	NA	NA	20	NA	50	50	NA	NA	NA	NA	NA	NA	ND	1.000	0.200
EQA Std. B	NA	NA	50	NA	100	100	NA	NA	NA	NA	NA	NA	10	1.000	1.000
INWQS Class III	NA	NA	6	3-5	150	50	NA	0.90	NA	NA	NA	NA	NA	0.400	NA

Note: NTU is Nephelometric Turbidity Unit, NA is Not Available, Std A & Std B: Standard A & B in the EQA of Malaysia the Class III limits given in the INWQS (Table 1). Class III was chosen, because this is the minimum quality required to protect common and moderately tolerant aquatic species of economic value. Water under this class may be used for water supply with advanced treatment (DOE, 1994). However, the water quality index (WQI) of sullage calculated from Equation 1 indicated that the mean quality of the sullage was inferior to Class IV of INWQS, as given in Table 2.

Usually the mean concentrations of DO, BOD, COD and AN were outside the limits set for Class III in the INWQS (Table 2). High concentration of nutrients causes algal problem in the water bodies. The median concentrations of AN, TKN and Orthophosphate in the sullage were high enough (Table 1) to degrade the aquatic status of the urban stream where the assimilative capacity of the streams is low. The concentration of Ammoniacal Nitrogen (AN) in the sullage was at levels, which would be toxic to most of the fish species. That is why only the tough fish species can be seen in most of the urban rivers in Malaysia.

Probable Impact of Sullage

Sullage or greywater has various impacts on water treatment facilities (Jefferson et al., 2004) and on the urban ecosystem. Due to little base flow, the urban streams exhibit low assimilative capacity to absorb the pollution loads released form various point sources. It was calculated that about 67% of consumed water is discharged untreated as sullage from the study area. Similar situation exists in other residential areas throughout the country, which are developed before 1990s when the Government started putting more effort to make sure that the returned water form the residential and commercial premises are directed to the sewer lines not to the

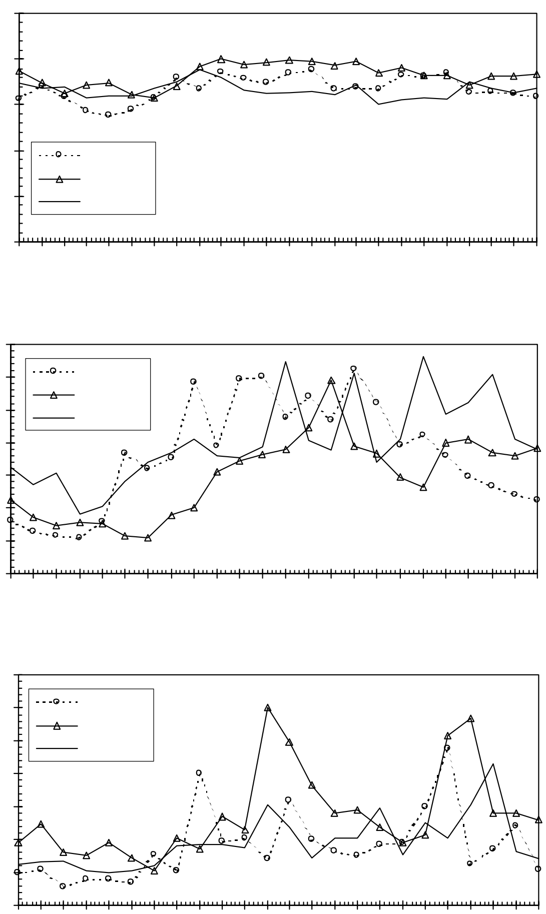

Fig. 3. Hourly variation of TDS, Turbidity and TSS on various days.

