UNIVERSITI PUTRA MALAYSIA

NONPOINT SOURCE POLLUTION FROM A TROPICAL URBAN RESIDENTIAL AREA

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

July 2005

DEDICATION

For a better environment

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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July 2005

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Despite all efforts taken by the Government, water quality related problems in Malaysian rivers remain unresolved. This is mainly due to the fact that most of the attention is focused on the point source (PS) pollutions whereas a significant amount of annual pollution load is also generated from the nonpoint sources (NPS) as a result of storm runoff. After the endorsement of the urban stormwater management manual by the cabinet in June 2000, it was realised that in order to quantify the significance of NPS pollution there was an urgent need to conduct detail studies on the storm runoff quality from various landuses in Malaysia. As such, this pioneer study was conducted in detail to characterise the storm runoff quality from a developed urban residential area.

Rainfall is the main driving force of nonpoint source pollution. Therefore, the daily rainfall data was collected from a nearby station to study the distribution of daily rainfall from 1985 to 2003. It was found that about 83% of the storm

events was less than or equal to 25 mm. This proved that the most frequent and small rainfall events were responsible for more NPS pollution. This finding was in agreement with the hypothesis that frequent rainfall events cause more NPS pollution. Frequency analysis of monthly maximum rainfall revealed that rainfall amount of 3-month return period for the NPS pollution control would be 60 mm.

Fifty-six rain events were monitored to calculate the event mean concentration (EMC) values of the parameters, which are contributed mostly from the nonpoint pollution sources. The median EMC values for Turbidity, TDS, TSS, BOD, COD, Pb, Zn, Cu and Cr were calculated to be 36 NTU, 47.3, 126.5, 29, 120, 0.0143, 0.3046, 0.0135 and 0.0187 mg/L, respectively. These data can be used to calculate the annual pollution loading from an urban residential area with combined sewerage system, which conveys sullage and storm runoff.

It was determined that TSS (78.4%), COD (51.8%), Pb (100%), Zn (80%), Cr (100%) and Cu (52.7%) were mostly generated from the nonpoint pollution sources. This finding was in agreement with the second hypothesis that nonpoint sources contributed more annual TSS, COD and heavy metal loads than point sources in a developed urban residential area. Compared to the point sources, lesser amounts of BOD and TDS loadings were generated from the nonpoint sources, which were 39.1% and 20%, respectively. However, according to the existing water quality guideline, contribution of BOD loading from runoff was considered significant. The hypothesis was not true in the case of BOD and TDS annual loading, which were more generated from the point sources.

First flush phenomenon was also analysed for the selected parameters. It was found that the first flush phenomenon in the study area was weak and irregular indicating that the capture of first flush would not be an effective way to control NPS pollution from the area. Based on the frequency analysis of rainfall data, it was recommended that isolation of first 25 mm runoff would be a more feasible way to control NPS pollution loading from the study area.

Multivariate regression models were proposed for TDS, TSS, Zn and Cu, which could be used to estimate pollution loading from the residential areas having activities and drainage system similar to this study area. Models for other parameters exhibited low coefficients of determinations (less than 0.50) and, therefore, considered not useful for the estimation of pollution load form nonpoint sources of a developed urban residential area.

Water quality indices (WQI) of sullage and storm runoff were calculated to evaluate the average quality of the wastewaters released from the study area. The median WQI of sullage during the working, weekend and non-working days were, 30.2, 31.2 and 26.8, respectively. Sullage quality during the Sunday was inferior to other days by about 3 to 4 WQI points. The mean water quality index of sullage discharged from the study area was equivalent to Class V of INWQS. The median WQI values of storm runoff during minor, medium and large rain events were 38.3, 44.1 and 39.9, respectively. The average runoff quality at the drainage outlet of the residential area was equivalent to Class IV of the INWQS. The study also proposed a water quality index (WQI_R) to evaluate the return water quality form the developed urban residential area. However, further detailed analyses might be required to adopt the proposed WQI_R for implementation.

