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ON-SITE TREATMENT SYSTEMS IN THE WASTEWATER TREATMENT PLANTS (WWTPs) SERVICE AREAS IN THAILAND: SCENARIO BASED POLLUTANT LOADS ESTIMATION

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In the previous studies, discharge of "seepage and septage from septic tanks and leachate from composting" (SSL) were found to occupy a larger portion of pollutant load in the ambient water in the peri-urban area around Bangkok, Thailand. On-site treatment methods including septic tanks are traditionally applied even in wastewater treatment plants (WWTPs) service areas in Thailand. Therefore, evaluation of the existence of on-site treatment facilities in WWTPs service area is considered to be important. Three scenarios were developed to estimate pollutant discharges per capita (PDCs) from domestic wastewater treatment systems in Thailand. PDCs estimation results showed that pollutant discharges to the ambient water are still larger even in the WWTPs sevice areas. Some of the reasons for the larger pollutant discharges are smaller pollutant removal ratios defined based on the treatment efficiencies in the existing WWTPs. Further consideration should be necessary on the traditional domestic wastewater treatment systems which combine on-site treatment and centralized treatment in Thailand.

Key Words : *canal (klong), domestic wastewater treatment, on-site treatment, pollutant discharge per capita (PDC), wastewater treatment plant (WWTP)*

1. INTRODUCTION

Smaller organic carbon concentrations in the influent of wastewater treatment plants (WWTPs) have been pointed out for WWTPs in Thailand. Consideration on the reasons for the smaller organic concentrations is necessary because these situations can also happen in other developing countries. The reasons for the smaller concentration were explained by Giri *et al.* (2006) as "(1) continued use of leaching septic tanks, (2) the tradition of using water after defecation, instead of toilet paper, and (3) high organic degradation potential under tropical monsoon conditions". In Thailand, on-site treatment methods are commonly applied even in WWTPs service areas, which is different from domestic wastewater treatment systems in Japan. Therefore, such application with both on-site and centralized domestic wastewater treatment systems should be investigated. Moreover, water quality deterioration in canals (*klongs* in Thai) is also an important problem to be solved especially in the Bangkok area. These points are important to consider sustainable domestic wastewater treatment systems especially in urban and peri-urban areas in developing countries in advanced development stages and should be investigated and discussed quantitatively to improve the effectiveness of investments in domestic wastewater treatment fields.

