

Analysis and Characterization of the Nutrient Concentration of Thatluang Marsh Attributed to Wastewater Discharges from Vientiane City, Lao PDR

Somphone Inkhamseng^{1,*} and Veokham Vilaysane²

^{1,2} Water Resources Engineering Department, Faculty of Engineering, National University of Laos, Vientiane Capital, Lao PDR

inkhamsengs@gmail.com^{1,*}

Abstract. *The analysis and characterization of the nutrient concentration of Thatluang Marsh is needed in order to evaluate the ability of a natural marsh to assimilate waste as well as to develop management schemes to maintain and enhance the integrity of the marsh. This study is mainly concerned with the analysis and characterization of the temporal and spatial variation of nutrient concentrations in Thatluang marsh (i.e., a natural marsh) as well as its major tributary rivers and canals located in the Makhiao river basin. The marsh area is about 20 km² and mainly occupied by residential areas and some agricultural areas. Monthly nutrient concentration and daily water discharge observed from October 2011 to August 2012 were used in this study. In particular, the nutrient data from the marsh and major tributary rivers and canals were sampled for nitrogen and phosphorus species in the form of ammonium-nitrogen (NH₄-N), nitrite-nitrogen (NO₂-N), nitrate-nitrogen (NO₃-N), total nitrogen (TN), phosphate-phosphorus (PO₄-P) and total phosphorus (TP). The nutrient concentrations at Kae canal were the highest compared to the other stations during the study period with values of 16.04 mg/l for TN and 14.80 mg/l for TP. The NH₄-N concentration at Kae canal and the outlet sometimes exceeded the water quality for irrigation water by FAO standards. The results indicate that relatively high amounts of NH₄-N emanate from the municipal area. The NH₄-N, NO₂-N and NO₃-N concentrations were low during the entire observation period at Khae river and Papiao river, compared to Kae canal. The low concentrations might be attributed to the low population density upstream of these sampling points. The TN and TP loads at the outlet of the marsh were higher than the sum of the loads at the other gauging points.*

Keywords:

Makhiao river basin, nitrogen, nutrient, phosphorus, Thatluang marsh

1. Introduction

Vientiane, the capital city of Lao PDR with its population of 616,000, has a unique waste water treatment system. Most of the wastewater discharges from factories and households in Vientiane city directly goes into Thatluang marsh, whose water surface area is about 20 km². The water undergoes natural purification processes in Thatluang marsh, before it is discharged to Mekong river through Makhiao river.

However, it is seriously concerned that the purification capacity of Thatluang marsh may be declining because of recent shrinkage of its water surface area. The expansion of arable land by the local people and the construction of building by Lao government are considered as the major causes of the shrinkage of the marsh. It is also concerned that the rapid shrinkage of the marsh greatly alters the natural ecosystem of the marsh and consequently causes various environmental problems around the marsh and the downstream areas.

In order to seek an appropriate management plan of the marsh coping with both population increase and environment protection, it is necessary to grasp the current movement of the water and the contaminants flowing through the marsh. It is important to evaluate the current purification capacity of the marsh accurately.

2. Methods

2.1 Sampling Point

The sampling points where water samples were taken from the rivers and the canal were selected near Thatluang marsh, which is located in the southern part of Makhiao watershed. The locations of the canal and rivers in which the samples were taken and the land covers around the marsh are shown in Fig. 1. Samples were collected from Kae canal, Papiao river and Khae river that flow into Thatluang marsh.

Kae canal locates at the northwest of Thatluang marsh and both sides of the canal consist of urban areas with factories and households. Samples were also taken at the outlet of Thatluang marsh, which is about 15 km west of Vientiane downtown.

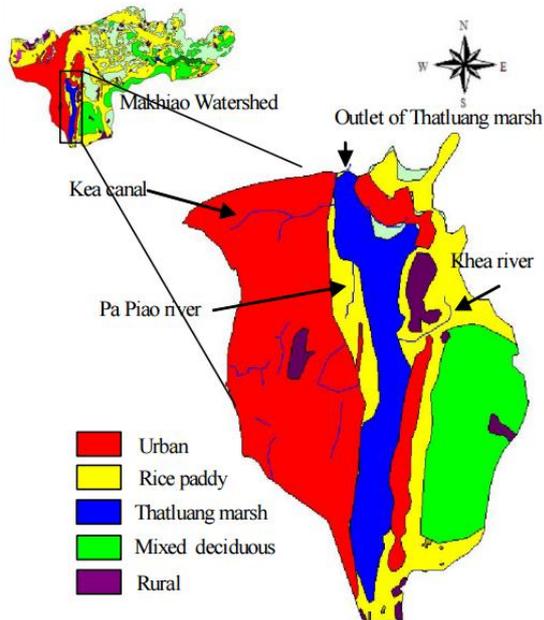


Fig. 1 Location of the canal and the rivers in which the samples were taken and the land cover around the marsh.

