Transmission of Nutrient in Urban Environment

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Certificate

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Abstract

Gross pollutant traps (GPT) are installed in many urban drainage systems in Australia to control stormwater pollutants from urban catchments. Stormwater pollutants (e.g. leaf litter) are trapped in the GPT during stormwater runoff events. If these devices are not managed properly, they may lead to deterioration of receiving water quality by introducing nutrients (phosphorus and nitrogen) from the leaf litter during dry weather periods between events. This study evaluated the release of nutrients from leaf litter in a GPT system and a novel conceptual model was developed for the prediction of phosphorus at the outlet of GPT. Catchment runoff and mathematical model were used to create an integrated model able to predict the phosphorus response from a GPT. The knowledge gained in this research is expected to contribute to improve understanding the impact of GPT on downstream water bodies.

Leaf litter collected from Centennial Park was found to be a significant source of nitrogen and phosphorus where the total nitrogen (TN) and total phosphorus (TP) content were 5.1 mg g^{-1} and 0.381 mg g^{-1} respectively. The releases of TN and TP from leaf litter were determined by considering a GPT environment. Initially, the phosphorus release declined exponentially with time. Consideration of the results indicated that the rate of phosphorus release was 0.0274 d^{-1} for the first 90 days and the release rate was 0.0195 d^{-1} for 180 days. Measured higher phosphorous release rate (90 days) was used to develop conceptual model. The quantity of TP loss from leaf litter was ~88% of the P in the leaf litter for the first 90 days and ~6% for the second 90 days. This suggests that the initial rapid TP release was due to higher rate of leaching of phosphorus. It was observed that the variation of phosphorus release from GPT is associated with the quantity of trapped leaf litter and inter-event dry period. The study also found that longer retention time released more phosphorus confirming the degradation of leaf litter.

Results showed that the TP released from leaf litter was faster than the release of TN. About 54% of the total phosphorus was released while 20% of the total nitrogen was released within the same time frame (22 days). This suggests that nitrogen released at a slower rate. The change of pH, increase in electrical conductivity (EC) and decrease in dissolved oxygen (DO) further confirmed the decomposition of leaf matrix.

As part of this study, a model of catchment runoff quantity and quality was used. This model was based on the Stormwater Management Model (SWMM) and was used to consider different factors influencing stormwater quantity and quality from the catchment. In this study, different rainfall temporal patterns were used to investigate the influence of rainfall characteristics on catchment runoff. It was found that the predicted peak flow and loss varied significantly with rainfall temporal patterns. The rainfall loss increased and the rainfall loss rate decreased with storm duration. Furthermore, it was found that the runoff volume generated by 1 year ARI was enough to replace the volume of water stored within GPT. Therefore, rainfall events with 1 year ARI and durations of 5, 10, 20, 30, 45, 60 and 120 min were considered to determine the inlet hydrograph for the GPT.

Appropriate model was developed for quantification of phosphorus, in particular the TP released from leaf litter in GPT system. The SWMM model was applied to determine the catchment runoff flow in GPT which enabled estimating of phosphorus in the stormwater runoff. The catchment runoff was used as inflow to the GPT while the out flow was obtained from level pool routing of flow through the GPT. Model simulation results showed that the predicted total phosphorus load from decay of the leaf litter in the GPT was transported downstream for most storm events.

This confirmed that novel conceptual model developed in this study is capable to estimate outlet phosphorus concentration of GPT for different storm events. This information may be useful to recommend catchment management approaches to improve water quality and to set management priorities and thereby enhance the design of stormwater management systems. Hence, the results of this research have shown that catchment management need to consider leaf litter as a source of phosphorus and nitrogen in assessing downstream receiving water quality.

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Abbreviations

AHD	Australian Height Datum
APHA	American Public Health Association
ARE	Absolute Relative Error
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ARR	Australian Rainfall & Runoff
BMP	Best Management Practice
CDS	Continuous Deflective Separation
CV	Coefficient of Variance
EC	Electrical Conductivity
EMC	Event Mean Concentration
DIP	Dissolved Inorganic Phosphorus
DOP	Dissolved Organic Phosphorus
GPT	Gross Pollutant Trap
N	Nitrogen
P	Phosphorus
PP	Particulate Phosphorus
TN	Total Nitrogen
TP	Total Phosphorus
TSP	Total Soluble Phosphorus
SD	Standard Deviation
SWMM	Storm Water Management Model
USEPA	United States Environmental Protection Agency

Nomenclature

X	mass of dry matter remaining at time t
X_o	initial mass of dry matter
k	decomposition rate constant
Q_{GI}	inflow in GPT during time Δt, $m^3\ s^{-1}$
Q_{GO}	outflow in GPT during time Δt, $m^3\ s^{-1}$
Δt	time step, s
V	volume of water in GPT, m^3
Q_1^I	inflow in GPT at the beginning of time step Δt, $m^3\ s^{-1}$
Q_2^I	inflow in GPT at the end of time step Δt, $m^3\ s^{-1}$
Q_1^O	outflow in GPT at the beginning of time step Δt, $m^3\ s^{-1}$
Q_2^O	outflow in GPT at the end of time step Δt, $m^3\ s^{-1}$
V_1	volume of water in GPT at the beginning of time step Δt, m^3
V_2	volume of water in GPT at the end of time step Δt, m^3
C_1^G	concentration of P in GPT at the beginning of time step Δt, mg L^{-1}
C_2^G	concentration of P in GPT at the end of time step Δt, mg L^{-1}
C_1^I	concentration of P at inlet of GPT at the beginning of time step Δt, mg L^{-1}
C_2^I	concentration of P at inlet of GPT at the end of time step Δt, mg L^{-1}
C_1^O	concentration of P at outlet of GPT at the beginning of time step Δt, mg L^{-1}
C_2^O	concentration of P at outlet of GPT at the end of time step Δt, mg L^{-1}
P_{LL}	mass of P release from leaf litter in GPT at Δt, mg
P_{LL1}	P release from leaf litter at the beginning of time step Δt

P_{LL2}	P release from leaf litter at the end of time step Δt
ΔP	change in mass of P in GPT mg
P_{GI}	mass of P entering in GPT at Δt, mg
P_{GO}	mass of P leaving GPT at Δt, mg
S	storage, m^3
A	wetted cross-sectional area, m^2
R	hydraulic radius
n	Manning’s roughness co-efficient

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