In the previous studies, we conducted field

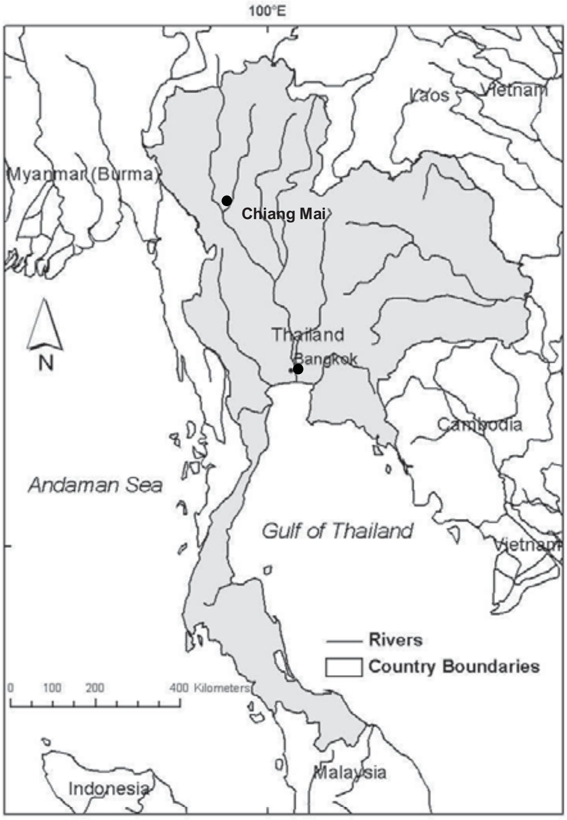

Fig. 1 Map of Thailand

surveys to find the relationships between domestic wastewater pollutant discharges and pollutant loads in the ambient water in and around Bangkok (Tsuzuki *et al.*, 2008a,b; Tsuzuki and Thammarat, 2008). Based on the results, pollutant discharges per capita (PDCs) were estimated. Tsuzuki *et al.* (2008a,b) found that "seepage and septage from on-site treatment methods including septic tanks and leachate from composting" (SSL) contributed much to total pollutant discharges from domestic wastewater to the ambient water. Jiawkok *et al.* (2007) evaluated the onsite sanitation systems and fecal sludge management in the peri-urban area of Bangkok, and found the tasks still to be solved in management of on-site sanitation were treatment performance improvement and appropriate fecal sludge management.

A step-wise improvement scheme was proposed by a Japanese professional group for domestic wastewater collection and treatment systems in developing countries (Japan Sewage Association, 1997). Quantitative evaluation of domestic wastewater pollutant discharges in the current and planned wastewater treatment systems is considered to be necessary. PDCs are similar to basic units (*gentan'i* in Japanese) or pollutant discharges per capita from domestic wastewater treatment methods, however, PDCs are advanced and more synthetic indices which can be estimated for total population in the targeted regions.

In this study, we conducted field surveys to collect information on on-site treatment methods in WWTPs service areas in Bangkok and Chiang Mai (**Fig. 1**). In this paper, we (1) summarized organic carbon concentrations in the influent and effluent of some WWTPs in Thailand to show the current situations in these WWTPs, (2) summarized outlines of water quality improvement plants (WQIPs) or WWTPs in northern Thailand to show other examples of the existing WWTPs in Thailand other than the Bangkok area, (3) summarized current conditions of canals in the Bangkok area, (4) conducted estimations of PDCs based on current and modified scenarios, and (5) discussed how to apply on-site treatment systems in WWTPs service areas.

2. METHOD

Information collection was conducted in Bangkok and Chiang Mai. Collected information on domestic wastewater treatment including centralized and on-site treatment was summarized.

Based on the results of the field survey, three scenarios were developed to illustrate domestic wastewater treatment systems in the near future in Thailand. PDCs were newly estimated for the scenarios based on the existing data and PDCs estimation results in the previous studies using the following equations.

$$PDC_i = PGC \times (1 - WTE_i) \tag{1}$$

where PDC_i is pollutant discharge per capita (PDC) of the domestic wastewater treatment method i; PGC is pollutant generation per capita (PGC); and WTE_i is wastewater treatment efficiency of the domestic wastewater treatment method i.

$$PDC_j = \frac{\sum_i (PDC_i \times POP_{i,j})}{\sum POP_{i,j}} \tag{2}$$

where PDC_j is averaged PDC in area j; and $POP_{i,j}$ is population served with domestic wastewater treatment method i in area j.

The reasons and functions of the existing on-site treatment systems in WWTP service areas were discussed based on the results.

3. RESULTS AND DISCUSSIONS

(1) WWTPs in Thailand

BOD_5 (hereafter, cited as BOD), COD_{Cr}, TN and TP

Table 1 Influent and effluent of nine WWTPs in dry and rainy seasons (Source: Prepared by the authors based on Environment & Laboratory, 2005)