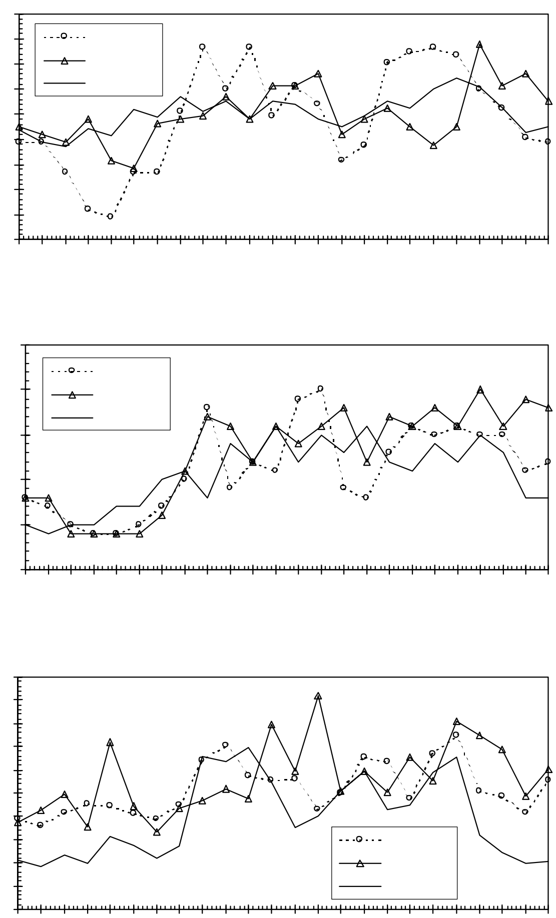

Fig. 4. Hourly variation of BOD, COD and AN on various days.

Table 2 Quality of sullage compared to INWQS guidelines.

Parameter	Mean Value for Sullage	Limits in Interim National Water Quality Standards for Malaysia				
		Class I	Class II	Class III	Class IV	Class V
AN (mg L^{-1})	4.90	< 0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	> 2.7
BOD (mg L^{-1})	49.62	< 1	1 – 3	3 – 6	6 – 12	> 12
COD (mg L^{-1})	115.60	< 10	10 – 25	25 – 50	50 – 100	> 100
DO (mg L^{-1})	1.56	> 7	5 – 7	3 – 5	1 - 3	< 1
pH	6.67	> 7.0	6.0 – 7.0	5.0 – 6.0	< 5.0	< 5.0
TSS (mg L^{-1})	43.18	< 2.5	25 – 50	50 - 150	50 - 30	> 300
WQI	28.8	> 92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	< 31.0

Notes
Class I: Represent water bodies of excellent quality. Water bodies in this category meet the most stringent requirements for human health and aquatic life protection.
Class II: Represent water bodies of good quality. Class II water suitable for the protection of human health, sensitive aquatic species and recreational use.
Class III: Defined with the primary objective of protecting common and moderately tolerant aquatic species of economic value. Water under this classification may be used for water supply with extensive / advanced treatment. This class of water is also defined to suit livestock drinking needs.
Class IV: Defines water quality required for major agricultural irrigation activities which may not cover minor applications to sensitive crops.
Class V: Represents other water which does not meet of the above uses.

open drains. This indicated that a significant amount of domestic wastewater is released in the urban streams untreated. It is obvious that despite adequate control of point and nonpoint pollution sources, quantity and quality of sullage could be a challenge towards the conservation of urban streams. Discharge of untreated sullage adds oxygen-demanding substances (BOD, COD, etc.), nutrients (TKN, OP, etc.) and toxic elements (AN) into the water, which in turn converts the streams to become unsuitable for aquatic flora and fauna. Thus, it is of utmost importance that the relevant authorities take necessary structural and non-structural measures to treat sullage before discharged in the river system.

