Water quality situation in the Chao Phraya Delta

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ABSTRACT: *The Pollution Control Department (PCD) has been monitoring the water quality of the Chao Phraya Delta (Chao Phraya, Tha Chin, and Meklong Rivers) for decades. The results indicated that river quality in the lower parts of the Chao Phraya and Tha Chin Rivers have been degraded and the levels of parameters concerned have been lower than the Surface Water Quality Standard and its Classification. The major water quality problems for the year 1999 were low dissolved oxygen (DO) (27.5 %), high ammonia-nitrogen (25.5 %), high fecal coliform bacteria (23.0 %), high turbidity (14.4 %), high organic matter (biochemical oxygen demand, BOD) (5.0 %) and others (4.6 %). Major sources of water pollution are from communities, industries, and agriculture, which contributed proportion of sources varied from region to region. For example, major source of pollutant discharged in the lower part of the Chao Phraya River is from communities, while industries is play major contribution in the lower part of the Tha Chin River.*

The implications of water quality impairment in the delta are serious. Fish kills during dry season were believed to have been caused by sudden DO depletion, which may have resulted from flushing of land-based wastes into the main streams during heavy rainfall after extended dry period (a condition typical in the monsoon-driven climate). Such conditions occur regularly in the middle and upper sections of the Tha Chin River. The middle sections of the rivers are strongly influence by excessive wastewater from domestic and industrial sources as well as pig farms. The lower sections of The Chao Phraya and Tha Chin Rivers is further degraded, and continue to deteriorate there as a result of the rapid population growth currently being recorded in the delta.

Basin management approach is trying to apply for controlling both point and non-point source pollution. With the budget limitation, priority on implementation of the wastewater management projects should be based on carrying capacity or assimilative capacity of receiving waters. Future decision for the water quality management intended to reduce wastewater should not only focus exclusively on domestic loadings, but also should include measures for controlling other urban and rural sources, especially industries and pig farms. Additionally, nutrient loads from agricultural areas must be considered integral to future planning strategies. Even though farms currently

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contribute only a small fraction of overall waste loading, a widespread tendency to increase intensive agricultural practices can be discerned throughout the region and pollutant loading can be expected to increase dramatically as this occurs.

1 Introduction

The Chao Phraya Delta comprises of three major basins, Chao Phraya, Tha Chin, Meklong Basins (Figure 1). These rivers supply water, support fisheries, transportation and recreation and receive wastewater discharge. There are many environmental problems such as water pollution and ecological deterioration in these basins. Deterioration of river water quality has the greatest environmental impact. There are a variety of sources of water pollution in these basins including communities, industries and agriculture. Water pollution, through point and non-point sources, has become a major environmental concern in these basins. Major point sources of pollution, to these river basins include domestic and industrial waste discharges as well as some agricultural point sources such as pig, poultry, fish and other farms. Non-point sources include agricultural areas such as paddy fields, dry and vegetable farms, which constitute the main land uses in these basins. These rivers have water quality problems, which have been a major concern to citizens and officials for more than two decades. Hence, the formulation and evaluation of pollution control measures, which include measures to control, prevent and remedy environmental problem caused by pollution are processing in order to set national water quality standard and monitor the quality of these rivers.

PCD has monitored water quality in the Chao Phraya Delta for decades. The results of the rivers' water quality monitoring indicated that the lower parts of the Chao Phraya and Tha Chin Rivers have been facing water pollutant problems with lower quality than the Surface Water Quality Standard and its Classification. The major source of pollutant discharge in the lower part of the Chao Phraya River is communities, while industries and agriculture play as a major contributor in the lower part of the Tha Chin River.

The objectives of this paper are to evaluate and review water quality, to identify major water quality problems and their potential sources, and finally to assess water quality management strategies in the major rivers of the Chao Phraya Delta.

2 Water quality of the Chao Phraya delta

2.1 Water Quality Standards

The National Environmental Board was notified the Standard of Surface Water Quality and its Classification for the country's surface water in 1994 (Pollution Control Department, 2000a). This issue is used to support the receiving water based on major beneficial uses. There are 5 classes that are considered for surface water quality as follows:

FIGURE 1 LOCATION OF THE CHAO PHRAYA DELTA

- Class 1: Extra clean for conservation purposes

- Class 2: Very clean used for (1) consumption which requires ordinary water treatment processes (2) aquatic organism conservation (3) fisheries, and (4) recreation (for example, DO (Dissolved oxygen) > 6 mg/L, BOD (Biochemical oxygen demand) < 1.5 mg/L, TCB (Total coliform bacteria) < 5,000 MPN /100 mL)

- Class 3: Medium clean used for (1) consumption but passing through ordinary treatment process and (2) agriculture (for example, DO > 4 mg/L, BOD < 2 mg/L, and TCB < 20,000 MPN/100 mL)

- Class 4: Fairly clean used for (1) consumption, but requires special treatment process and (2) industry (for example, DO > 2 mg/L, BOD < 4 mg/L)

- Class 5: Water is not classified in class 1 – 4 and used for navigation

The rivers in Chao Phraya Delta have also been classified into various classes as shown in Table 1.

