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Abundance of Particulate Phosphorus and its Form in Mae Klong River, Thailand

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ABSTRACT

Phosphorus is an essential element for living organisms. However, an excess loading of phosphorus produces undesirable eutrophication in water bodies. However, different phosphorus species play different roles in the bioavailability and geochemical cycling of phosphorus in the water column. Few studies on the abundance and form of particulate phosphorus have been conducted in Thailand. This study investigated the abundance of particulate phosphorus, in both organic and inorganic forms, in the Mae Klong river, Thailand. The variation in abundance of particulate phosphorus and its form were examined. Low Total Particulate Phosphorus (TPP) concentrations were found upstream, with two TPP peaks at the MK7 and MK10 stations, which are located near urban areas. Within the TPP pool, Particulate Organic Phosphorus (POP) was the dominant form of particulate phosphorus at eight sampling stations, whereas Particulate Inorganic Phosphorus (PIP) was the dominant form at four sampling stations. The high proportion of POP in the TPP pool and strong relationship between TPP, POP, and chlorophyll *a* suggested that phytoplankton was a source of particulate phosphorus in the Mae Klong River. Our findings on the abundance and chemical speciation provide a better understanding of the cycle of this bioactive element and, will support the establishment of water management and regulation in the Mae Klong River.

Keywords: Phosphorus; Particulate inorganic phosphorus; Particulate organic Phosphorus; Mae Klong River

1. Introduction

Phosphorus is an essential element for all living organisms. In freshwater and coastal water, phosphorus has an important role as a limiting factor of primary production of phytoplankton. It also plays a role in the biogeochemical processes of carbon and nitrogen dynamics [1, 2]. An

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excess loading of phosphorus has undesirable consequences, producing eutrophication in water bodies Important sources of phosphorus include natural processes (weathering and soil erosion) and human activities such as wastewater from urban settlements, industry, and agriculture.

Phosphorus in dissolved and particulate forms, is found in water bodies. Both are further divided into two forms: inorganic and organic. Dissolved Inorganic Phosphorus (DIP) is the most frequently studied due to its being the most biologically available form encouraging growth of phytoplankton. However, some phosphorus forms that are not available directly may be transformed into bioavailable phosphorus. The soluble ortho-phosphorus concentration is largely controlled by the release of phosphorus from suspended particulate matter (SPM) [3]. Phosphorus from SPM in the aquatic environment is as significant as DIP [4]. Inorganic phosphorus attached to the surface of SPM is released as DIP when the salinity changes or in conditions of hypoxia (low oxygen concentration) [2, 5]. The abundance and form of particulate phosphorus in Thailand has not widely studied.

In this study, the abundance of particulate phosphorus, both organic and inorganic forms in the Mae Klong River, was investigated. The relationship between each form of particulate phosphorus and water quality was also studied.

2. Materials and Methods

Surface water at a depth of 0.5 m. was taken from 12 sampling stations on the Mae Klong River in March 2015 (Fig. 1; Table 1).

All samples were collected with a pre-cleaned plastic bucket and kept in a dark and cool place at 4°C for transporting to laboratory. Water quality factors such as temperature (°C), salinity (ppt), and pH were measured in the field.

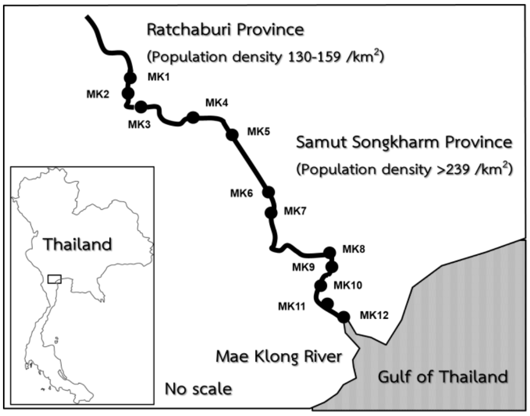

Fig. 1. Locations of sampling sites in the Mae Klong River, Thailand.

Table 1. Positions of sampling sites in the Mae Klong River from station MK1 to MK12

Station	Position (UTM)
MK-1	587725E 1502610N
MK-2	588658E 1499444N
MK-3	589512E 1497171N
MK-4	595388E 1495987N
MK-5	598637E 1494356N
MK-6	602069E 1488505N
MK-7	602323E 1486269N
MK-8	606621E 1483819N
MK-9	607937E 1482573N
MK-10	606602E 1480049N
MK-11	607372E 1479032N
MK-12	609031E 1476410N

A portion of each water sample (0.5 L) was passed through two 47 mm pre-combusted (550°C, 2 h) Whatman Glass Fiber Filters (GF/F). Filtered samples were dried at 60°C and kept in a dry place for TPP and PIP determination. Filtrate samples were stored in pre-cleaned glass bottles and kept at -20°C. For chlorophyll *a* determination, water samples were passed through a 47 mm GF/F filter, and extracted in 90% acetone for ca. 24 h.

