17. Pollutant discharge and pollutant load in the tidal area of the rivers in the developing countries: Survey results in the autumn and winter in 2006 and desirable direction for water quality improvement

途上国の感潮域における汚濁負荷排出量と河川等の汚濁負荷量—2006年秋、冬の調査結果と水質改善の方向性についての提言

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ABSTRACT: For the purpose of pollutant load analyses for the calculation of pollutant loads per capita flowing into the water body (PLCwb) and preparation of environmental accounting housekeeping (EAH) books in the developing countries, the preliminary surveys and secondary information/data collection were conducted in Thailand and Bangladesh, in autumn and winter in 2006. Water quality and quantity (flow rate) were analyzed in the rivers and canals in and around Bangkok, Thailand, and a river and inner-city lakes in and around Dhaka, Bangladesh. Water depth, water temperature, salinity, electricity, density, turbidity, chlorophyll a were monitored vertically with a compact type water quality recorder, Compact-CTD ® (ALEC electricity, Japan). Other parameters including TOC, COD_{Cr}, TN were measured in the laboratories. Pack Tests ® (Kyoritsu Chemical, Japan) were used to analyze COD_{Mn}, PO_4-P, NO_2-N and NO_3-N to investigate their effectiveness in monitoring the water quality in these rivers and lakes. In the Sitalakhaya River, vertical homogeneity was observed with the parameters measured with the water quality data logger. The characteristics of water quality in the estuary area in the rivers in Bangkok were observed. The Pack Test measurements were identified effective to illustrate water quality profiles of the water environment in the river and the three lakes in and around Dhaka, and two rivers and a canal in and around Bangkok. Based on the results of the field survey and secondary data, recommendations were proposed for the water quality improvement in the surface water.

KEYWORD: Thailand, Bangladesh, domestic wastewater, pollutant load per capita flowing into the water body (PLCwb)

1. INTRODUCTION

In the context of the Millennium development goals (MDGs), decreasing the population without access to safe drinking water and appropriate domestic wastewater treatment facilities was determined as very urgent tasks of the world community. In regards to the efficiency of domestic investment and overseas development assistance (ODA), it is important to consider and discuss on the efforts of stakeholders in the developed countries such as Japan including national and local governments, private companies, citizens, fisheries and researchers. Tsuzuki (e.g. 2006c) proposed pollutant loads per capita flowing into the water body (PLCwb) as an appropriate indicator of the domestic wastewater contribution to the water pollution in the targeted water body.

We have conducted secondary data collection and field survey in regards to pollutant discharge with domestic wastewater and pollutant load in the rivers, lakes and canals in urban and peri-urban area of Bangkok, Thailand, and Dhaka, Bangladesh in October, November and December, 2006. The purpose of this paper is to present a part of the summary of the secondary data and the field survey results, in order to make comparison of the situations of domestic wastewater treatment between Japan, Thailand and Bangladesh. A conceptual proposal for preparation of the comprehensive basin based domestic wastewater strategies with centralized and decentralized domestic wastewater treatment system will be presented in the future opportunity based on these results. A part of this paper was presented in the International symposium on the 'Restoration and Sustainability of Estuaries and Coastal Lagoons' in January, 2007, Matsue, Japan, in the International Forum on Water Environmental Governance in Asia in March, 2007, Bangkok, Thailand, and in the annual meeting of Japan Society on Water Environment in March, 2007, Osaka, Japan.