CONCLUSION

In spite of significant efforts made by the enforcement agencies in the country, point source pollution remains a challenge towards the conservation of urban streams in Malaysia. Sullage is one of the main point pollution sources, which is released from many urban (residential and commercial) areas without any treatment. This study revealed that quantity and quality of sullage (grey-water) is a major contributor of pollution source in urban areas, especially where sullage is directly discharged into the streams without any treatment. High BOD, COD, AN, TKN, Orthophosphate and low DO are the main pollutants in sullage discharged from the residential area. About 67% of the water consumed in the study area is released in the surface waster bodies without any treatment. The Quality of the sullage from the study area was equivalent to Class V of INWQS, whereas Class III water is required in the streams to be suitable for general water usages. Due to reduced base flow and low assimilative capacity of urban streams, discharge of untreated sullage is a threat towards the conservation of the rivers. It would be virtually impossible to maintain good quality water in the urban streams if the present practice of releasing untreated sullage in the streams is continued. Therefore, it is of utmost importance to make necessary technical, institutional and legal arrangement to treat sullage adequately before it is discharged in the urban streams.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to all staff and students of the university who helped in this study. Water consumption data provided by PUAS Berhad is also greatly acknowledged.

REFERENCES

Al-Jayyousi, O.R., 2003. Greywater reuse: towards sustainable water management. *Desalination*, 156: 181–192.
American Public Health Association – APHA, 1995. *Standard*

methods for the examination of water and wastewater. 19th ed. American Public Health Association, American Water Works Association, Water Pollution Control Federation.

Christova-Boal, D., Eden, R.E., & McFarlane S., 1996. An investigation into greywater reuse for urban residential properties. *Desalination*, 106: 391–397.

Department of Environment Malaysia – DOE, 1979. Environmental quality Act. Ministry of Science, Technology and Environment.

Department of Environment Malaysia – DOE, 1994. Classification of Malaysian rivers – Final report on development of the water quality criteria and standards for Malaysia. Ministry of Science, Technology and Environment.

Department of Environment Malaysia – DOE, 2003. The study of pollution prevention and water quality improvement of Sungai Tebrau and Sungai Segget. Department of Environment Malaysia, Ministry of science, technology and the environment.

Department of Environment Malaysia – DOE, 2004. The study on pollution prevention and water quality improvement of Sg. Melaka. Department of Environment Malaysia, Ministry of natural resources and environment Malaysia.

Department of Irrigation and Drainage – DID, 2000. Urban storm water management manual for Malaysia. Ministry of Agriculture, Malaysia.

Eriksson, E., Aufferth, K., Henze, M, & Ledin, A., 2002. Characteristics of grey wastewater. *Urban Water*, 4: 85-104.

Friedler, E., and Hadari, M., 2006. Economic feasibility of on-site greywater reuse in multi-storey buildings. *Desalination*, 190: 221-234.

Gray, S.R., & Becker, N.S.C., 2002. Contaminant flows in urban residential water systems. *Urban Water*, 4: 331-346.

Hypes, W.D., 1974. Characteristics of typical household greywater. *Manual of greywater treatment practices*, Winneberger J.H.T. (Ed.), Michigan, Ann Arbor Science, pp. 79-88.

Idris, A., Mamun, A.A., Azmin, W.N.W., & Amin, M.S.M., 2003. Review of water quality standards and practices in Malaysia. *Pollution Research*, 22(2): 145-155.

Jefferson, B., Palmer, A., Jeffrey, P., Stuetz, R., & Judd, S., 2004. Grey water characterisation and its impact on the selection and operation of technologies for urban reuse. *Water Sci. Technol*., 50(2): 157–164.

Jeppesen, B., 1996. Domestic greywater re-use: Australia's challenge for the future. *Desalination*, 106: 311–315.

Nolde, E., 2000. Greywater reuse systems for toilet flushing in multi-storey buildings — over ten years experience in Berlin. *Urban Water*, 1(4): 275–284.

Selangor Water Management Authority – SWMA, 2004. Master plan study on integrated catchment management and urban storm water management for Sg. Damansara. Draft final report. Selangor Water Management Authority (SWMA), Government of Malaysia.