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The Guidelines for Water Quality Management on the Middle of Tha Chin River

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Abstract

The objectives of this research were to study the Water Quality Index (WQI) in the Middle Tha Chin River, conduct a comparative analysis of land use in the Middle Tha Chin River Basin between 2007 and 2019, and prepare the guidelines/mechanism where required for water quality restoration in the Middle Tha Chin River. Based on the research, the overall water quality in the Middle Tha Chin River was classified as poor, with the WQI of 58. Land uses in Suphan Buri and Nakhon Pathom have changed to a large extent in 2019, compared to those in 2007, in both upward and downward directions, especially in urban and built-up land. The guideline /mechanism, which is required for polluted water remediation, the wastewater treatment system should be improved, to make it more effective and better function, while the water treatment service should be extensively provided to cover the whole area. At the same time, local administrative organizations should also be encouraged to issue the municipal laws about wastewater treatment, determine wastewater treatment service fees and push for the collection of such fee. Apart from that, public relations campaigns should also be conducted to provide knowledge to the public, especially those living on riverbanks. Public participation should be promoted in the preparation of the local wastewater management plan while grease traps should also be installed, with maintenance-related knowledge provided, especially to those living on riverbanks, in order to minimize the amount of wastewater released into the river and its tributaries.

Keywords: Guideline, Water Quality, Land use

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Introduction

The current situation of fierce trade and investment competitions, including population growth despite the limitation of natural resources, have resulted in the overconsumption of resources and hence caused several impacts to environment. One of them is water pollution[1] which is considered the problem that brings about various types of effects, for example, health effects,[2] life effects, effects to industrial and agricultural sectors, etc. As water pollution sources have not been managed effectively, wastewater generated by households, industrial waste, and agricultural sites both plantation and animal husbandry. In addition, there is no community wastewater system that is available and suitable for agricultural wastewater including swine farming and aquaculture.

The Water Quality Index (WQI) has been used as a tool to raise public and stakeholders' awareness of the surrounding surface water qualities. The Chin River Basin covers an area of 13,446.49 sq.km. or 8,403,041 rai,[3] and is divided into 3 parts, namely, upper, middle, and lower part. The upper Tha Chin River Basin starts from Pho Phraya Floodgate, Suphan Buri Province, and ends at Ban Pak Khlong Makham Thao, Wat Sing District, Chainat Province (km. 202 - 325). Its surface water quality has been categorized as Class 2 (WQI = 71-90). As for the middle Tha Chin River Basin, which starts from Nakhon Chai Si District Office, Nakhon Pathom Province, and ends at Poh Phraya Floodgate, Suphan Buri Province (km. 82 - 202), its surface water quality has been categorized as Class 3 (WQI = 61-70) whereas the lower Tha Chin River Basin, which starts from the river mouth in Mueang Samut Sakhon District, Samut Sakhon Province, and ends at Nakhon Chai Si District Office, Nakhon Pathom Province (km. 0 – 82), has its surface water quality categorized as Class 4 (WQI = 31-60).

At present, the wastewater produced by the households in Tha Chin River Basin is approx. 502,799 cu. m. per day despite the limited capacity of the Wastewater Treatment System that can only support 34,358 cu. m. of wastewater per day,[4] or equivalent to 6% of the wastewater generated. The water demand in the middle Tha Chin River Basin can be classified into 5 types as follows: 1) Water for Consumption and Tourism – This is the demand of the people living in both urban and suburban areas. It was found that in the middle Tha Chin River Basin, the total demand for raw water was 146.84 million cu. m. per year, which was equivalent to 0.40 million cu. m. per day while the production capacity of raw water was only 122.37 million cu. m. per year, or equivalent to 0.33 million cu. m. per day. Quantitatively, there was a water shortage of 70,000 cu. m. per day. 2) Water for Agricultural Use – There was a demand of 6,773.30 million cu. m. per year. 3) Water for Industrial Use – There was a demand of 118.08 million cu. m. per year. 4) Water for Livestock Use – There was a demand of 58.85 million cu. m. per year. 5) Water for Ecosystem Preservation – There was a demand of 977.70 million cu. m. per year. The total water demand for all categories was approx. 8,074.77 million cu. m. per year.[5]