WWTP	Type	Capacity	Dry season (April-May) BOD$_5$		COD$_{Cr}$		TN		TP		Flood season (June-July) BOD$_5$		COD$_{Cr}$		TN		TP	
			Inflow	Effluent	Inflow	Effluent	Inflow	Effluent	Inflow	Effluent	Inflow	Effluent	Inflow	Effluent	Inflow	Effluent	Inflow	Effluent
		m^3 day^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}	mg l^{-1}
Kampaeng Phet	SP[a]	13,500	19	8	61	57	16.5	0.1	3.7	0.6	9	18	40	97	1.8	1.8	0.8	0.2
Chumsaeng	SP[a]	1,650	27	16	57	32	13.3	2.1	2.5	0.3	17	17	40	44	10.4	1.5	2.0	0.3
Tarrae	SP[a]	2,054	27	13	39	36	3.1	0.0	0.5	0.5	4	5	8	38	2.4	1.7	0.3	0.0
Sriacha Chonburi	OD[b]	18,000	54	3	114	29	10.9	16.5	3.0	2.1	102	5	138	29	6.9	6.2	2.6	2.1
Banphe Rayong	OD[b]	8,000	105	19	197	69	20.2	7.7	4.5	2.3	27	8	46	46	2.0	6.3	1.5	1.1
Patumthani	OD[b]	11,000	20	8	42	35	10.2	13.8	1.6	0.3	72	42	290	68	8.5	9.3	4.9	2.6
Chaam Chaburi	AL[c]	14,000	66	20	136	113	23.5	1.4	4.0	0.7	74	82	22	29	11.0	0.8	2.0	0.6
Songkhla	AL[c]	21,900	105	24	200	136	31.5	11.7	20.5	3.8	30	26	96	113	7.3	0.3	4.4	2.8
Chiengrai	AL[c]	27,200	14	4	61	53	6.3	9.7	1.4	0.1	8	6	24	8	0.6	1.6	0.5	0.1

a: Stabilization pond system; b: Oxidation ditch; and c: Aerated lagoon.

concentrations in the influent and the effluent of WWTPs were summarized from a JICA Report (Environment & Laboratory, 2005) (**Table 1**). BOD in the influent was 14~105 mg l^{-1} in the dry season and 3.6~102 mg l^{-1} in the rainy season in nine WWTPs in Thailand. COD$_{Cr}$ in the influent was 39~200 mg l^{-1} in dry season and 8.2~290 mg l^{-1} in rainy season. The influent BOD concentrations were comparatively lower than those of conventional WWTPs in Japan, which are in most cases 150~300 mg l^{-1}. In regards to organic carbon discharge from domestic wastewater, Tsuzuki and Thammarat (2008) found that BOD discharge per capita (PDC-BOD) of WWTPs in Thailand was comparatively smaller than those of on-site treatment systems. The effluent BOD and COD$_{Cr}$ concentrations (**Table 1**) and pollutant load estimations, which are not described in this paper, based on the JICA Report were considered to be coincide with the finding, i.e. smaller PDC-BOD and COD$_{Cr}$ discharge per capita (PDC-COD$_{Cr}$) with WWTPs.

In regards to nutrients removal, a certain level of organic carbon concentration is required especially in nutrients removal activated sludge plants. So, lower organic carbon concentrations will be a negative aspect if activated sludge systems are applied for nutrients removal. Greater removal rates of both nitrogen and phosphorus were observed for some WWTPs especially for stabilization ponds (SP) and aerated lagoons (AL) (**Table 1**). Nutrients removal and organic carbon concentration in the influent of WWTPs should be considered in further research.

Hourly surveys in 24 hours were conducted for the influents of Kampaeng Phet and Patumthani WWTPs (Environment & Laboratory, 2005). Influent concentrations fluctuated in the range of 2.7~15 mg-BOD l^{-1}, 20.3~81.3 mg-COD l^{-1} and 16~33 mg-SS l^{-1} in the dry season, and 3~42 mg-BOD l^{-1}, 16.2~80.0 mg-COD l^{-1} and 14~406 mg-SS l^{-1} in the rainy season at Kampaeng Phet WWTP. The fluctuations of Patumthani WWTP were 11~33 mg-BOD l^{-1}, 21~56 mg-COD l^{-1} and 18~56 mg-SS l^{-1} in the dry season. Greater influent concentration fluctuations in the rainy season suggested accumulation of sediments in the wastewater collection water ways and larger influence of first flush.

Photo 1 Chiang Mai City Water Quality Improvement Plant (WQIP)

Photo 2 Chiang Mai University Wastewater Treatment Plant (WWTP)

(2) Wastewater treatment in Chiang Mai City, North of Thailand

In Chiang Mai City, North of Thailand, wastewater collected with piped systems and septage sludge from septic tanks collected by vacuum cars are treated in the central treatment plants, namely Chiang Mai City Water Quality Improvement Plant (WQIP) (**Photo 1**). The treatment method of the WQIP is aerated lagoon. Septic tanks are commonly used even in the WQIP area.