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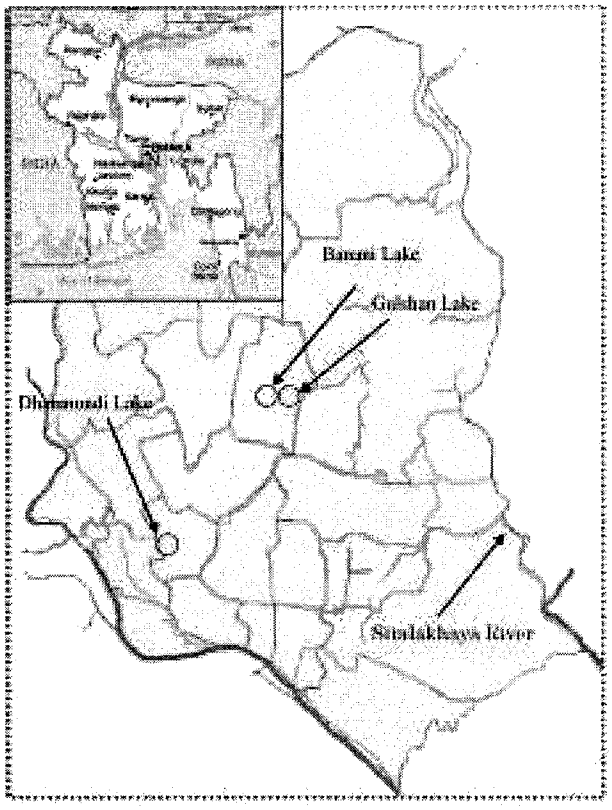

Figure 1 Rivers and lakes in urban and peri-urban area of Dhaka, Bangladesh (Original Source: Texas University Library and Wikipedia)

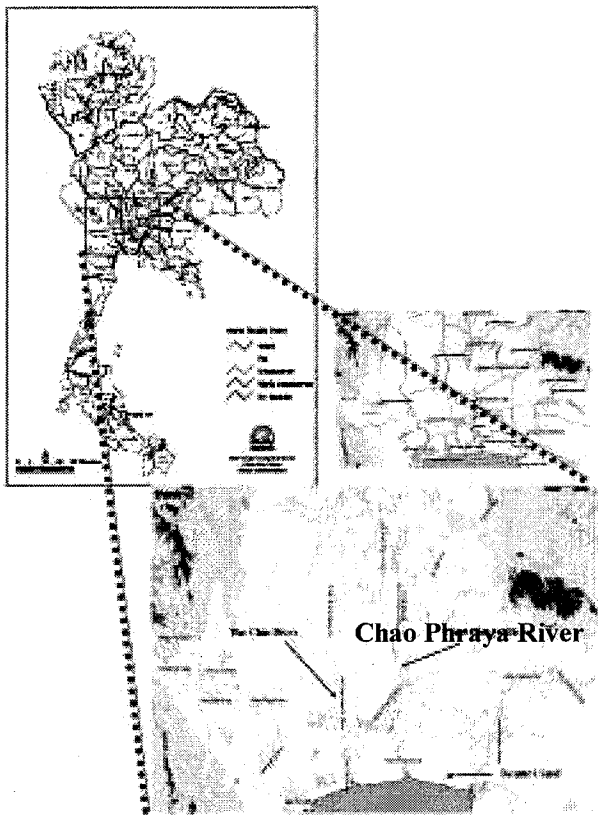

Figure 2 Rivers and canals in urban and peri-urban area of Bangladesh, Thailand (Original source: PCD (2006a) and Thinknet ®)

2. METHODS

Secondary information/data collection from documents, papers and web-sites and field surveys were conducted in regards to water quantity and quality in urban and peri-urban area of Dhaka, Bangladesh (Fig. 1), and Bankok, Thailand (Fig. 2). The Sitalakhya River flows west of Narayanganj District, Bangladesh, and flowing into the Dhaleshuari River, which flows into the Megha River at Bandar. The Narayanganj District is one of the highest population density district in Bangladesh with more than 2,000 person km^{-2} (Alam ed., 2005). The Chao Phraya River and the Tha Chin River flow in the central area of Thailand. Pak Kret District (Amphoe) (area: 89.0 km^2, population: 201,399 person in 2004, population density: 2,296.6 person km^{-2}) was located at northeast of Notanburi Province (Wikipedia, 2006). Pak Kret Municipality was located in Pak Kret District as one of the twelve communities (Tambon). Total pollutant discharge and PDC in the Pak Kret Municipality was estimated from Sinsupan (2004).