Abstrak tesis yang disertakan kepada Senat Universiti Putra Malaysia bagi memenuhi syarat untuk mendapatkan ijazah Doktor Falsafah

PENCEMARAN PUNCA BUKAN TITIK DARIPADA KAWASAN PERUMAHAN BANDAR BERIKLIM TROPIKA

Oleh

ABDULLAH-AL-MAMUN

Julai 2005

Pengerusi: **Profesor Azni Idris, PhD**

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Walaupun pelbagai langkah telah diambil oleh Kerajaan, masalah berhubung kualiti air masih tidak dapat dikawal. Ini adalah kerana kebanyakan tumpuan adalah kepada pencemaran punca titik (PS) sedangkan sebahagian besar beban pencemaran tahunan dihasilkan oleh pencemaran punca bukan titik (NPS) menerusi air larian hujan (ribut). Susulan persetujuan Jemaah Kabinet terhadap pelaksanaan Manual Saliran Mesra Alam pada Jun 2000, disedari bahawa untuk menilai kepentingan pencemaran oleh NPS, kajian-kajian terperinci mengenai kualiti air larian hujan (ribut) dari pelbagai guna tanah di Malaysia adalah perlu. Sehubungan itu, kajian perintis ini dilaksanakan untuk menentukan ciri-ciri kualiti air larian hujan (ribut) dari satu kawasan kediaman bandar yang merupakan sebahagian besar guna tanah kawasan yang telah dibangunkan di negara ini.

Hujan adalah faktor utama punca pencemaran NPS. Oleh itu, data hujan harian telah dikumpul dan dianalisis untuk mendapatkan taburan hujan harian dari tahun 1985 hingga 2003. Hasil kajian menunjukkan 83% dari peristiwa hujan, jumlahnya tidak melebihi 25 mm. Ini menunjukkan bahawa kebanyakan peristiwa hujan yang kerap dan sedikit merupakan faktor utama pencemaran NPS. Analisa

kekerapan hujan bulanan untuk nilai maksimum menunjukkan rekabentuk hujan (untuk tempoh 3 bulan kala kembali) untuk kawalan pencemaran NPS di kawasan kajian ialah 60 mm.

Lima puluh enam peristiwa hujan dipantau untuk mendapatkan nilai-nilai "Event Mean Concentration" (EMC) bagi parameter-paramater utama akibat pencemaran NPS. Nilai median EMC untuk Kekeruhan, TDS, TSS, BOD, COD, Pb, Zn, Cu dan Cr masing-masing ialah 36 NTU, 47.3, 126.5, 29, 120, 0.0143, 0.3046, 0.0135 dan 0.0187 mg/L. Data ini boleh digunakan untuk menilai beban pencemaran tahunan dari sebuah kawasan kediaman bandar dengan sistem gabungan kumbahan-limbahan yang mengalirkan air limbah dan air larian hujan.

Dinyatakan di sini bahawa 78.4% TSS, 51.8% COD, 100% Pb, 80% Zn, 100% Cr dan 52.7% Cu adalah disebabkan oleh pencemaran NPS. Kajian ini menepati hipotesis kedua, di mana NPS merupakan penyumbang besar kepada beban tahunan TSS, COD dan logam berat berbanding PS di kawasan penempatan yang membangun. Beban BOD dan TDS yang dihasilkan oleh punca bukan titik iaitu 39.1% dan 20% masing-masing adalah lebih rendah jika dibandingkan dengan punca titik.

Walaubagaimanapun, berdasarkan panduan kualiti air sediada, sumbangan beban BOD daripada air larian hujan adalah dianggap penting. Dalam keadaan ini, hipotesis yang menyatakan beban tahunan BOD dan TDS lebih banyak dihasilkan oleh punca titik adalah tidak sahih.