At Chiang Mai University, wastewater was treated with a central WWTP in the campus (Karnchanawong, 1991) (**Photo 2**), which was the biggest one in the North at that time. The inflow of the WWTP consisted of collected septic tank effluent, wastewater from dormitories, staff houses, hospital buildings, offices and so on. The WWTP consists of screens, sedimentation tanks, aeration tanks, clarifier tanks, chlorination tanks, sludge thickener, an anaerobic sludge digester and sludge drying beds. Treated sludge is applied as fertilizer for agriculture purposes. Chiang Mai University started in 1964 and the WWTP started its operation in 1983. At the beginning of the operation, inflow volume was 85,000 m^3 day^{-1}, which increased to 100,000 m^3 day^{-1} in 2007. Before the operation of the

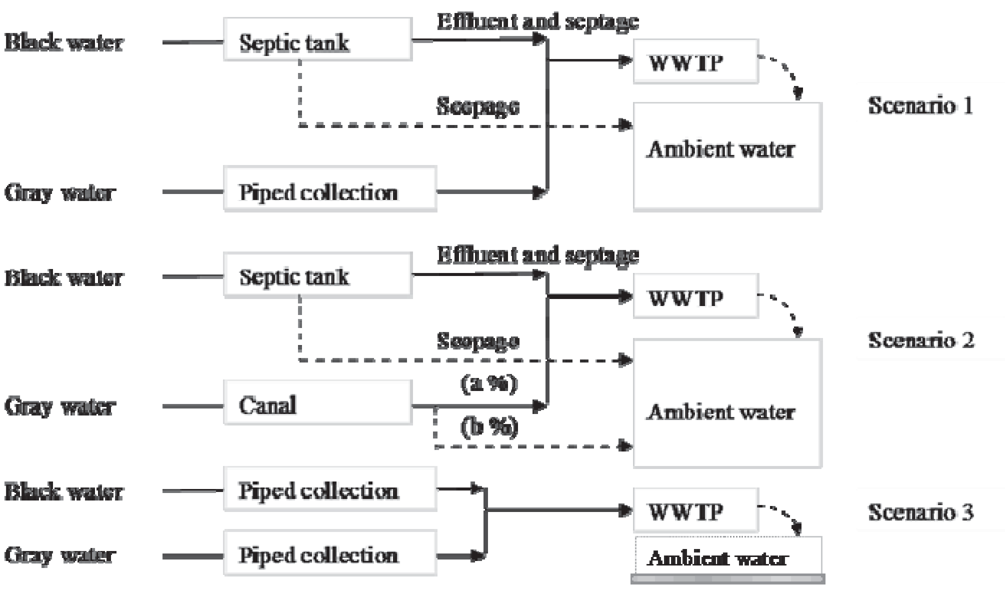

Fig. 2 Scenarios of current and modified wastewater treatment systems in Thailand

Table 3 PDCs estimations conditions of the three scenarios

Scenarios and cases	Category	BOD	TN	TP	Source
		g person^{-1} day^{-1}			
PGC & PDC	PGC of black water	13.7	5.85	0.47	Tsuzuki and Thammarat, 2008
	PGC of gray water 1 [a]	51.6	3.52	3.25	
	PGC of gray water 2 [b]	17.8	1.36	0.52	
	PDC with SSL [c]	48.4	12.4	2.38	Tsuzuki et al. 2008a,b
	PDC with SSL [c] (black water)	19.2	7.6	1.47	
	PDC with SSL [c] (gray water)	27.2	3.9	0.39	
	PDC without SSL [c]	29.2	4.8	0.91	
	PDC without SSL [c] (black water) (Effluent of septic tank)	1.4	0.8	0.46	
	PDC without SSL [c] (gray water)	27.2	3.9	0.39	
	Seepage of septic tank	17.8	6.7	1.01	
	Septage of septic tank	0.9	0.9	0.47	
Scenarios 1-3	Percentage of seepage flowing into ambient surface water (%)	10	10	10	
Scenario 2: Case 1	Percentage of WWTP influent from canal water (a %)	30	30	30	
	Percentage of directly flow to the ambient water from canal water (b %)	70	70	70	
Scenario 2: Case 2	Percentage of WWTP influent from canal water (a %)	70	70	70	
	Percentage of directly flow to the ambient water from canal water (b %)	30	30	30	
Scenarios 1-3	Removal rate at WWTP (%)	50	50	50	

a: Bowl bathing, machine cloths washing, and no screen kitchen; b: Shower bathing, hand cloths washing, and screen kitchen; c: seepage and septage of septic tank and leachate of composting.