From October to December, 2006, field surveys were conducted in the Sitalakhya River and lakes in Dhaka City, namely, Dhanmondi, Banani and Gulshan Lakes, Bangladesh, and in the Chao Phraya and the Tha Chin Rivers and the Tamru Canal, Thailand. Water quality was measured with a water quality data logger, Compact-CTD ® (Alec Electronics, Japan), and water quality monitoring kits, Pack Test ® (Kyoritsu Chemical, Japan), and laboratory measurements. Parameters measured with the Compact-CTD were water depth, water temperature, salinity, electricity, EC25 (electricity calibrated at water temperature of 25 °C), density, sigma-T, chlorophyll-a and turbidity. Parameters measured with the Pack Test were COD_{Mn} and PO_4-P.

3. RESULTS AND DISCUSSION

Figure 3 shows the water quality measurement results with the Pack Test in the Sitalakhaya River and the three lakes, which

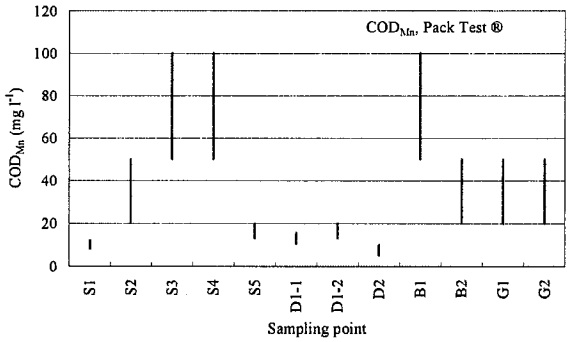

Figure 3 Water quality measurement results with Pack Test ® in the Sitalakhaya River and the three lakes in Dhaka, Bangladesh

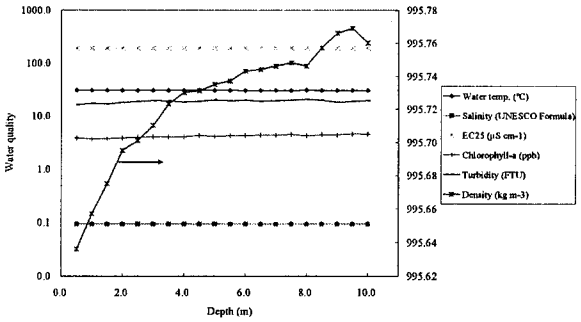

Figure 4 An example of vertical profiles of water quality parameters at the sampling point No.4, the Sitalakhaya River, Bangladesh

effectively showed the water quality characteristics in the river and lakes, water quality deterioration near the river side community in the sampling points S2, S3 and S4, and natural purification or dilution in the sampling point S5 were observed. The Dhanmondi Lakes (D1, D2) was in the residential area and used for recreation of the people, however, Banani (B1, B2) and Gulshan Lakes (G1, G2) were in the office and commercial area. The relatively lower concentration of the Dhanmondi Lakes might reflect these characteristics of the lakes. The measurement results with the Compact-CTD in the Sitalakhaya River showed vertical homogeneity of the water quality measured in this study (Figure 4).

The Pack Test water quality measurement results showed the characteristics of water quality in the rivers and canals in Thailand also. The simple water quality measurement was considered to be effective methods especially in the field of community participation. Development of more cost-effective water quality measurement methods might be desirable for these developing countries. Further collection of information/data was considered to be required for the estimation of PDC and PLCwb in Bangladesh.

Horizontal water quality profiles in the Chao Phraya River calculated from the administrative data (Pollution Control Department (PCD), 2006c) are shown in Figures 5. BOD at 50-350 km of the Chao Phraya River was 1.0-2.0 mg l^{-1}, increased to 4.1 mg l^{-1} at 30 km, then decreased to 2.8 mg l^{-1}. DO was larger than 5.0 mg l^{-1} at 150-350 km, and smallest as 1.5 mg l^{-1} around 15 km. Estuarine zone was 0-50 km. TN and TP was lower concentration at 150-350 km. TN increased gradually with down-flow from 0.4 to 0.6 mg l^{-1}, and TP was fluctuated around 0.1-0.3 mg l^{-1}. TN increased to 2.1-2.4 mg l^{-1}, and TP increased to 0.4-0.7 mg l^{-1} near the river mouth.

