

# ASSESSMENT OF NUTRIENT LOADS AND SELF-REMEDIATION: A CASE STUDY OF THE SOUTH RANGSIT CANAL IN THAILAND'S PATHUM THANI PROVINCE

\* Boontarika Thongdonphum<sup>1</sup>, Kittima Vanichkul<sup>1</sup>, Saming Champasri<sup>1</sup> and Jirapon Kulkham<sup>1</sup>

<sup>1</sup>Faculty of Agricultural technology, Rajamangala University of Technology Thanyaburi, Thailand

\*Corresponding Author, Received: 16 May. 2017, Revised: 11 Sept. 2017, Accepted: 1 Dec. 2017

**ABSTRACT:** This research investigates the effects of seasonal variability (rainy and dry seasons) and nutrient transfer patterns on the nutrient loads (dissolved inorganic nitrogen (DIN) and orthophosphate phosphorus (P)) and the self-remediation of the south *Rangsit* canal in Thailand's central province of *Pathum Thani*. The results showed that the physicochemical characteristics of the canal water severally varied from season to season, with the ammonium-nitrogen ( $\text{NH}_4^+\text{-N}$ ), nitrite and nitrate-nitrogen ( $\text{NO}_2^- + \text{NO}_3^-\text{-N}$ ) and orthophosphate phosphorus ( $\text{PO}_4^{3-}\text{-P}$  or P) concentrations in the range of 10.79-85.35; 56.70-135.79; and 0.74-5.66  $\mu\text{mol L}^{-1}$ , respectively. The DIN and P loads were 5.05 and 0.40 tons/day in the rainy season (September); and 5.12 and 0.32 tons/day in the dry season (March). The relative remediation efficiency ( $\text{EF}_R$ ) were mostly negative, especially in the dry season, indicating the inadequate self-remediation and nutrient input-output imbalance. The findings also showed that water mass transfer directions influenced the self-remediation and nutrients accumulation in the study area.

*Keywords: Nutrient loads, Self-remediation, Dissolved inorganic nitrogen, Orthophosphate phosphorus*

## 1. INTRODUCTION

The south *Rangsit* canal is located in Thailand's central province of *Pathum Thani*, 50 km north of the capital Bangkok [1]. The canal is on the east of the *Chao Phraya River* and approximately 54 km in length [2]. Land utilization along the canal is categorized into four main categories: urban areas, agriculture, aquaculture, and industry [3]. In fact, the unregulated development in the area contributes to the deteriorating biochemical composition in the canal, including excessive nutrient loadings [4].

A recent census shows that there are approximately 1.1 million people living along or near the south *Rangsit* canal, equivalent to 660 residents per  $\text{km}^2$ . In addition, the quality of the canal water deteriorates as the area develops due to increasing volumes of sewage, domestic discharges and agricultural chemical residues [5]. Typically, the quality of waterways in urban areas is inversely correlated with the level of urbanization [6]. Rapid urbanization and industrial and agricultural development, coupled with inadequate sewerage systems, contribute to elevated material inputs in the water resources, e.g. nitrogen (N) and phosphorus (P) [7].

The causes of water pollution range from untreated municipal and industrial wastewater, eutrophication, trace metals contamination to petroleum hydrocarbons [8]. Specifically, river water chemistry is tied to natural (e.g. rainfall) and anthropogenic factors, e.g. land use, urbanization,

sewage discharge and nonpoint sources, including stormwater runoffs from agricultural and urban areas [9]. Thus, this current research aims to comparatively investigate the effects of seasonal variability (the rainy and dry seasons) and nutrient transfer patterns on the anthropogenic nonpoint-source nutrient loads (DIN and P loads) and the self-remediation, in terms of the relative remediation efficiency ( $\text{EF}_R$ ), of the south *Rangsit* canal. The findings are expected to be applied to effectively manage the water resources and the anthropogenic wastewater drainage in the area.