WWTP, most domestic wastewater was treated only with a septic tank which was installed in each building. Black water was treated with the septic tank, however, gray water was discharged directly into the ambient water without treatment at that time. Even nowadays, black water is treated with septic tanks in some old buildings (**Photo 3**), and their effluent and collected septage is treated with the WWTP. The combination of on-site systems and central systems is considered to be a typical domestic wastewater treatment system in Thailand. Most of both black water and gray water from new buildings is directly discharged to the WWTP as the influent.

(3) Wastewater treatment in Lamphun City, northern Thailand

In Lamphun City, adjacent to Chiang Mai City, with a population of 225 thousand and a total area of 4,505 km^2 (2000), the WQIP of Lamphun Municipality was constructed in 2000-2003 (Lamphun City, 2006). The main treatment system of the WQIP is a modification of the activated sludge system, or sequencing batch reactor (SBR). The current inflow volume is 2,500 m^3 day^{-1} including collected septage from septic tanks by vacuum cars, which could be increased to 10,000 m^3 day^{-1} with a possible expansion of the piped collection system.

Photo 3 A septic tank in Chiang Mai University

(4) Canals in the Bangkok Metropolitan area

There are many canals in the Bangkok metropolitan area. Water quality in some canals is much deteriorated (**Photo 4**). In the canals, surface aeration is conducted to enhance biological degradation of pollutants. Most small canals are connected to large canals. The canal water is finally discharged to the WWTPs as influent, or to the Chao Phraya River and the Gulf of Thailand. Main sources of the canal water should be gray water directly discharged without treatment and effluent of onsite treatment facilities. Because of the flatness of the land in the Bangkok area, the canal water does not flow rapidly and tend to stay longer in the collection system especially in the dry season. Water quality deterioration has been identified as a problem and surface aeration is conducted in some canals (**Photo 5**). The government sectors including the Bangkok Metropolitan Authority (BMA) focuses the function of the canals more on flooding control (BMA, 2008).

Water quality profiles of some main canals along the Chao Phraya and the Tha Chin Rivers are summarized in **Table 2**. Larger concentrations of organic carbon, phosphorus, nitrogen, dissolved solid and bacterial parameters were found in some major canals.

Three scenarios were developed to describe the current domestic wastewater treatment systems and modified ones in Thailand (**Fig. 2, Table 3**). Scenarios 1 and 2 were based on the traditional domestic wastewater treatment systems with on-site treatment systems in WWTPs service area. Effluent and septage were collected and treated at WWTPs for the households served with WWTPs. Gray water was collected and treated at WWTPs in Scenario 1, meanwhile a% of gray water was collected and treated at WWTPs and b% of gray water was discharged directly without treatment to ambient water. We defined two cases for the percentages of gray water distributions to WWTPs and direct discharge. Both black water and gray water were collected with a piped collection system and treated at WWTPs in Scenario 3.

Photo 4 Water quality deterioration in a Bangkok canal

Photo 5 Surface aeration in a Bangkok canal

(5) On-site treatment systems in WWTPs service areas

On-site domestic wastewater treatment systems are commonly applied in Thailand even in WWTPs service area (Giri *et al.*, 2006). On the contrary, black water and gray water are combined and treated together in both centralized and de-centralized treatment methods in Japan within the latest municipal wastewater treatment regulations. Moreover, some separate treatment systems for toilet wastewater including ecological sanitation have been applied especially in rural area in the world. Therefore, the meanings and the desirable directions of the domestic wastewater treatment systems in Thailand should be considered further.

Traditionally, on-site treatment methods were commonly applied before construction of the centralized WWTP systems and canals were applied as gray water discharge water bodies. Some canals were used as wastewater collection water ways of WWTPs influent when WWTPs were introduced in Thailand. Budget deficiency for piped collection systems might be one of the reasons for the procedure.