2.2 Hydrological Observation

The study period of the present study covers 11 months from October 2011 to August 2012. At the gauging stations in the selected rivers and the canal, the water depth was measured daily by a scale and the flow velocity was measured daily by a float. The cross section areas of the flow were calculated from the observed water depth and the shape of the river cross section surveyed beforehand. The discharge was calculated as a product of the cross section area and the flow velocity. Water samples were taken once a month directly from the water surface by a 500 ml clear plastic bottle at the gauging stations. 44 river water samples were taken during study period.

2.3 Analytical Methods

The After the immediate pre-treatment to prevent possible quality changes, the samples were kept at about 4°C until being analyzed in the laboratory at Water Quality Monitoring center, Ministry of Agriculture and forestry, Vientiane. The samples were analyzed for total nitrogen (TN), ammonium-nitrogen ($\text{NH}_4\text{-N}$), nitrate-nitrogen ($\text{NO}_3\text{-N}$), nitrite-nitrogen ($\text{NO}_2\text{-N}$), phosphate-phosphorus ($\text{PO}_4\text{-P}$) and total phosphorus (TP) by a spectrophotometer (Hach, Model DR/4000U) and a digester boy (Model TNP-1).

3. Results and Discussions

3.1 Flow Characteristics

The flow characteristics of the 4 gauging stations for the period from October 19, 2011 to August 31, 2012 were examined. Changes in the discharge at the gauging stations are shown in Fig. 2. During the study period, the discharge varied in the range from 0.36 to 5.19 m^3/s , from 0.09 to 2.21 m^3/s , from 0.03 to 1.29 m^3/s and from 0.03 to 0.75 m^3/s for the outlet of Thatluang marsh, Kae canal, Papiiao river and Khae river, respectively.

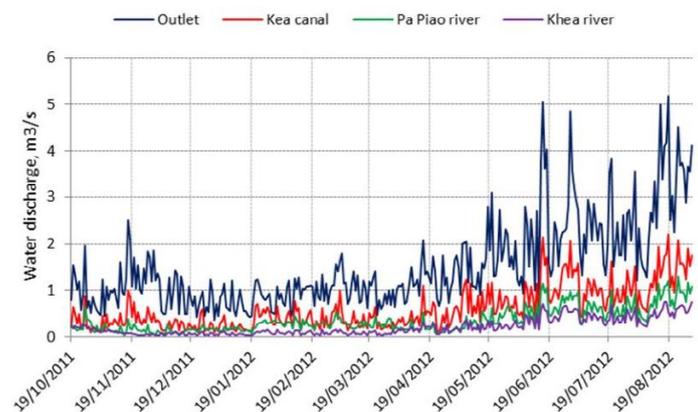


Fig. 2 Change in discharge flows at the gauging stations.

3.2 Nutrient Concentration Level

Table 1 and Table 2 show the mean and the range of the observed nutrient concentrations. The mean is the simple arithmetic average and is not weighted by the corresponding discharge. The TN concentration at the outlet varied in the range between 3.00 and 13.06 mg/l and the mean TN concentration was about 80% of that in Kae canal. The $\text{NO}_2\text{-N}$ and $\text{NO}_3\text{-N}$ concentrations at all stations were not so high compared to the maximum concentration for drinking water recommended by USEPA (1996) and WHO (1993). The $\text{NH}_4\text{-N}$ concentration at Kae canal and the outlet sometimes exceeded the water quality for irrigation water presented by FAO (website). It is suggested that a relatively higher amount of $\text{NH}_4\text{-N}$ flowed out from the municipal area and was detected at the sampling station in Kae canal and the outlet.

The $\text{PO}_4\text{-P}$ concentrations at all station were high compared to the international standards for drinking water and water quality for irrigation water as mentioned above. It is considered that the $\text{PO}_4\text{-P}$ concentration would be elevated by effluents from agricultural land and municipal areas. TP concentrations at the outlet stayed in the range between 1.40 and 10.60 mg/l and the mean TP concentration was about 69% of that in Kae canal.

Parameters (mg/ L)	Outlet of the Marsh	
	Mean	Range
NH ₄ -N	1.59	0.10-5.60
NO ₂ -N	0.07	0.02-0.18
NO ₃ -N	0.84	0.15-1.70
TN	8.64	3.00-13.06
PO ₄ - P	2.00	0.50-5.80
TP	5.42	1.40-10.60

Table 1 The mean and the range of the observed nutrient concentrations at the outlet of the marsh .