## 2. MATERIALS AND METHODS

### 2.1 Sampling sites

In this research, six localities with high population density along the south *Rangsit* canal were selected as the sampling stations (Fig.1). The water sampling was conducted in two separate time periods to take account of the effects of seasonal variability on the nutrient loadings: September 2014 (rainy season) and March 2015 (dry season). Under the influence of monsoon winds, Thailand has three seasons: the rainy season (May-September), winter season (October-February) and dry season (March-April) [10]. In addition, the south *Rangsit* canal receives most water from the *Chao Phraya River*, which is situated on the west side of the canal and is under the jurisdiction of the South Rangsit Irrigation Office, which is responsible for management and

maintenance of the canal water to meet the local demand [6].

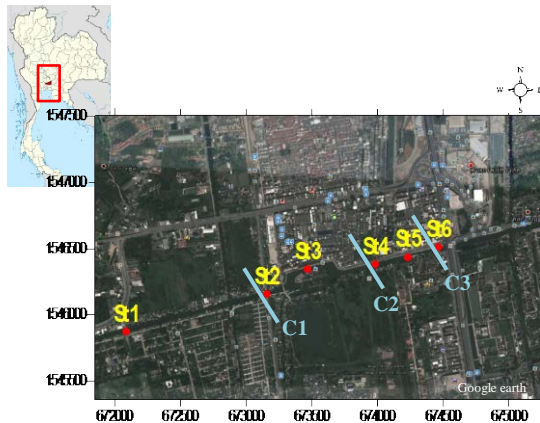


Fig. 1 Satellite image of the south Rangsit canal with the six sampling stations (Stn.1-6) and three cross-sectioned sites (C1, C2, C3), where the Chao Phraya River is on the west side

### 2.2 Sample collection and analysis

The temperatures, dissolved oxygen (DO), salinity and pH of the water samples were measured with a multi-parameter probe (YSI-6600 Sonde instrument) at the sampling sites (stn.1-6). In the nutrient loads (DIN and P) analysis, surface water samples (30 cm deep) were collected and pre-filtered using GF/F (Whatman) and retained at 4°C for further analysis. The ammonium (NH<sub>4</sub><sup>+</sup>), nitrite and nitrate (NO<sub>2</sub><sup>-</sup>+NO<sub>3</sub><sup>-</sup>) and orthophosphate (PO<sub>4</sub><sup>3-</sup>) concentrations were determined using a SKALAR segmented flow analyzer, given the corresponding detection limits of 0.70-57.14; 0.70-14.28 and 0.03-3.87 μmol L<sup>-1</sup>.

Specifically, the DIN and P loads were assessed at the three cross-sectional sites (C1 (stn.2), C2 (stn.4), C3 (stn.6)) using a two-dimensional Surfer model. The nutrient loads were approximated by (1)

$$M_i = 8.64 \times 10^{-7} [\text{Conc}] A_i U_h \Delta t_i \quad (1)$$

where M<sub>i</sub> is the amount of nutrient load (ton/day), Conc is the nutrient concentration (μg L<sup>-1</sup>), A<sub>i</sub> is the cross-sectional area of section i (m<sup>2</sup>), U<sub>h</sub> is the flow velocity of section i (cm/s) and Δt<sub>i</sub> is the length of time (i.e. 1 day) [11].

### 2.3 Data analysis

The physicochemical properties of the water samples associated with both sampling periods (September 2014 and March 2015) were determined using descriptive statistics and presented as the means ± standard deviations (SD). A t-test was used to verify the statistical difference

between the two study periods, with p≤0.05. The self-remediation of the south Rangsit canal at the three cross-sectional sites (C1, C2, C3) was approximated in terms of the relative remediation efficiency (EF<sub>R</sub>) using (2)

$$EF_R (\%) = \frac{[\text{Input}-\text{Output}]}{\text{Input}} \times 100 \quad (2)$$

where Input and Output are respectively the nutrient (DIN and P) loads that transfer into and out of each cross-sectional site (C1, C2, C3).