(6) Scenario-based estimations of PDCs

Based on the three scenarios developed in "section (4) Canals in Bangkok Metropolitan area" (**Fig. 2, Table 3**), PDCs were estimated (**Table 4**). In almost all of the estimations, PDCs of Pak Kret Municipality, the peri-urban of Bangkok (Tsuzuki *et al.*, 2008a,b), were applied as base data except for Case 2 of Scenario 3, in which PGCs of black water and gray water (Tsuzuki and Thammarat, 2008) were applied (**Table 3**). Fo example, PDC in the WWTP influent in Scenario 1 was estimated as equation (3):

$$PDC_{WWTP,S1} = PDC_{woSSL,b} + PDC_{woSSL,g} + Sep \tag{3}$$

where $PDC_{WWTP,S1}$ is PDC in WWTP inflow pollutant load in Scenario 1 (g person^{-1} day^{-1}), $PDC_{woSSL,b}$ is PDC from black water without SSL (g person^{-1} day^{-1}), $PDC_{woSSL,g}$ is PDC from gray water without SSL (g person^{-1} day^{-1}), and *Sep* is Septage of septic tank (g person^{-1} day^{-1}).

For Scenario 2, two case estimations were made for percentages of WWTPs influent (a %) and direct flow to the ambient water (b %), 30 % and 70 %, and 70 % and 30 %, respectively (**Fig. 2**). In two cases of Scenario 3, when both black water and gray water were assumed to directly flow into WWTPs, PDCs in the WWTPs influent was estimated as 31.5-48.4 g-BOD person^{-1} day^{-1}, 7.2-12.4 g-N person^{-1} day^{-1}, and 1.0-2.4 g-P person^{-1} day^{-1}. Comparing to BOD loads of the WWTP influent in Scenario 3, those of the other two scenarios were rather smaller. The results suggested the smaller influent concentrations which should be similar to the current domestic wastewater treatment systems in Thailand. Largest direct discharges of pollutants to the ambient water were estimated especially in Case 1 of Scenario 2.

Total PDCs of the three scenarios were almost in the same range. In the estimation, pollutant removal rates at WWTP were fixed at 50 %. When WWTP influent organic carbon concentration is larger, pollutant removal rates including nutrients removal rates should be larger and total PDCs should decrease especially for Scenario 3.

The estimations showed rather larger direct pollutant discharges to the ambient water even in WWTPs service area in Thailand. The results showed the necessity of comprehensive improvement of domestic wastewater treatment systems in Thailand. The estimation conditions should be updated in the further study. WWTPs influent and effluent concentrations will be considered further based on the results of this paper.

(7) Pros and cons on on-site treatment facilities in WWTPs service areas

Table 4 PDCs estimation results of the three scenarios

Scenarios and cases	Category	BOD	TN	TP	Source of PGCs and PDCs applied in the estimation
		g person^{-1} day^{-1}			
Scenario 1	WWTP influent	29.5	5.6	1.3	Tsuzuki et al. 2008a,b
	Ambient water	1.8	0.7	0.1	
	Total PDC	16.6	3.5	0.8	
Scenario 2: Case 1	WWTP influent	10.5	2.9	1.0	Tsuzuki et al. 2008a,b
	Ambient water	20.8	3.4	0.4	
	Total PDC	26.1	4.8	0.9	
Scenario 2: Case 2	WWTP influent	21.4	4.5	1.2	Tsuzuki et al. 2008a,b
	Ambient water	9.9	1.8	0.2	
	Total PDC	20.6	4.1	0.8	
Senario 3: Case 1 [a]	WWTP influent	48.4	12.4	2.4	Tsuzuki et al. 2008a,b
	Total PDC	24.2	6.2	1.2	
Senario 3: Case 2 [b]	WWTP influent	31.5	7.2	1.0	Tsuzuki and Thammarat, 2008
	Total PDC	15.8	3.6	0.5	

a: WWTP influent was estimated as equal to PDC with SSL; b: WWTP influent was estimated as total of PGC of black water and gray water 2.