Although there were 35 large dams around the country, carrying 70,926 million cu. m. of water totally, Thailand was still severely suffering from droughts.[6] As droughts had occurred occasionally in the Tha Chin River Basin, the problems of saltwater intrusion into the Tha Chin River have been faced, esp. during dry seasons.[7] To make it worse, the water quality deterioration, combined with the increasing water demand due to population growth, also resulted in a shortage of fresh water required to replace the wastewater although dilution is not a solution. Referring to the Tha Chin River data as of year 2022, the Upper Tha Chin River water quality was fair (having of average WQI = 67) while the Middle and Lower Tha Chin River were deteriorated (for both middle and lower having of average WQI = 57). As the results of WQI, it is not in accordance with the Notification of the National Environment Board No. 8, B.E. 2537 (1994), Prescribing the Surface Water Quality Standards, which are showing that the Middle Tha Chin River is risky to generate the water pollution problems and possibly makes the water quality of the lower Tha Chin River more deteriorate.

Based on the land use statistics in the Tha Chin River Basin from 2007 to 2017, the following changes were found: The area of land use for urban expansion and various constructions had changed from 0.774 to 0.867 million rai, or 0.093 million rai increase; the land use for field crops had increased by 0.169 million rai; the land use for horticulture had increased by 0.099 million rai; and the land use for pasture planting had increased by 0.028 million rai. On the other hand, the land use for paddy fields had changed from 2.943 to 2.715 million rai, or 0.228 million rai decrease; the land use for perennial trees had decreased by 0.009 million rai; the land use for orchards had decreased by 0.118 million rai; and the land use for aquaculture land had decreased by 0.033 million rai. Changes in land use during the past 10 years, both in upward and downward directions, might affect changes in water quality.[8] There were some researches where WQI had been used to identify the quality of water, both domestically and overseas, for example, the test of Duhok Lake water quality conducted in 1999, 2000 and 2009, showed that its WQI was over 100, which exceeded the criteria required for drinking water standard, and could be interpreted as low quality. This resulted from human activities and hence, regular monitoring would be essential for prompt management of the situation.[9]

However, to achieve a comprehensive water quality analysis, the most important factor is a selection of water quality parameters and the setting of scores, in a way that it will truly reflect water classification, enabling an accurate trend analysis of the water quality in each region.[10] WQI had also been used to assess the water quality in the Li River, which problem was found to be resulted from human activities, including the continual expansion of communities, which caused the Li River water quality to deteriorate, not to mention the lack of effective integration guidelines among the public sector, the private sector, and the public.[11] In this research, the WQI calculation method published by the Pollution Control Department and the land use data obtained from the Land Development Department were applied to identify the surface water quality, the data of which would be used for preparing the guidelines for water quality restoration in the middle Tha Chin River, to have the water quality improved in compliance with the Notification of the National Environment Board No. 8, B.E. 2537 (1994), Prescribing the Surface Water Quality Standards[12], and the Notification of the Pollution Control Department, dated 7 June 1994, Regarding Classification of the Water Sources in Tha Chin River.[13]

Methods

This study was conducted in a form of the survey research and spatial data analysis where was from the Office of Environment and Pollution Control Division 5 and Land Development Department, with interviews conducted, to obtain valuable recommendations from the specialists concerned; with an aim to work out the guidelines for water quality management in the middle Tha Chin River. The following methodologies had been applied in the study:

The study area was the middle Tha Chin River Basin which covered both provinces of Suphan Buri and Nakhon Pathom. In this regard, land use had been categorized into 3 types, namely, 1) Urban and Built-up Land; 2) Agricultural Land (paddy field, horticulture, aquaculture, and swine farming); 3) Industrial Land; and 4) Livestock Farming Land.

This study was conducted in a form of the survey research and spatial data analysis, with specialists' recommendations included, which was a part of the dissertation and had been approved by the Human Research Ethics Committee, Maejo University, Project Code: MJUIRB ST010/66 and Certification Number: COA No. ST009/66, dated 24 October 2023.

WQI assessment for surface water

This research was to find out the current status of the water quality, which would suggest how such water should be taken care of, controlled and restored, enabling the cause of problem to be found, which would lead to prompt management.[14] There were 5 parameters adopted for WQI calculation, including Dissolved Oxygen (DO), Biological Oxygen Demand

(BOD), Ammonia (NH_3-N), Total Coliform Bacteria (TCB) and Fecal Coliform Bacteria (FCB), all of which were calculated based on the Pollution Control Department's method.[15,16] According to the WQI assessment, water quality could be classified into 5 ratings as shown in Table 1.