Vertical water profile was measured with Compact-CTD twice at each monitoring point. Vertical water quality profile at the

Table 1 Pollutant discharge from the Pak Kret Municipality estimated based on the secondary data

Pollutant	Pollutant discharge kg day^{-1}	PDC kg $person^{-1}$ day^{-1}
BOD	11,935	49.2
TN	3,791	15.6
TP	1,530	6.30

Source: calculated by the authors based on Sinsupan (2004).

Table 2 Pollutant load in the Chao Phraya River calculated with the field survey results and the secondary data of flow rate

	Distance from the river mouth km	Flow rate[a] m^3 s^{-1}	TOC t day^{-1}	TN t day^{-1}	CODcal[b] t day^{-1}	BODcal[c] t day^{-1}
Pibulsongkram Pier	58	1,082	581	117	1,453	88.6
Wat Tumnuktai	67	955	523	97	1,308	79.8
Wat Potongbon	80	784	388	78	971	59.2

a: Lohani et al. (1980); b: CODcal=2.5*TOC; c: BODcal=0.061*CODcal

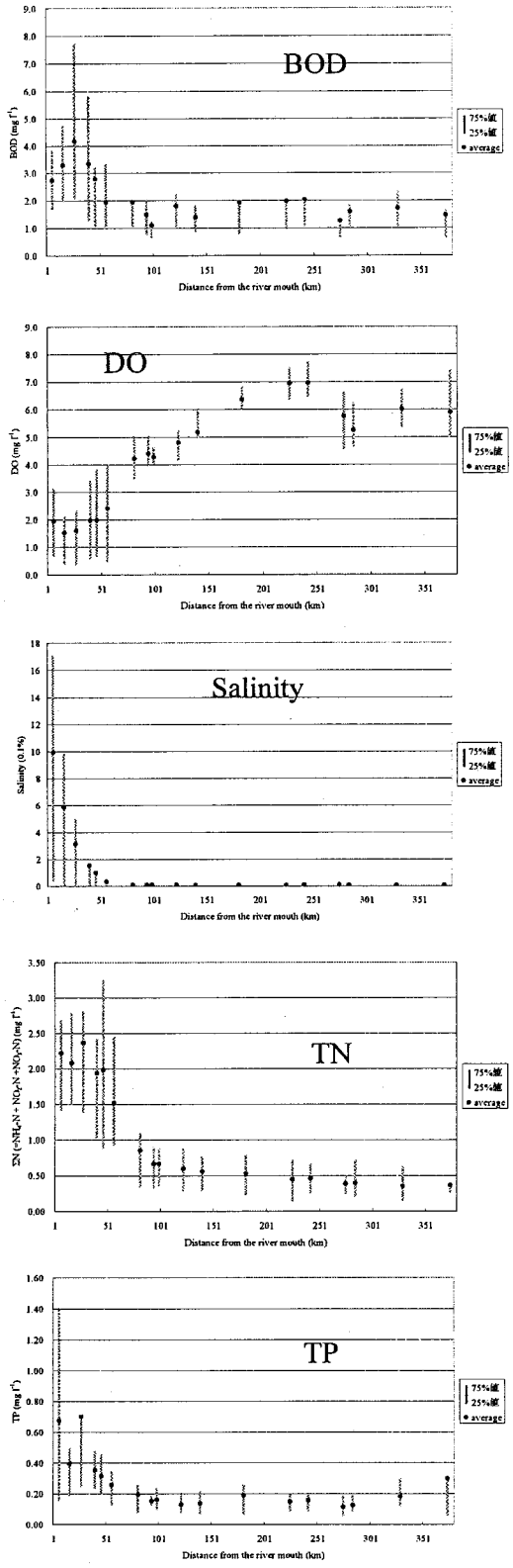

Figure 5 Water quality of the Chao Phraya River (1999～2000) (PCD, 2006b)

67 km (Wat Tumnuktai, Figures 6-1 and 6-2) and 80 km (Wat Potongbon, Figures 6-3 and 6-4) from the river mouth of the Chao Phraya River was rather homogeneous. Water temperature decreased by 0.10-0.17 °C with water depth increase at 67 km. Water temperature measurement results at 80 km were not consistent for the twice measurements. The reasons of the obscure layer were considered as the influence of tidal water and solar radiation. Chlorophyll-a was 5.0-5.5 ppb at almost all the depth at both monitoring points. Lots of water hyacinths were found on the surface of rivers. The effects of planktons and water hyacinths should be considered with the relationships between nutrients pollutant discharges and nutrient pollutant loads in the river and canals.