On-site treatment systems including septic tanks are conventionally applied in households even in WWTPs service areas in Thailand. These combined methods are considered to be the traditional treatment systems (Giri *et al.*, 2006). A larger organic carbon concentration in the influent is considered as one of the necessary or common conditions to revive the activated sludge treatment plants performance for both conventional and nutrient removal activated sludge systems. In regards to the existence of on-site treatment in WWTPs service area, in addition to the traditional wastewater treatment systems, possibility of the problem of leakage and divergence of wastewater in piped systems should be considered because of imperfect piped systems.

PDCs estimation results in this study showed seepage from on-site treatment methods and direct discharge to the ambient water through canals will contribute much to the pollutant loads in the ambient water.

A lot of biodegradation in the collection systems with a large retention time in a tropical area was suggested (eg. Giri *et al.*, 2006). In this study, we did not include the effect of biodegradation in the collection system. The effect of biodegradation should be further studied.

A Master Plan of wastewater treatment in the Bangkok Metropolitan area prepared in 1993 was base on PDC of 40 g-BOD person^{-1} day^{-1} (**Tables 5 and 6**) (PDC, 1993). In the Master Plan, average BOD_5 concentration of wastewater from household and commercial was estimated as 161~249 mg l^{-1}, and that of wastewater from industry was estimated as 99~162 mg l^{-1}. In the Chaopia River drainage area wastewater master plan survey, PDC was estimated as 11 g person^{-1} day^{-1} for black water and 40 g person^{-1} day^{-1} for gray water (JICA and PWD, 1994). In the master plan survey, a stepwise planning concept was included. However, we can find smaller BOD_5 influent concentration in some WWTPs from the WWTPs management data. Therefore, when we consider about the current situations of the existence of on-site treatment systems such as septic tanks especially for black water in the WWTPs service areas, PDC values should be modified in the planning stage for newly installed WWTPs with consideration of the mixed situations of on-site treatment systems and centralized

Table 5 Estimation of wastewater volume and BOD5 loading from household and commercial and those from industria sources in the Bangkok Metropolitan Region

Province	Household and commercial			Industrial		
	Volume	BOD_5 loading	Average concentration	Volume	BOD_5 loading	Average concentration[a]
	m^3 day^{-1}	kg day^{-1}	g m^{-3}	m^3 day^{-1}	kg day^{-1}	g m^{-3}
BMA	1,231,390	198,550	161	305,120	39,330	129
Pathum Thani	65,840	16,300	248	39,890	6,470	162
Nontaburi	96,720	24,070	249	43,130	4,260	99
Samut Prakan	121,700	29,600	243	75,990	11,470	151
Samut Sakhon	52,150	12,800	245	26,140	4,180	160
Nokhon Pathon	96,430	23,650	245	43,420	4,920	113
Total	1,664,230	304,970	183	533,690	70,630	132

a: Estimated by the authors based on the source data. Source: PCD (1993) Bangkok Metropolitan Region wastewater management master plan, Volume 4, Exective summary, 103p.

Table 6 Wastewater volumes and BOD_5 loadings used in the planning of wastewater collection and treatment systems