TABLE 1 CLASSIFICATION OF THE RIVERS IN THE CHAO PHRAYA DELTA

Control Areas (kmth from the river mouths, RKM)	River Classification (Class)
1. Chao Phraya River	
• 7 – 62	Class 4
• 62 – 142	Class 3
• 142 – 379	Class 2
2. Tha Chin River	
• 0 – 82	Class 4
• 82-202	Class 3
• 202-325	Class 2
3. Meklong River (0 – 140)	Class 3

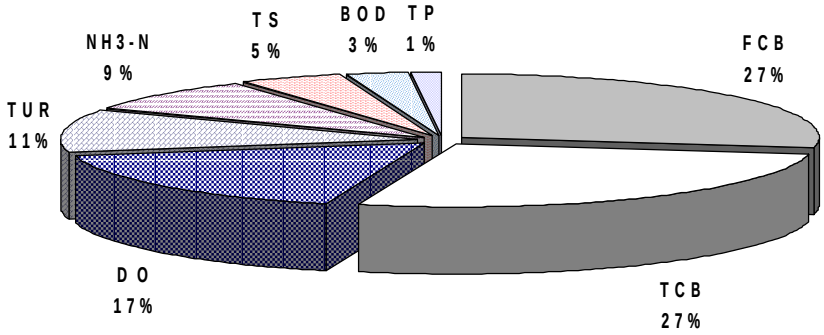
2.2 Water quality monitoring programs

The Chao Phraya River was subdivided into 3 sections and the water-quality classification of each sector is shown in Table 1. There are 18 monitoring stations covering the 3 sections of this river. The Tha Chin River was also subdivided into 3 sections and the water-quality classification of each sector is shown in Table 1. There are 13 monitoring stations covering the 3 sections. Meklong River has only one section (Class 3 of the Standard) with 10 monitoring stations in this river. Water quality sampling are routinely taken 4 times a year. Water quality parameters measured are physic-chemical parameters (Temperature, pH, conductivity, turbidity, total suspended solids, total solids, biochemical oxygen demand (BOD), dissolved oxygen (DO), total phosphorus, ammonia-nitrogen, nitrate-nitrogen and heavy metals) and biological parameters (fecal and total coliform bacteria). The method of water sampling and analysis procedures follows the Standard Method for the Examination of Water and Wastewater published in 1998 (Pollution Control Department, 2000a).

2.3 Chao Phraya River

The Chao Phraya River is the largest river in Thailand. The Chao Phraya River has been subdivided into three sections: lower (RKM 7 to 62), middle (RKM 62 to 142) and upper (RKM 142 to 379) based on the river water quality standard and its classification. Water quality monitoring results during the last decade (1984 – 1995) showed that water quality in the upper region were better than in the middle and lower parts of the river, respectively. Simachaya and Noikeang (2000) reported that the first three major polluted contributors in the Chao Phraya River regarding the respective parameters (Figure 2) are high coliform bacteria both total and fecal (54 %), low DO (17 %) and high turbidity (11 %).

FIGURE 2 PROBLEM'S PARAMETERS IN THE CHAO PHRAYA RIVER 1991-2000



In the lower part of the river, from the river month in Samut Prakarn Province (RKM 7) to the Rama VI Bridge in the Bangkok (RKM 62), the river was seriously polluted especially from organic contamination. The most alarming water quality problem in this part was low concentrations of DO during the dry period. DO levels of most monitoring stations were lower than the regulated value in the established water quality standard for industrial use (not less than 2 mg/L). The average DO value in this section from1978 to 1999 was 1.7 mg/L and the P20 (20th percentile) value during that period of time was only 0.5 mg/L (Table 2). From Figure 3, DO values in this section were very low especially from the river mouth to Pak Khlong Thevet in Bangkok. The DO levels in most monitoring stations in the year 2000 were still lower level than the DO standard levels of the lower part of the Chao Phraya River (the observed DO values ranged from 0 to 0.9 mg/L). BOD levels in this section were mostly below the established water quality standard (not more than 4 mg/L) with averaging BOD 2.6 mg/l and the P80 (80th percentile) 3.5 mg/L. TCB (Total coliform bacteria) values were found the maximum as 16,000,000 MPN/100 mL, average as 200,000 MPN/100 mL and P80 as 160,000 MPN/100 mL. Concentrations of TP (Total phosphorus), NH_3-N (Ammonia-nitrogen) and NO_3-N (Nitrate-nitrogen) in this section were averaged 0.22, 1.55 and 0.85 mg/L, respectively. For NH_3-N, the standard was set to be not more than 5 mg/L, for the river classifications 2, 3, and 4 (see Appendix). For the lower section of the Chao Phraya River, DO, FCB (Fecal coliform bacteria) and TCB were the major problems of water quality degradation by averaging 80, 75 and 71 %, respectively during 1991 to 2000 (Table 3). The major contributors to water pollution in this section were generated mainly from domestic and industrial activities.