## 3. RESULTS

Table 1 tabulates the physicochemical characteristics of the water samples for both study periods (rainy and dry seasons). The results revealed that the water temperatures and salinity minimally varied from season to season (p≤0.05) and were lower in the dry season. The location (stn.1-6) and seasonal variability had no significant impact on the pH levels as they remained relatively constant throughout. The DO varied in response to the seasonal variability and alarmingly below Thailand's minimum threshold of 4 mgL<sup>-1</sup>. In addition, the average levels of NH<sub>4</sub><sup>+</sup> and NO<sub>2</sub><sup>-</sup>+NO<sub>3</sub><sup>-</sup> varied significantly (p≤0.05) with seasons. The minimum and maximum concentrations of NH<sub>4</sub><sup>+</sup>, NO<sub>2</sub><sup>-</sup>+NO<sub>3</sub><sup>-</sup> and PO<sub>4</sub><sup>3-</sup> associated with the rainy and dry seasons were respectively 10.79 and 85.35 μmol L<sup>-1</sup>; 1.87 and 135.79 μmol L<sup>-1</sup>; and 0.74 and 5.66 μmol L<sup>-1</sup>. The observations also revealed that NH<sub>4</sub><sup>+</sup> was high in the rainy season, while NO<sub>2</sub><sup>-</sup>+NO<sub>3</sub><sup>-</sup> was high in the dry season.

Table 1 The physicochemical properties of the water samples (mean±SD)

Parameters	Study period	
	September 2014 (rainy)	March 2015 (dry)
Temp (°C)	31.43±0.09 <sup>a</sup>	30.07±0.05 <sup>b</sup>
DO (mg L <sup>-1</sup> )	0.75±0.35 <sup>a</sup>	2.90±0.61 <sup>b</sup>
Salinity (psu)	0.27±0.01 <sup>a</sup>	0.17±0.01 <sup>b</sup>
pH	7.40±0.12 <sup>a</sup>	7.50±0.08 <sup>a</sup>
NH <sub>4</sub> <sup>+</sup> (μmol L <sup>-1</sup> )	79.99±4.33 <sup>a</sup>	27.73±24.66 <sup>b</sup>
NO <sub>2</sub> <sup>-</sup> +NO <sub>3</sub> <sup>-</sup> (μmol L <sup>-1</sup> )	5.21±5.08 <sup>a</sup>	90.52±29.42 <sup>b</sup>
PO <sub>4</sub> <sup>3-</sup> (μmol L <sup>-1</sup> )	3.94±1.37 <sup>a</sup>	2.20±1.42 <sup>a</sup>

Note: The values in the same row with different superscript letters are significantly different (p≤0.05).

Furthermore, variations in the DIN:P molar ratio were determined and compared against the Redfield N:P ratio of 16:1 to assess the status of nutrient contamination. The DIN:P molar ratios associated with the rainy and dry seasons were in the range of 15.01-43.66 and 29.92-197.64,

respectively. Specifically, the DIN:P molar ratios varied from season to season and were elevated in the dry season. The large variation (>16:1) was attributable to the elevated DIN load as the land along both sides of the canal is densely populated and predominantly utilized for economic purposes.

Table 2 tabulates the cross-sectional area, the water volume and the current velocity associated with the three cross-sectional sites (C1, C2, C3). In the rainy season (September), C2 exhibited the highest volume and velocity of  $4.84 \times 10^6$  tons/day and 50.31 cm/s, respectively. Meanwhile, in the dry season (March), C1 had the lowest volume and velocity of  $0.91 \times 10^6$  ton/day and 10.06 cm/s.

Table 2 Water volume and velocity of the three cross-sectional sites (C1, C2, C3) in the rainy (September) and dry (March) seasons

Sectional site	Section area (m <sup>2</sup> )	Volume (10 <sup>6</sup> ton/day)		Velocity (cm/s)	
		September 2014	March 2015	September 2014	March 2015
C1	105.24	2.68	0.91	29.44	10.06
C2	111.28	4.84	1.66	50.31	17.28
C3	98.61	2.81	3.49	32.95	40.95

The nutrient loads (DIN and P) associated with C1, C2 and C3 were estimated using (1), and the results indicated that the DIN and P loads were respectively in the range of 1.48 - 5.12; and 0.05 - 0.40 tons/day. The highest DIN load of 5.12 tons/day was registered at C3 in the dry season and the highest P load (0.40) at C3 in the rainy season.