Table 1 Water Quality Ratings

WQI Score	Water Quality Rating	Source of Water (Class)
0 - 30	Very Poor	5
31 – 60	Poor	4
61 - 70	Fair	3
71 – 90	Good	2
91 – 100	Very Good	1

Source: Pollution Control Department

The researcher had collected the water data and samples, during 2011 and 2020, from 8 Water Sampling Stations [17], namely, 1) MSC Station - Khlong Maha Sawat-Nakhon Chai Si District, Nakhon Pathom Province; 2) JBC Station - Khlong Chedi Bucha - Nakhon Chai Si District, Nakhon Pathom Province; 3) TC15 Station - the bridge over the Tha Chin River - Bang Len District, Nakhon Pathom Province; 4) TC17 Station - the area under Bang Khlong Phraya Banlue - Song Phi Nong District, Suphan Buri Province; 5) TC22 Station – Tai Mueang Suphan Buri - Mueang District, Suphan Buri Province; 6) TC23 Station - Pho Phraya Floodgate - Mueang District, Suphan Buri Province; 7) TC25 Station - the bridge over the Tha Chin River - Sam Chuk District, Suphan Buri Province; and 8) TC25.1 Station – the bridge over the Tha Chin River - Doem Bang Nang Buat District, Suphan Buri Province. Water samples were collected 4 times a year, when there were no abnormal floods or droughts. Therefore, the WQI assessment had not been affected.

Comparison on land use in Suphan Buri and Nakhon Pathom Provinces, between 2007 and 2019

In this research, land use was categorized into 4 major types, including: 1) Urban area and construction Land - This consisted of the areas used for human activities, residences, business operation, commercial and public services, government agencies, institutions or other construction land; 2) Agricultural Land - This consisted of the areas used for agricultural activities, paddy fields, field crops planting, perennials and orchard planting, horticulture, pasture, etc.; 3) Livestock Farming Land - This consisted of the areas used for livestock activities, swine farm houses, aquaculture; and 4) Industrial Land - This was the type of land use that was related to human activities. Land use data are normally collected once every 5 years by the Land Development Department, and the data in 2019 are the most recent ones available.

Setting guidelines for water quality restoration in the Middle Tha Chin River

This was to improve the water quality, to make it complied with the Notification of the National Environment Board No. 8, B.E. 2537 (1994), Prescribing the Surface Water Quality Standards, and the Notification of the Pollution Control Department, dated 7 June 1994, Regarding Classification of the Water Sources in Tha Chin River.

Results

Referring to the WQI calculations conducted from 2011 to 2020, it was found that the water quality was poor (WQI = 58), not being in compliance with the Notification of the Pollution Control Department, dated 7 June 1994, Regarding Classification of the Water Sources in Tha Chin River, and was therefore categorized as Class 3 (WQI ≥ 61). When WQI calculations were made based on area, it was found that the water qualities at TC22 Station (Tia Mueang Suphan Buri), TC17 Station (the area under Khlong Phraya Banlue, Song Phi Nong District, Suphan Buri Province) and TC15 Station (the bridge over the Tha Chin River, Bang Len District, Nakhon Pathom Province), were poor, whereas those of MSC Station (Khlong Maha Sawat) and JBC Station (Khlong Chedi Bucha), which are the main canals connected to the Tha Chin River, were classified as poor, as showed in Table 2.

Table 2 Parameter-Based Water Quality Values in the Tha Chin River

Station	DO	BOD	TCB	FCB	NH_3	WQI
TC25.1	4.4	2.0	5,528	1,679	0.2	62
TC25	4.3	2.0	8,421	1,295	0.2	62
TC23	4.1	2.1 (Poor)	6,976	1,315	0.2	63
TC22	3.9 (Poor)	2.6 (Poor)	35,092 (Poor)	8,763 (Poor)	0.2	54 (Poor)
TC17	3.0 (Poor)	2.6 (Poor)	6,144	789	0.3	57 (Poor)
TC15	3.0 (Poor)	2.9 (Poor)	10,875	2,004	0.3	57 (Poor)
MSC	3.2 (Poor)	3.1 (Poor)	20,587(Poor)	5,259 (Poor)	0.3	50 (Poor)
JBC	3.4 (Poor)	6.3 (Poor)	248,321(Poor)	69,245 (Poor)	0.8 (Poor)	32 (Poor)
Standard Value	> 4.0 mg/l	< 2.0 mg/l	20,000 M.P.N./100 ml	4000 M.P.N./100 ml	2.8 mg/l	≥ 61