Concentrations of TPP and PIP were analyzed using combustion and colorimetric methods [5, 6, 7]. Filter samples were combusted at 470°C for 2 h, then soaked with 1 N HCl in glass vials for 12-16 h. After extraction, the supernatant was neutralized by 1 N NaOH and absorption was measured following the method by Murphy and Riley [8]. The concentrations of TPP were calculated from the absorbance of the extractions. The concentrations of PIP were estimated by a similar method but without the use of combustion. Concentrations of POP were estimated from the difference in concentration between TPP and PIP [5]. The PIP concentration was divided by the TPP concentration to give the molar ratio. The DIP and chlorophyll *a* concentrations were measured using the method by Murphy and Riley [8] and Strickland and Parsons [9].

The relationship between TPP, POP, and PIP and the water quality parameters of salinity, DIP, and chlorophyll *a* were analyzed using Pearson's correlation coefficient.

3. Results and Discussion

The abundance of TPP, PIP, and POP in Mae Klong River during the study period is shown in Fig. 2 and Table 2. The TPP concentration was low at station MK1 (upstream) and increased gradually until the maximum was reached at station MK7. The TPP concentration then decreased, producing a second peak at station MK10 (downstream) near Samut Songkram city. The average TPP was 0.072 ± 0.021 µM. The PIP concentration first increased, reaching a peak at MK7 same station with TPP, then fell before rising again to form a second peak at MK11. The POP showed the same overall trend, but with peaks at MK6 and MK10. The average PIP and POP concentrations were 0.034 ± 0.016 and 0.038 ± 0.015 µM, respectively. The TPP, PIP and POP concentrations were lower than those reported for the Bang Pakong River Estuary [10] which was at 0.14 to 0.70 µM for PIP and 0.22 to 1.19 µM for POP. Low phosphorus concentrations in the upstream and higher concentration near Samut Songkram city which had the highest population density supported the findings of Lebo and Sharp [11], who reported low TPP concentrations in the upstream Delaware River and higher concentrations around urban and industrial areas. Hence the increasing of TPP, PIP and POP concentrations in the Mae Klong River might associate with the discharge of municipal wastewater. High concentration of TPP, PIP and POP around station MK 6 and 7 might have been a result of the discharge of wastewater from local community i.e. Amphawa Floating Market.

In this study, the form of particulate phosphorus showed a considerable variation through the river. A low PIP/TPP ratio (0.21) was observed at station MK1 and a higher ratio (0.91) at station MK11 (Table 1), with an average of 0.462 ± 0.173. Thus, again confirmed previous studies, a significant variation in the PIP/TPP ratio has been reported in several studies. For example, Suzumura [5] found that the PIP/TPP ratio in the Arakawa River ranged from 0.12 to 0.86. Asahi [12] reported that the PIP/TPP ratio ranged from 0.12 to 0.79 in Harima Nada, Seto Inland Sea. Loassachan [10] reported that the PIP fraction made a smaller contribution than POP in low salinity zone with an average of 0.39. Lin [2] suggested that the dominant form of particulate phosphorus may indicate a TPP source in the water column. Asahi [12] reported that terrestrially derived TPP contains a higher abundance of PIP than autochthonous TPP in water, whereas phytoplankton derived TPP contains a lower abundance. We also found that the average PIP/TPP ratio (0.46 ± 0.17) of particulate phosphorus in the Mae Klong River is close to that produced by *Alexandrium minutum* cultures [13]

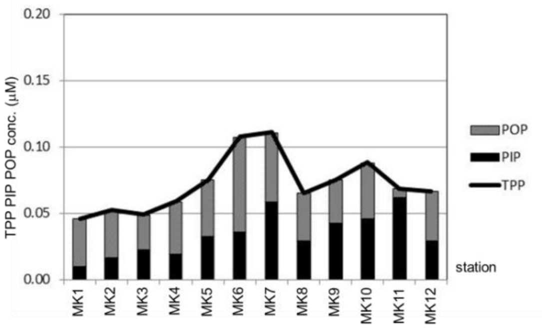

Fig. 2. TPP PIP POP concentration in the Mae Klong River from station MK1 to MK12

Table 2. PIP POP concentration and PIP/TPP ratio in Mae Klong River from station MK1 to MK12

station	PIP (µM)	POP (µM)	PIP/TPP
MK1	0.010	0.036	0.22
MK2	0.017	0.036	0.32
MK3	0.023	0.026	0.47
MK4	0.020	0.039	0.34
MK5	0.033	0.042	0.44
MK6	0.036	0.072	0.34
MK7	0.059	0.052	0.53
MK8	0.030	0.036	0.45
MK9	0.043	0.033	0.57
MK10	0.046	0.042	0.52
MK11	0.062	0.007	0.91
MK12	0.030	0.037	0.44