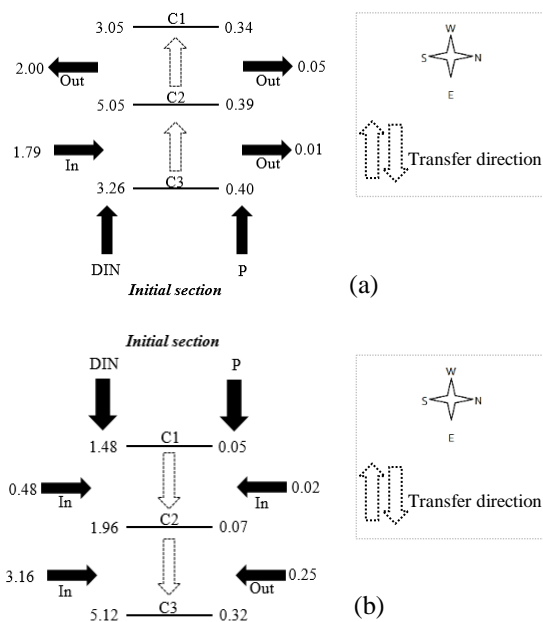


Fig. 2 DIN and P transport (ton/day) at the three cross-sectional sites: (a) rainy season (September 2014), (b) dry season (March 2015)

Figs. 2a-b respectively illustrate the nutrient transport at the three cross-sectional sites (C1, C2, C3) in the rainy and dry seasons. In the rainy season, the canal water travels in the east-west direction (C3→C2→C1) toward the *Chao Phraya* River (Fig. 2a), while the course is reversed (C1→C2→C3) in the dry season (Fig. 2b). The results showed no nutrient overload in the rainy season (September), as evidenced by the DIN and P loads of 3.05 and 0.34 tons/day, vis-à-vis the initial loads of 3.26 and 0.40 tons/day. This, in turn, suggested adequate self-remediation by the canal. However, the situation was reversed in the dry season (March), when the DIN and P loads rose to 5.12 and 0.32 tons/day from originally 1.48 and 0.05 tons/day, indicating low self-remediation and the subsequent nutrient overload.

In Fig. 3, the positive relative remediation efficiency (EF<sub>R</sub>) was achievable only in the C2→C1 section in the rainy season, with EF<sub>R</sub> for DIN and P of 39.60% and 12.82%, respectively. Meanwhile, the EF<sub>R</sub> associated with the other sections (C3→C2, C1→C2, C2→C3) were negative, indicating the nutrient input-output imbalance. To improve the self-remediation of the canal, especially in the C3 →C2 section during the dry season, requires a larger recharge from the *Chao Phraya* River in the dry season and the imposition of restrictions on the discharge of wastewater into the canal.

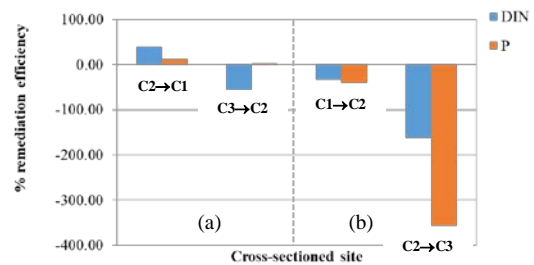


Fig. 3 The relative remediation efficiency (EF<sub>R</sub>, %) for DIN and P: (a) rainy season (b) dry season, where C1, C2, and C3 respectively denote the cross-sectional sites 1, 2 and 3

#### 4. DISCUSSION

The research results indicated that the temperature and salinity of the canal water minimally varied with seasons, while the pH levels remained relatively constant throughout. According to [4], freshwater inflow and precipitation-induced drainage influenced the salinity level. The findings also revealed the alarmingly low dissolved oxygen (DO), below Thailand's minimum threshold of 4 mgL<sup>-1</sup>, rendering it unfit for the aquatic animals [12]. The low DO could be attributed to the bacterial decomposition of organic waste matters [4].