Parameters (Unit)	Kae Cannel		Pa Piao River		Khae River	
	Mean	Range	Mean	Range	Mean	Range
NH ₄ -N	2.33	0.29-5.40	0.45	0.10-0.93	0.35	0.10-0.80
NO ₂ -N	0.06	0.02-0.11	0.16	0.01-0.34	0.06	0.02-0.14
NO ₃ -N	0.83	0.10-2.40	1.10	0.20-2.00	0.63	0.20-1.80
TN	10.87	3.66-16.04	2.48	1.03-4.62	1.36	0.74-2.90
PO ₄ - P	2.35	0.49-5.00	0.82	0.08-2.80	0.79	0.01-2.80
TP	7.90	2.10-14.80	2.08	0.26-5.10	1.95	0.18-8.10

Table 2 The mean and the range of the observed nutrient concentrations at the Kae cannel, Pa Piao river and Khae river.

3.3 Seasonal Variation in Nutrient Concentrations

Several interesting facts were revealed by the in-situ observation in the present study. For example, the nitrogen and phosphorus concentrations showed different characteristics in their seasonal variation. The variation in the concentrations in nitrogen and phosphorus species during the study period is shown in Fig. 3 – Fig. 6. The highest TN concentration at Kae canal was observed to be 16.04 mg/l in January 2012. While at Khae river and Papiiao river, the highest TN concentration were observed to be 2.90 and 4.62 mg/l in October 2011 and in May 2012 respectively. For the TN concentration peak in May at Papiiao river, it is considered that nitrogen accumulated in the watershed and the stream bed during the dry season was flushed by the first runoff in the beginning of the rainy season. The NH₄-N, NO₂-N and NO₃-N concentrations were low during the whole observation period at Khae river and Papiiao river, compared to Kae canal. The lower concentrations might be attributed to the lower population density in the upstream of these sampling points.

On the other hand, the TP concentrations at Khae river, Papiiao and the outlet of the marsh were high in October. It is suggested that higher coverage of agricultural land in the upstream of the sampling points and fertilizer utilized by farmers in dry season may contribute the TP concentration peak in October. The maximums of the PO₄-P concentration were recorded to be 5.8, 5.0, 2.8 and 2.8 mg/l in April 2012 at the outlet, Kae canal, Papiiao river and Khae river, respectively. The sharp increase in the phosphorus species corresponded to the first small rise of the discharge after the low flow period. It is suggested that the first runoff after the

dry season took the accumulated in the marsh and on the river bed to the river water and consequently brought about the sharp increase of the phosphorus concentrations.

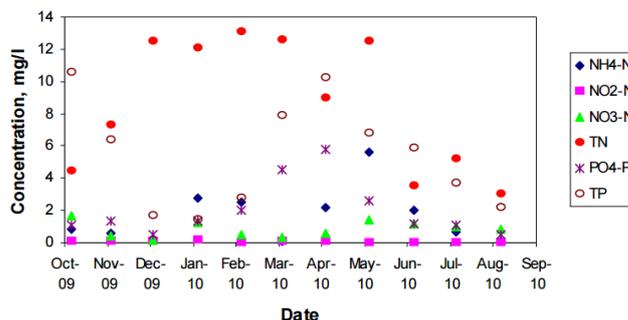


Fig. 3 The variation in the concentrations in nitrogen and phosphorus at the outlet of Thatluang marsh.

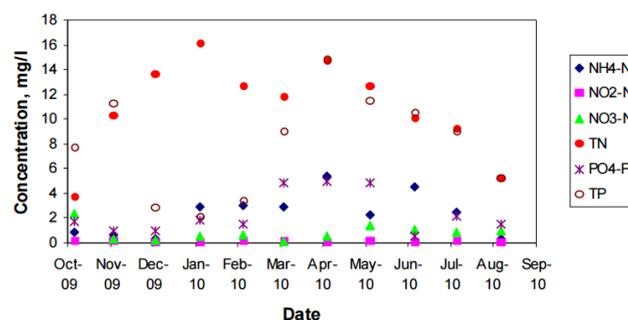


Fig. 4 The variation in the concentrations in nitrogen and phosphorus at Kae canal.