Total pollutant discharge and PDC of the Pack Kret Municipality were estimated as shown in Table 1 based on the material flux analysis (MFA) results (Sinsupan, 2004). BOD discharge per capita (PDC-BOD) was estimated as 49 g-BOD person^{-1} day^{-1}, which was a comparable amount as the previous estimation based on the UNEP report, 43 g-BOD person^{-1} day^{-1} (Tsuzuki, 2006b).

Pollutant loads in the Chao Phraya River were estimated with the field survey results of water quality and the flow rate in the secondary data (Table 2). The estimated PDC in the Pak Kret Municipality were compared to PDC in Japan (Figure 7). Pollutant discharge and pollutant load estimation should be further investigated. These results would be base data for the calculation of PLCwb in the region.

Pollutant discharges have been investigated in Thailand especially with MFA methods (e.g. Sinsupan, 2004). The river water quality including basic parameters including carbon, nitrogen, phosphorus, bacterial pollution, and heavy metals have been monitored periodically by PCD (2006a, b, c). Water pollution control program by the Thai government has been consisted of 1) wastewater treatment and disposal, 2) waste minimization, 3) cleaner production, 4) legal framework, 5) institutional and financial management, 6) monitoring and enforcement, 7) cooperation with related agencies and local communities, and 8) river basin management approach (Simachaya, 2000). Integral water resource management (IWRM) has been researched in Thailand (Lekphet et al., 2004). Environmental education program has been conducted, for example, in the drainage area of the Tha Chin River (Thongnopphakun, 2006). Information dissemination has been conducted by PCD by the web-site (PCD, 2006b). The results of this research would be base information for the environmental education and dissemination in regards to water environment in Thailand.