Furthermore, the high DIN and P nutrient concentrations suggested the anthropogenic contamination, given the high population density along and near both sides of the south *Rangsit* canal. Generally, nutrient loadings in the river are linked to the natural and anthropogenic sources, e.g. runoff from urban areas and plantations; and inflow through organic-rich ground [13]. In addition, the non-point sources, e.g. stormwater runoff and runoff from agricultural and urban areas, contributed significantly to the riverine biogeochemistry [9].

In water quality assessment,  $\text{NH}_4^+$  is an important determinant of the water quality [14]. Specifically, the  $\text{NH}_4^+$  levels in water bodies should be below  $1 \text{ mg L}^{-1}$  (or  $71.4 \text{ } \mu\text{mol L}^{-1}$ ) [15], and the  $\text{PO}_4^{3-}$  levels below  $1 \text{ } \mu\text{mol L}^{-1}$  to avert eutrophication [4]. Nevertheless, the  $\text{PO}_4^{3-}$  levels in the south *Rangsit* canal were in excess of the limit.

In essence, the anthropogenic activity and water mass transfer direction of the south *Rangsit* canal contributed to the high DIN and P loads and a nutrient input-output imbalance in the dry season when the nutrient loads were excessive. According to [11],[13], nutrients in the water could be diluted or enhanced in response to the areas that the water flows through and the nutrient concentrations in turn influence the self-remediation of the waterway. Specifically, the pollutants loads during the rainy season are linked to the point and non-point sources [16]. In addition, land use could contribute to nitrogen enrichment in the river [17], while phosphorus emission from wastewater is prevalent in highly populated areas [18].

Moreover, the  $\text{EF}_R$  of the area (along with the south *Rangsit* canal) were predominantly negative, indicating inadequate self-remediation and the nutrient input-output imbalance [11], a phenomenon that could be attributed to diverse anthropogenic activities that subsequently altered the land-sea fluxes [19] and the balance in the aquatic ecosystem [20].

## 5. CONCLUSION

This research has investigated the effects of seasonal variability (rainy and dry seasons) and nutrient transfer patterns on the anthropogenic nonpoint-source nutrient loads (DIN and P loads) and the self-remediation of the south *Rangsit* canal in Thailand's central province of *Pathum Thani*. The findings revealed the maximum DIN and P loads of 5.12 tons/day in the dry season (March) and 0.40 ton/day in the rainy season (September), respectively. In addition, the predominantly negative  $\text{EF}_R$  for DIN and P indicated the inadequate self-remediation and subsequent nutrient input-output imbalance. To address such

an imbalance requires a larger recharge from the *Chao Phraya* River in the dry season and the imposition of restrictions on the discharge of wastewater into the canal. The observations also showed that water mass transfer directions influenced the water drainage, nutrient dilution and nutrient accumulation in the area.

## 6. ACKNOWLEDGMENTS

The authors would like to extend deep gratitude to the Faculty of Agricultural Technology, Rajamangala University of Technology Thanyaburi (RMUTT) for the financial support.

## 7. REFERENCES

- [1] Pathum Thani Office Center, Development Plan of Pathum Thani Province, assessed: <http://www2.pathumthani.go.th/551017.pdf>. (April 3, 2017)
- [2] RIO 11, Data Project, South Rangsit Irrigation Project, Regional Irrigation Office 11, Royal Irrigation Department, Ministry of Agriculture and Cooperatives, assessed: <http://ridceo.rid.go.th/pathum/rangsit/s/Data.html> (Aug 22, 2012)
- [3] Thongkumpow J. and Sumpnanpanit P., Water Use Patterns of the Irrigation Area in Klong Rang Sit Tai, Environmental research institute, Chulalongkorn university intellectual repository, 1997.
- [4] Thongdonphum B., Meksumpun S., Meksumpun C., Sawasdee B. and Kasemsiri P., The Predictive Model for Biochemical Component of Phytoplankton in the River and Estuary System of the Mae Klong River, Thailand, International Journal of Environmental and Rural Development, Vol. 4-1, 2013, pp. 13-18.
- [5] REO 6, Environmental Status in the Western Report, 2011, Ministry of Natural Resources and Environment, Thailand.
- [6] RIO 11, Data Project, South Rangsit Irrigation Project, Regional Irrigation Office 11, Royal Irrigation Department, Ministry of Agriculture and Cooperatives, assessed: <http://ridceo.rid.go.th/pathum/rangsit/s/Data.html> (May 2, 2017)
- [7] Gilbert P.M., Mayorga E. and Seitzinger S., *Prorocentrum minimum* Tracks Anthropogenic Nitrogen and Phosphorus Inputs on Global Basis: Application of Spatially Explicit Nutrient Export Models, Harmful Algae, Vol. 8, 2008, pp. 33-38.
- [8] Cheevaporn V. and Menasveta P., Water Pollution and Habitat Degradation in the Gulf of Thailand, Marine Pollution Bulletin, Vol. 47, 2003, pp. 43-51.