During the study period, the average surface water temperature, salinity, and pH were 28.5 ± 0.84°C, 0.8 ± 0.86 ppt, and 7.8 ± 0.18, respectively. Fig. 3 showed a variation in the DIP and chlorophyll *a* concentration from station MK1 *to* MK12. Average DIP and chlorophyll *a* concentrations were 0.1 ± 0.08 µM and 9.5 ± 4.12 µg/L, respectively. No relationship was found between salinity or DIP concentration, and any form of particulate phosphorus. Nor was a relationship found between chlorophyll *a* concentration and PIP (r = 0.110, n = 12, P = 0.733). However, significant correlations were found between TPP or POP, and chlorophyll *a* concentration (r = 0.651, n = 12, P = 0.021 and r = 0.788, n = 12, P = 0.002). Fig. 4 shows the relationship between chlorophyll *a* and TPP, and POP concentration. Yoshimura [14] found that POP concentrations in North Pacific Ocean surface water correlated closely with chlorophyll *a* concentrations (r = 0.950, n = 18). This correlation suggest that the POP pool was composed of mainly living algal cell constituents, including nucleic acids, nucleotides and phospholipids. Our finding suggested that phytoplankton is a major source of particulate phosphorus in the Mae Klong River based on the high proportion of POP in the TPP pool and the strong relationship found between TPP, POP, and chlorophyll *a*.

Lin [2] reported that different forms of phosphorus have different biogeochemical reactivity, and that different phosphorus species may play different roles in the bioavailability and geochemical cycling of phosphorus in the water column. Even under the conditions where the total phosphorus loading is constant, the changes in the stoichiometry of the bioavailable forms of P can have dramatic impacts on the receiving waters. Corell [4] suggested that particulate or dissolved organic phosphorus in the aquatic systems should not be inert, as under appropriate conditions these forms can be converted to PO_4^{3-}. Particulate phosphorus may release PO_4^{3-} and organic phosphorus compounds in solution to the water column. The organic phosphorus compounds may be chemically or enzymatically hydrolyzed to

PO_4^{3-} [4, 15]. Our finding on the abundance and chemical speciation provide an understanding of the role of this bioactive element. Different forms of particulate phosphorus may play different roles in the bioavailability and impacts on the receiving waters. This information will support the establishment of water management and regulation in the Mae Klong River.

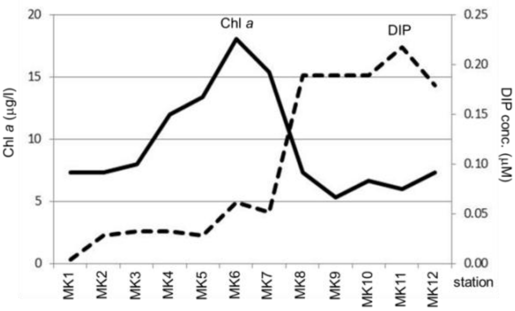

Fig. 3. DIP and chlorophyll *a* concentration in the Mae Klong River from station MK1 to MK12

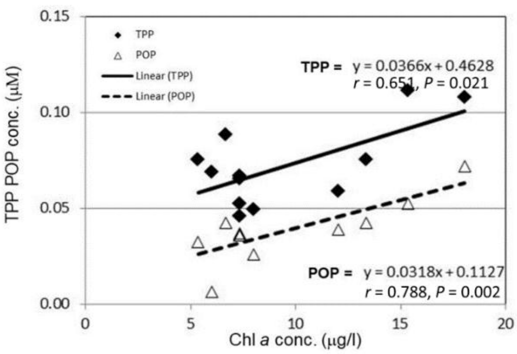

Fig. 4. Relationship between Chlorophyll *a* against TPP, and POP concentration

4. Conclusion

This study was the first to investigate the variation in particulate phosphorus abundance and its form in the Mae Klong River. We found low TPP concentrations upstream and two TPP peaks at stations MK7 and MK10, which are located near urban areas. Within the TPP pool, POP was found to be the major form of particulate phosphorus (PIP/TPP ratio < 0.5) at eight sampling stations. Thus, phytoplankton is a major source of particulate phosphorus in the Mae Klong River. However, PIP was a major form at four sampling stations (PIP/TPP ratio > 0.5). Change of major form of TPP pool might be caused by the effect of terrigenous input. Our finding on the abundance and chemical speciation provide an understanding of the cycle of this bioactive element, and will support the establishment of water management and regulation in the Mae Klong River.

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