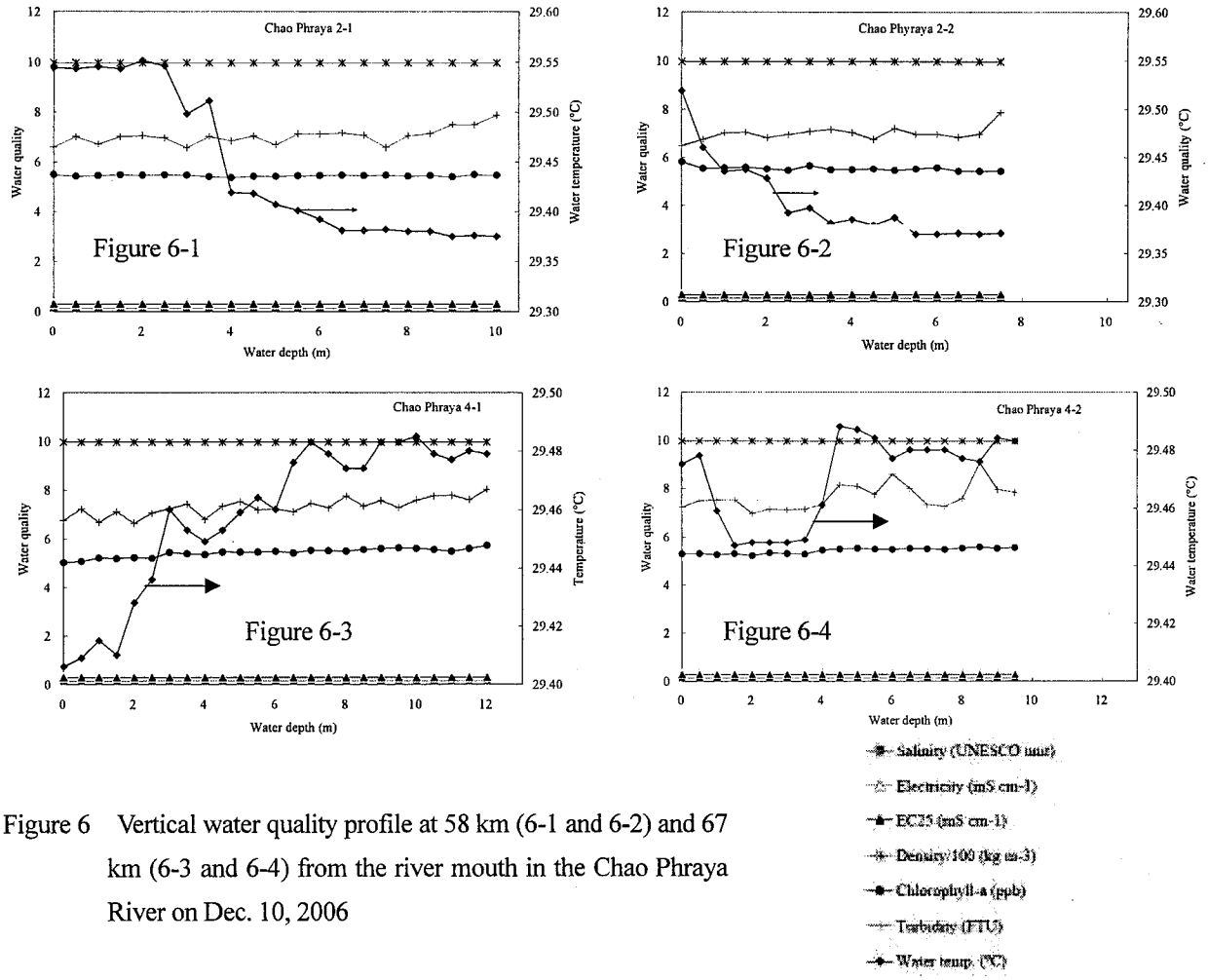

Figure 6 Vertical water quality profile at 58 km (6-1 and 6-2) and 67 km (6-3 and 6-4) from the river mouth in the Chao Phraya River on Dec. 10, 2006

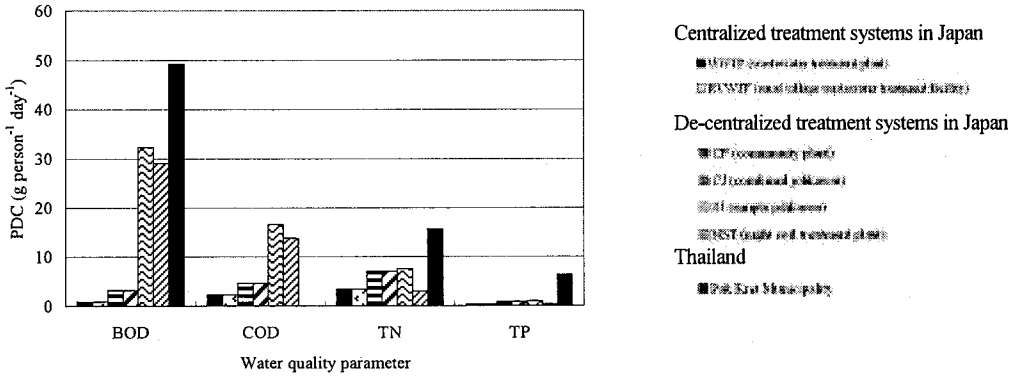

Figure 7 PDC in Japan and Thailand

Current estimated PDC in Thailand were larger than PDC in Japan. Estimation should be considered further with colleted information/data. Based on the current estimation, appropriate hardware deployment including centralized and de-centralized treatment systems, and software measurements in the households should be accomplished.

4. CONCLUSION

Simple water quality measurement with the Pack Test effectively demonstrated the water quality in the rivers, lakes and canals in Bangladesh and Thailand. PDC in the Pak Kret District, north of Bangkok was estimated as 49 g-BOD person^{-1} day^{-1} based on the existing research results. Water quality and pollutant loads in the rivers were summarized based on the secondary data and the field surveys. These results would be the base information for the consideration of the relationships between pollutant discharges and pollutant loads in the rivers and canals.

IRBM has been widely advocated among the researchers and governments, and MFA has also been studied. The results of this research would be base information for water environment improvement in the countries.

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