In terms of parameter-based calculations, it was found that values of the Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Ammonia (NH_3-N) and Total Coliform Bacterial (TCB) at JBC Station (Khlong Chedi Bucha) exceeded the criteria required for Class 3 of the surface water quality standard while at MSC Station, the only value not exceeding the criteria required for Class 3 of the surface water quality standard was Ammonia. At TC 22 Station (Tai Mueang Suphan Buri), values of the BOD and TCB were found to exceed the criteria required for Class 3 of the surface water quality standard, while at TC 17 Station (the area under Khlong Phraya Banlue, Song Phi Nong District, Suphan Buri Province) and TC15 Station (the bridge over the Tha Chin River, Bang Len District, Nakhon Pathom Province), the only value exceeding the criteria required for Class 3 of the surface water quality standard was the BOD, as showed in Figure 1.

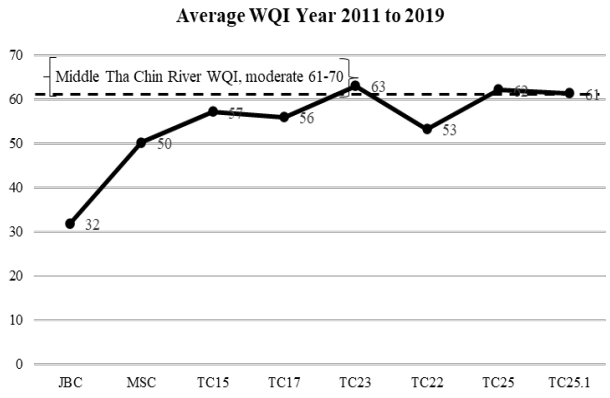

Figure 1 Comparison on the Middle Tha Chin River WQI's obtained from the 8 water sampling stations

Land use/land cover (LULC) transformation processes result in increased degradation of stream water quality through deposition of point and nonpoint source pollutants.[20] According to the comparison made on land use in 2007 and 2019, covering Suphan Buri and Nakhon Pathom Provinces, both of which were located on the middle Tha Chin River Basin and categorized as Agricultural Land, Urban and Built-up Land, Industrial Land and Livestock Farming Land; it was found that land uses in Suphan Buri Province had most increased, i.e., the land use in Industrial Land had increased by 59%, followed by Livestock Farming Land and Urban and Built-up Land, which had increased by 16% and 2% respectively, when compared to those in 2007, as showed in Table 3.

In Nakhon Pathom Province, changes in land use were also found, i.e., the land use in Industrial Land had increased by 125% and the land use in Urban and Built-up Land had increased by 113%, when compared to those in 2007, as can be found in Table 4.

The water quality restoration guidelines/mechanism of the middle Tha Chin River has been proposed by the experts as follows: 1) Large- and medium-sized Local Administrative Organizations (LAO) should establish the central Wastewater Treatment System for communities and the LAOs with existing Wastewater Treatment Systems, the service should be extended to cover the whole area. 2) Grease traps should be installed for those living on riverbanks, with maintenance knowledge provided, such as grease removal and

Table 3 Comparison on Land Uses in Suphan Buri Province, Between 2007 and 2019

Suphan Buri Province	2007 (Rai)	2019 (Rai)	Changes (Rai)
Agricultural Land	2,340,175	1,429,237	910,939 (38% Decrease)
Urban and Built-up Land	255,872	262,559	6,686 (2%) Increase
Industrial Land	13,025	20,813	7,788 (59% Increase)
Livestock Farming Land	108,787	126,920	18,133 (16% Increase)
Total	**2,717,860**	**1,839,529**	

Table 4 Comparison on Land Uses in Nakhon Pathom Province, Between 2007 and 2019

Nakhon Pathom Province	2007 (Rai)	2019 (Rai)	Changes (Rai)
Agricultural Land	700,802	526,132	174,669 (24% Decrease)
Urban and Built-up Land	117,903	251,331	133,428 (113% Increase)
Industrial Land	16,035	36,224	20,189 (125% Increase)
Livestock Farming Land	152,939	199,484	46,545 (30% Increase)
Total	**987,679**	**1,013,172**	

disposal procedures, etc. 3) Invite the authorities concerned, including the private sector and civil society, to participate in wastewater recovery planning, and 4) The laws related to pollution sources should be strictly enforced.

