Nutrient Sources and Dynamics in the Parafield Stormwater Harvesting Facility and Implication to Water Quality Control

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Table of Contents

ABSTRACT

The quantity of stormwater runoff from the city of Adelaide almost matches the demand for drinking water. It therefore becomes increasingly important as an alternative source for water supply. This research focused at the Parafield Stormwater Harvesting Facility near Adelaide in order to better understand: (1) nutrient dynamics between the water column, sediments and plant community, (2) allochthonous and autochthonous sources of nutrients and (3) nutrient retention capacity of the reed bed.

A weekly monitoring programme for the physical and chemical parameters of the water column, sediment and plant community was carried out over three years for specific locations within the reed bed. Ordination and clustering of the time series data revealed distinctive seasonal and spatial nutrient patterns.

The concentrations for total nitrogen (TN) showed high concentrations for the summer period (1.04 to 1.86 mg/L) and low concentration for the winter season (0.25 to 0.46 mg/L). For the other nitrogen fractions in form of nitrate (NO_3^-) and ammonium (NH_4^+) the seasonal patterns were different to that of TN. In NO_3^- the concentrations were high during the summer and winter seasons and NH_4^+ showed high concentration during the spring. The seasonality for total phosphorus (TP) showed high concentration for the spring period (0.049 to 0.163 mg/L) and low concentration for the other seasons (0.01 to 0.019 mg/L). A similar pattern has been observed for phosphate (PO_4^{3-}) as well. The dissolved organic carbon (DOC) concentrations showed high concentrations during the summer period (21.36 to 31.64 mg/L) and low concentration during the winter seasons (5.48 to 7.14 mg/L).

The seasonal pattern for the nutrient contents of the plant community showed highest concentrations during summer (5.5 to 34.2 gTN/kg) and lowest concentrations in winter (0.2 to 7.7 gTN/kg).

Nutrient concentrations in the sediments were highest during the non-growing seasons (autumn and winter). This result indicated that the function of sediments changes seasonally from being a sink during the non-growing season by accumulating both allochthonous and autochthonous nutrients in the rainy season, and becoming a source during the growing seasons due to nutrient release from anaerobic sediments supporting the growth of the macrophyte community. Overall the function of sediment in reed bed pond of the Stormwater Harvesting Facility was to be a source of nutrients and therefore no accumulation of nutrients occurred during the study period.

The research has demonstrated that the reed bed currently performs as a reasonable nutrient retention system with following nutrient removal rates: 0.85 mg TN /m^2/day, 0.79 mg NO_3^- /m^2/day, 0.28 mg NH_4^+/m^2/day, 0.05 mg TP /m^2/day, 0.04 mg PO_4^{3-} /m^2/day, and 5.75 mg DOC /m^2/day. Seasonal difference in the water retention time showed that the for most of the nutrients the removal performance was most effective during autumn and winter with the exception of the removal performance of P forms, which most effective during spring and summer. For TN, NO_3^- and DOC the RE was most efficient at a residence time >15days, for TP and PO_4^{3-} it is 5-10 days and for NH_4^+ it is <5days.

Time–series modelling of the monitoring data resulted in rule-based prediction models for the different nutrients. Sensitivity analyses of the models revealed key driving variables for the nutrient dynamics of the reed bed. The prediction results revealed that the DO was the key driving variable influencing the nutrient concentrations in the water column and therefore to improve the water quality of the treatment water DO levels have to maintained above the threshold of 4 mg/L. Beside DO other key driving variables were turbidity, ORP and the nutrient levels from the previous site. Therefore the control of these parameters would be the start to develop a management plan for best-practice management in terms of water quality at the Parafield Stormwater Harvesting Facility.

Keywords: Parafield Stormwater Harvesting Facility, Constructed wetland, Stormwater, Nitrogen, Phosphorus, Dissolved Organic Carbon, Management

Statement of Originality

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Young Kil KIM

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List of Figures

List of Tables

List of Abbreviations

ANN = Artificial Neural Network

ASR = Aquifer storage and recovery

BOD = Biological Oxygen Demand

CO_2 = Carbon dioxide

COD = Chemical Oxygen Demand

CWS = Constructed wetland system

CWST = Constructed wetland for stormwater treatment

DIC = Dissolved Organic Carbon

DIP = Dissolved Inorganic Phosphorus

DNRA = Dissimilatory nitrate reduction to ammonia

DO = Dissolved Oxygen

DOC = Dissolved Organic Carbon

DOM = Dissolved Organic Matter

DON = Dissolved Organic Nitrogen

DOP = Dissolved Organic Phosphorus

EC = Electrical Conductivity

$FePO_4$ = Iron (III) phosphate

GPT = Gross Pollutant Trap

HEA = Hybrid Evolutionary Algorithm

HRT = Hydrologic Retention Time

KANN = Kohonen Artificial Neural Network

L-DOC = Labile Dissolved Organic Carbon

ML = Megaliter

N_20 = Nitrous oxide

NH_3 = Ammonia

NH_4^+ = Ammonium

NO_2^- = Nitrite

NO_3^- = Nitrate

NPS = Non-Point Source

NSNN = Non-Supervised Neural Network

NTU = Nephelometric Turbidity Units

PCA = Principal Component Analysis

PH_3 = Phosphine

PO_4^{3-} = Phosphate

POC = Particulate Organic Carbon

POM = Particulate organic Matter

PON = Particulate Organic Nitrogen

PP = Particulate Phosphorus

PS = Point Source

R-DOC = Refractory Dissolved Organic Carbon

RZM = Root Zone Method

RT = Residence Time

SF = Surface Flow

SOM = Self-Organizing Map

SSF = Subsurface Flow

TDS = Total dissolved solids

TSS = Total suspended solids

TN = Total Nitrogen

TP = Total Phosphorus