- [9] David S.E., Chattopadhyay M., Chattopadhyay S. and Jennerjahn T.C., Impact of Human Interventions on Nutrient Biogeochemistry in the Pamba River, Kerala, India, *Science of the Total Environment*, Vol. 541, pp. 1420-1430.
- [10] TMD, Climate of Thailand, Thai Meteorological Department, Thailand, assessed: <https://www.tmd.go.th/info/info.php?FileID=53> (April 4, 2017)
- [11] Thongdonphum B., Meksumpun S. and Meksumpun C., Nutrient Loads and their Impacts on Chlorophyll *a* in the Mae Klong River and Estuarine Ecosystem: An Approach for Nutrient Criteria Development, *Water Science and Technology*, Vol. 64(1), 2011, pp. 178-188.
- [12] Pollution Control Department, Water Quality Standard, assessed: [http://www.pcd.go.th/info\\_serv/reg\\_std\\_water06.html](http://www.pcd.go.th/info_serv/reg_std_water06.html) (March 20, 2016)
- [13] Xia Y., Ti C., She D. and Yan X., Linking River Nutrient Concentrations to Land Use and Rainfall in a Paddy Agriculture-urban Area Gradient Watershed in Southeast China, *Science of the Total Environment*, Vol. 566-567, 2016, pp. 1094-1105.
- [14] Wang S., Lu A., Dang S. and Chen F., Ammonium nitrogen Concentration in the Weihe River, central China during 2005-2015, *Environmental Earth Science*, Vol. 75, 2016, 512.
- [15] PHILMINAQ, Water Quality Criteria and Standards for Freshwater and Marine Aquaculture, Mitigating Impact from Aquaculture in the Philippines, assessed: <https://www.researchgate.net/file.PostFileLoader.html?id=571b93653d7f4b012861d0a1&asSetKey=AS%3A354056255098880%401461424997739>. (Mar 2, 2016)
- [16] Hema S. and Muthalagi S., Mass Balance Approach for Assessment of Pollution Load in the Tamiraparani River, *International Journal of Chem Tech Research*, Vol. 1(2), 2009, pp. 385-389.
- [17] Li R., Liu S., Zhang G., Ren J. and Zhang J., Biogeochemistry of Nutrients in an Estuary Affected by Human Activities: the Wanquan River Estuary, eastern Hainan Island, China, *Continental Shelf Research*, Vol. 57, 18-31.
- [18] Mockler E.M., Deakin J., Archbold M., Gill L., Daly D. and Bruen M., Sources of Nitrogen and Phosphorus Emission to Irish Rivers and Coastal Waters: Estimates from a Nutrient Load Apportionment Framework, *Science of the Environment*, Vol. 601-602, 2017, pp. 326-229.
- [19] Álvarez-Vázquez M.A., Prego R., Ospina-Alvarez N., Caetano M., Bernárdez P., Doval M., Filgueiras A.V. and Vale C., Anthropogenic Changes in the Fluxes to Estuaries: Wastewater Discharges Compared with River Loads in Small Rias, *Estuarine, Coastal and Shelf Science*, Vol. 179, 2016, pp. 112-123.
- [20] Markogianni V., Varkitzi I., Pagou K. and Dimitriou E., Nutrient Flows and Related Impacts between a Mediterranean River and the Associated Coastal Area, *Coastal Shelf Research*, Vol. 134, 2017, pp. 1-14.