Wastewater management zone	Year 2000			Year 2010			Year 2020		
	Volume	BOD_5 loading	Average concentration	Volume	BOD_5 loading	Average concentration	Volume	BOD_5 loading	Average concentration
	m^3 day^{-1}	kg day^{-1}	g m^{-3}	m^3 day^{-1}	kg day^{-1}	g m^{-3}	m^3 day^{-1}	kg day^{-1}	g m^{-3}
1	152,330	19,800	130	191,200	24,850	130	222,890	28,970	130
2	33,300	4,380	132	41,800	5,500	132	48,730	6,400	131
3	37,840	4,920	130	47,500	6,175	130	55,370	7,200	130
4	126,870	16,730	132	159,240	21,000	132	185,630	24,480	132
5	121,420	14,340	118	152,400	18,000	118	177,660	20,980	118
6	72,500	9,640	133	91,000	12,100	133	106,080	14,100	133
7	99,540	14,350	144	124,900	18,010	144	145,650	21,000	144
8	99,900	12,830	128	125,400	16,100	128	146,200	18,770	128
9	69,950	11,230	161	87,800	14,100	161	102,350	16,440	161
10	119,000	15,540	131	149,300	19,500	131	174,050	22,730	131
11	58,800	8,600	146	73,800	10,800	146	86,030	12,600	146
12	27,140	3,490	129	34,060	4,380	129	39,700	5,100	128
13	23,580	3,030	128	29,600	3,800	128	34,500	4,430	128
14	138,100	16,900	122	173,350	21,260	123	202,080	24,700	122
15	134,440	16,330	121	168,740	20,500	121	196,700	23,900	122
16	70,600	9,160	130	88,600	11,500	130	103,300	13,400	130
17	39,760	5,100	128	49,900	6,400	128	56,170	7,460	133
18	22,940	3,030	132	28,800	3,800	132	33,570	4,430	132
Total	1,448,010	189,400	131	1,817,390	237,775	131	2,116,660	277,090	131

a: Estimated by the authors based on the source data. Source: PCD (1993) Bangkok Metropolitan Region wastewater management master plan, Volume 4, Exective summary, 103p.

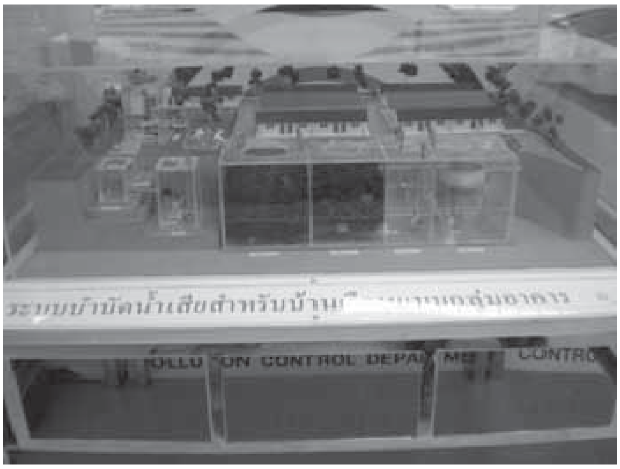

Photo 6 A model of on-site treatment system for both black and gray water in Thailand

Photo 7 On-site treatment system for both black and gray water being installed in Chiang Mai University campus

WWTPs.

Some on-site treatment systems in Thailand are newly introduced in domestic wastewater treatment for both black and gray water (**Photos 6 and 7**). A step-wise improvement scheme for wastewater treatment systems (Japan Sewage Association, 1997) should be planned together with the current situations, on-site treatment systems and comprehensive pollutant discharges estimations. We hope the results and discussions in this paper will contribute to wastewater treatment system improvement in developing countries especially in the advanced development stage, including Thailand.

4. CONCLUSIONS

While on-site treatment method usages in WWTPs service areas are conventional in Thailand, some consideration is necessary on the traditional domestic wastewater treatment systems, or a combination of on-site treatment for black water and centralized treatment.

The estimation results based on the two scenarios, Scenario 1 and 2, showed that pollutant discharges to the ambient water of the current domestic wastewater treatment systems in Bangkok will be still large even in the WWTPs service areas. The estimation results for septic tanks and a piped collection system (Scenario 1) and septic tanks and a canal collection system (Scenario 2) showed smaller PDC-BOD, which should suggest smaller BOD concentrations in the WWTPs influent similar to the current WWTP influent. Larger direct discharges of pollutants to the ambient water were estimated in Case 1 of Scenario 2. Larger pollutant loads per capita in the WWTPs influent were estimated for piped collection system (Scenario 3), which suggested larger BOD and nutrients concentrations in the WWTPs influent. Larger BOD concentrations in WWTPs influent will enhance nutrients removal in the WWTPs.

Some newly developed on-site treatment systems in Thailand are being introduced in domestic wastewater treatment for both black and gray water. A step-wise improvement scheme for wastewater treatment systems should be planned together with the current situations, advanced on-site treatment systems and comprehensive pollutant discharges estimations to the ambient water and WWTPs.

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