Fenomena pancur pertama ("first flush phenomenon") juga telah dianalisa untuk parameter-parameter terpilih. Di kawasan kajian, didapati fenomena ini adalah lemah dan tidak menentu. Oleh itu, pengasingan pancur pertama adalah

tidak berkesan dalam pengawalan pencemaran NPS dari kawasan tersebut. Sebaliknya, adalah disyorkan pengasingan 25 mm air larian pertama sebagai langkah paling baik untuk meminimumkan pencemaran NPS di bandar-bandar di Malaysia.

Model regrasi multivariat bagi TDS, TSS, Zn dan Cu telah disarankan untuk menganggar bebanan pencemaran dari kawasan penempatan yang mempunyai aktiviti-aktiviti dan sistem perpaipan yang serupa. Model-model untuk parameter-parameter yang lain menunjukkan kadar bacaan yang rendah (kurang daripada 0.50), dan dengan itu dianggap tidak begitu berfaedah dalam menganggar beban pencemaran NPS di kawasan penempatan membangun.

Indeks kualiti air (WQI) untuk air limbah dan air larian hujan telah dikira bagi menganalisis purata kualiti air kumbahan yang dihasilkan di kawasan kajian. Purata WQI untuk air limbah pada waktu bekerja, cuti hujung minggu dan bukan hari bekerja masing-masing adalah 30.2, 31.2 dan 26.8. Kualiti air limbah pada hari Ahad adalah lebih rendah daripada hari-hari yang lain di antara 3 ke 4 WQI. Purata indeks kualiti air untuk penghasilan air limbah dari kawasan kajian adalah setara dengan kelas V dalam piawaian kualiti air interim kebangsaan (INWQS). Nilai purata WQI untuk air larian hujan semasa minor, medium dan major peristiwa hujan masing-masing ialah 38.3, 44.1 dan 39.9. Purata kualiti air larian hujan di saluran keluar dari kawasan penempatan adalah setara dengan kelas IV dalam INWQS. Kajian ini juga menyarankan indeks kualiti air (WQI_R) dalam menilai kala kembali kualiti air dari kawasan penempatan yang membangun. Walaubagaimanapun, analisa lanjutan yang terperinci adalah perlu dalam pelaksanaan WQI_R.

ACKNOWLEDGEMENTS

With due gratitude to the most merciful Allah, the author would like to extend his heartiest appreciation to the chairman of the supervisory committee Professor Dr. Azni Idris, for providing invaluable guidance, untiring assistance, inspiration and all kinds of supports that helped conduct the study smoothly and efficiently. The author is also deeply indebted to Professor Dr. Mohd. Amin Mohd. Soom and Associate Professor Dr. Wan Nor Azmin Sulaiman, members of supervisory committee, for their various technical and logistical supports, constructive suggestions, proper guidance and encouragement throughout the study period.

The study would be more difficult to conduct if Mr. Robert would not be generously kind enough to allow UPM to install and keep the valuable equipments in his safe premises. The author would like to extend his special appreciation to Mr. Robert and his family members to allow the author enter their premises anytime during day and night.

Thanks are also due to the staff members of all laboratories (Chemical and Environmental, Biochemical, Environmental Science, Biology, Public Health and Sanitation, Geomatic, etc.), Mrs. Maslinda, Mr. Zoha, Mr. Sujat, Mr. Termizi, Mr. Ismail and Mr. Zakaria for their valuable and timely assistance throughout the course of the study. Also special thanks to Miss Aida for her help teaching me various laboratory techniques. Grateful acknowledgements are also extended to the members of the Department of Chemical and Environmental Engineering for their

help and cooperation. The author is grateful to MPSJ for the kind approval to conduct the study in their drainage system. Sincere appreciation is also due to StormLab Services Sdn. Bhd. for allowing the author to use their valuable equipments as and when necessary.

The author's heartfelt appreciation goes to his parents and relatives for their continuous anxiousness and prayers to the Almighty for the timely completion of the study. Sacrifices made by author's family members and kids are priceless.