Discussion

Referring to the study, we can conclude that the water quality index in the middle Tha Chin River, this area was classified as poor. DO levels exhibited fluctuations, ranging from 3.01 to >4.0 mg/L. The organic matter from untreated waste, surface runoff, and fertilizer runoff from agricultural areas along the river possibly cause the reduced DO. BOD was found ranging from <2 mg/L to 6.3 mg/L, the tolerance limit of BOD in surface water is 5 mg/L for aquatic life.[18] Higher BOD loading usually implies the presence of organic pollutants from improperly treated industrial wastewater and domestic wastes.[19] The presence of coliform bacteria indicated a potential contamination from human and animal wastes, the environmental hygiene must be conducted for the sites that exceeding the recommended standards were observed.

The overall water quality of the middle Tha Chin River tended to be fair in some areas as the Royal Irrigation Department would divert water from the nearby water sources to replace the polluted water in dry season. However, the water quality in some areas got poorer due to the scarcity of the nearby water sources and no better water quality available. From the research, we found that the overall land use in Suphan Buri and Nakhon Pathom Provinces has been changed due to extended urbanization, economic expansion and population growth.

According to the physical of the middle Tha Chin River, which is a meander river, resulted to the flow of the water and also affected to its capacity of drainage, comparing to the capacity of flow and drainage of the rivers which are in shape of the straight (e.g. Chao Phraya River, Bang Pakong River and etc.). Such that it is a major caused of slower water quality improvement by adding of a good quality water to dilute the wastewater due to the big adding of a good water quality volume can be resulted of flood at the downstream. Rivers with industrial and urban land use contained the highest level of pollution (positive correlation with all FCB, TCB, BOD_5, and ammonia nitrogen), followed by agricultural land use (positive correlation with BOD_5 influenced by high levels of nitrogen and phosphorus).[21]

The guidelines related to wastewater management in the middle Tha Chin River can be divided into 4 aspects as follows: 1) Problems related to the readiness for wastewater management, which include lacking of the budget required for Wastewater Treatment System feasibility study and design, insufficient budget for

Wastewater Treatment System maintenance, an absence of wastewater treatment fee collection and a shortage of the specialists required for System operation and maintenance. As for wastewater management guidelines/mechanism, budget allocation approaches and criteria should be provided to LAOs and, at the same time, make them ready to be qualified for budget granting, either by the Environment Fund or through provincial plans of action.

Problems related to the operation and maintenance of Wastewater Treatment System and Wastewater Collection System, esp. when the equipment is out of order and does not function effectively, or when the wastewater collection pipe does not work at full capacity, causing the amount of wastewater entering the system to be less than the standard required. The guidelines/mechanism proposed are that Wastewater Treatment System should be improved to make it function more effectively. As for the areas where the Wastewater Treatment System exists, the treatment service should be extended to cover the whole area. For those without Wastewater Treatment System, additional service areas should be included, esp. the LAOs that are located on the Tha Chin Riverbank and beside main canals.

Problems related to the explicit knowledge, public relations and public participation in wastewater and Wastewater Treatment System management - It was found that LAOs were lack of the skills and explicit knowledge about wastewater management and technics. There was neither the PR campaigning about wastewater management activities nor the participation of local people. The guidelines/mechanism proposed are, therefore, raising the potential of local people and LAOs for Wastewater Treatment System maintenance; campaigning for people to stop throwing garbage or food scraps into the river, esp. those living on river banks; encouraging people to take part not only in caring for rivers and main canals, but also in planning for local wastewater management.

Problems related to an ineffective enforcement of laws regarding wastewater and Wastewater Treatment System management, service fee determination and collection, including the control of wastewater drainage from its sources, etc. The guidelines/mechanism proposed are pushing for the authorities concerned to seriously enforce the laws against all sources of pollution, such as swine farm houses, building type A, B and C, industrial factories, small scale industries, etc.; encouraging the issuance of municipal laws and determination of wastewater treatment fee, including the collection of fees in the areas where Wastewater Treatment Systems are present.

Recommendations

Implications of the Study

Findings of the study may be applied for water quality restoration planning, prevention, and monitoring. Data storage and database management should be carried out in the digital format that is most practical for one's use.

Recommendations for Future Research

1) Due to the limitations in both the data storage budget and the difference in data formats stored, i.e., hard copy and soft copy (digital), causing the details to be inconsistent; there is a lack of relationships among them which results in the inability to utilize data effectively. It is, therefore, recommended that the data obtained from the authorities concerned be integrated so that they can be used in the form of Big Data.

2) For future research are that the study should not only cover the whole area of the middle Tha Chin River, but also include the river pollutant load carrying capacity, to further benefit the spatial problem-solving approach, in the correct and appropriate manner. This is anticipated to result in the reduction of the pollutant released into public rivers in the long run.

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