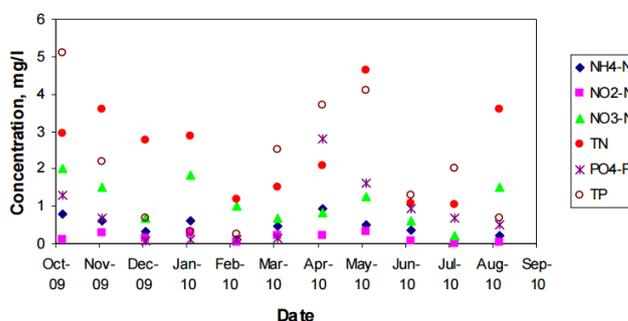


Fig. 5 The variation in the concentrations in nitrogen and phosphorus at Papiiao river.

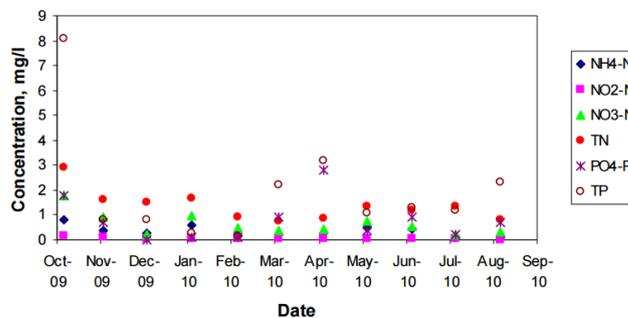


Fig. 6 The variation in the concentrations in nitrogen and phosphorus at Khae river.

3.4 Estimation of nutrient loads

The seasonal variations in the nitrogen and phosphorus loads were significantly governed by the changes in the discharge. The highest loads at all stations occurred in August, apparently because of a large amount of discharge carrying the nutrients.

During the study period (11 months), the TN and TP loads flowed through each observation station were calculated roughly to be 278, 153, 19, 7 tons and 179, 136, 13 and 11 tons at the outlet, Kae canal, Papiiao and Khae river, respectively.

4. Conclusions

To grasp the current movement of the water and the contaminants flowing through Thatluang marsh, the water flow and the nutrient concentrations in major inflow rivers and canal into the marsh were measured from October 2011 to August 2012.

The mean TN concentration at the outlet of the marsh was about 80% of that in Kae canal, while the mean TP concentration at the outlet of the marsh was about 69% of that in Kae canal. The $\text{NH}_4\text{-N}$ concentration at Kae canal sometimes exceeded the water quality for irrigation water given by FAO. It is suggested that a relatively higher amount of $\text{NH}_4\text{-N}$ flowed out from the municipal area. The $\text{PO}_4\text{-P}$ concentrations at all stations were also high compared to the water quality for irrigation. It is considered that the $\text{PO}_4\text{-P}$ concentration would be elevated by effluents from agricultural land and municipal areas. The maximums of the $\text{PO}_4\text{-P}$ concentration were recorded as 5.8, 5.0, 2.8 and 2.8 mg/l in April 2012 at the outlet, Kae canal, Papiiao river and Khae river, respectively. The sharp increase in the phosphorus species corresponded to the first small rise of the discharge after the low flow period.

The changes in the nutrient loads were governed by the changes in the discharge, clearly due to a large amount of discharge carrying the nutrients. The TN and TP loads at the outlet of the marsh were higher than the sum of the loads at other three observed stations at the upstream of the marsh.

5. Acknowledgments

This study was supported by fund of the Kurita Water and Environment Foundation, KWEF of Japan. The authors would like to express sincere thanks to all students who supported this study.

References

- [1] FAO, <http://www.fao.org/docrep/003/t0234e/T0234E01.htm#ch1-4and/or,http://www.fao.org/docrep/003/t0234e/t0234E00.htm>

- [2] USEPA (1996), "Quality criteria for water. EPA 440 / 5-86-001", U.S. Environmental Protection Agency, Washington DC, USA.
- [3] WHO (1993), Guidelines for drinking water quality. World Health Organization, Geneva, Switzerland.
- [4] Iida T. et al (2004) Seasonal variations in nutrient loads in the Mekong River at Vientiane, Lao PDR.
- [5] Iida T. et al (2007) Seasonal variation in nitrogen and phosphorus concentration in the Mekong River at Vientiane, Lao PDR.

Bibliography

Somphone INKHAMSENG was born in Vientiane, Laos in February 1965. He received this bachelor and master degree in Surface Water Hydrology from Saint Petersburg, Russia in 1992 and his doctoral degree in Environmental Engineering from the University of Philippines, the Philippines. He is currently an Acting Head of Department of Water Resources and Development in Faculty of Water Resources, National University of Laos. His research interests are water engineering, water quality modeling and environment management.