Very special thanks to Mr. Mamun for his valuable encouragements during the difficult times, to Dr. Taufik and Dr. Safa for teaching the author about the statistical techniques; to Dr. Katayon for valuable suggestions and guidance on the field work and laboratory analyses, to Mr. Hamid for his valuable time for various discussions, to Mr. Kyarul Anuar for AutoCAD drawings, to Mr. Amlir for checking English of the thesis and to translate the abstract into Bahasa Melayu.

It is too numerous to mention all names here, although the author would like to call upon every one's name who provided supports in various ways to complete this study.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Description
α	Constant or Interception of the Regression Model
β	Coefficient for Runoff of the Regression Model
δ	Coefficient for Storm Duration of the Regression Model
ϵ	Error Term
γ	Coefficient for Dry Duration of the Regression Model
ξ	A Removal Coefficient for Build-up and Wash-off Model
ψ	Coefficient for Peak 5-minute rain Intensity of the Regression Model
a	Pollutant Loading Factor or Total Groups of Data for ANOVA
A	Area
AAS	Atomic Adsorption Spectrophotometer
ADP	Antecedent Dry Period
ADT	Average Daily Traffic
AEC	Australian Environmental Council
AN	Ammoniacal Nitrogen
ANOVA	Analysis of Variance
APHA	American Public Health Association
APWA	American Public Works Association
ARI	Average Recurrence Interval
BCF	Biased Correction Factor
BMP	Best Management Practice
BOD	Biological Oxygen Demand
C	Runoff Coefficient
Cd	Cadmium
CI	Portion of Commercial and Industrial Area
cm	Centimetre
COD	Chemical Oxygen Demand
Cr	Chromium
CSO	Combined Sewer Overflow
Cu	Copper
CV	Coefficient of Variation
d	Depression Storage
D_d	Dry duration between two consecutive rain events
DA	Total Contributing Drainage Area
DBKL	Dewan Bandaraya Kuala Lumpur
DCIA	Directly Connected Impervious Area
DID	Department of Irrigation and Drainage
DOE	Department of Environment
DP	Dissolved Phosphorus
DUR	Duration
DWF	Dry Weather Flow
e	Exponent
EMC	Event Mean Concentration
EQA	Environmental Quality Act
f	Population Density Function
FF	First Flush

LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Description
GHD	Gutteridge, Haskins and Davey
GIS	Geographical Information System
gm	Gram
H	Curb Height
ha	Hectare
I	Average Imperviousness of the Catchment Area
I_5	Peak 5-minute Rainfall Intensity During an Event
IA	Impervious Area as a Percentage of the Total Catchment Area
IDF	Intensity-Duration-Frequency
INT	Rainfall Intensity
JICA	Japan International Cooperation Agency
K_u	Urban Wash-off Coefficient
kg	Kilogram
KL	Kuala Lumpur
L	Pollution Load
L_r	Pollution Loading Rate
LAS	Days since Last Rain Event Having Rainfall Higher than 25 mm
LUC	Amount of Commercial Landuse
LUI	Amount of Industrial Landuse
LUN	Amount of Residential Landuse
LUR	Amount of Undeveloped or Natural Landuse
m^2	Square Metre
mg	Milligram
mm	Millimetre
M_s	Amount of Pollutant
MAR	Mean Annual Rainfall
Max	Maximum
Min	Minimum
MJT	Mean Minimum Temperature in January
MMS	Malaysian Meteorological Services
MPN	Most Probable Number
MPSJ	Majlis Perbandaran Subang Jaya
MSMA	Manual Saliran Mesra Alam
N or n	Number of Storm Event
NA	Not Available
ND	Not Detected
Ni	Nickel
NPS	Nonpoint Source
NS	Not Sampled
NT	Not Tested
NTU	Nephelometric Turbidity Unit
NURP	Nationwide Urban Runoff Program
O&G	Oil and Grease
ON	Organic Nitrogen
OP	Ortho Phosphate