TABLE 2 THE MOST ALARMING WATER QUALITY PARAMETERS OF THE CHAO PHRAYA RIVER 1978 TO 1999

	DO		BOD		TCB	
River Reaches	Average	P20	Average	P80	Average	P80
Lower	1.7	0.5	2.6	3.5	200,000	160,000
Middle	4.6	3.9	1.5	1.9	80,000	22,000
Upper	6.3	5.5	1.5	1.8	350,000	35,000

TABLE 3 PERCENTAGE OF PROBLEMS OF EACH WATER QUALITY PARAMETER OF THE CHAO PHRAYA RIVER 1991-2000

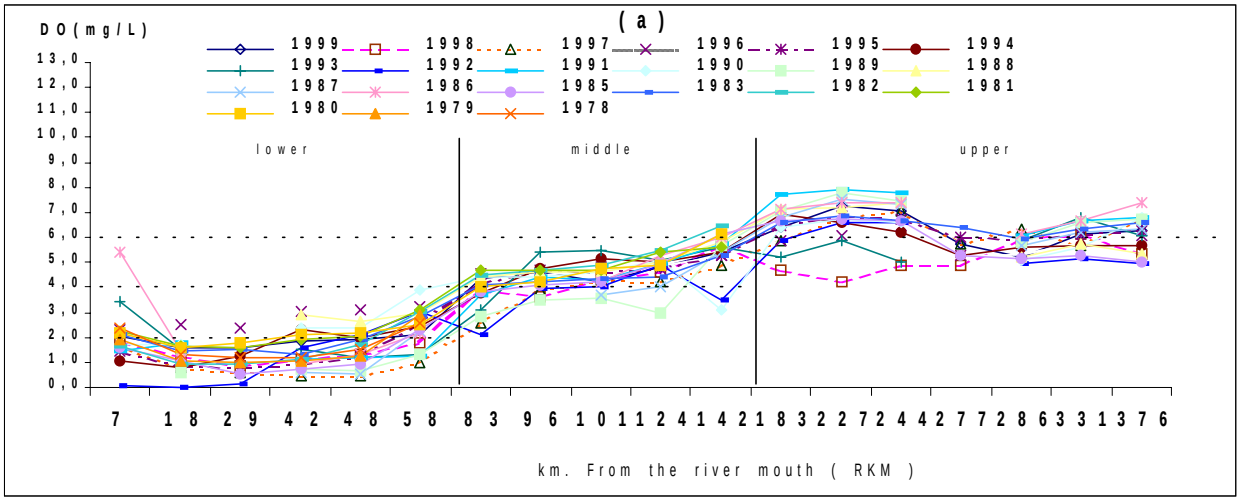
River Reaches	Tur.	DO	BOD	FCB	TCB	NH_3-N	TP	TS
Lower	24	80	10	75	71	56	7	31
Middle	36	6	2	40	36	2	0	0
Upper	26	1	2	36	37	1	1	0

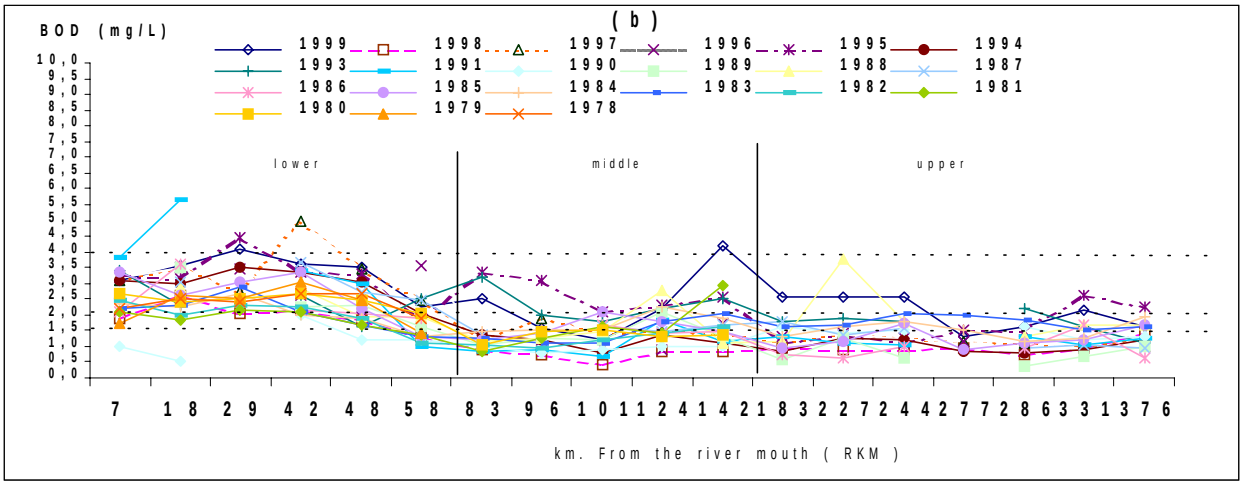
Water quality during 21 years (1978 – 1999) in the lower section has slightly sloped down trend of DO (Figure 4), slightly sloped up trend of BOD and extremely sloped up trend of TCB.

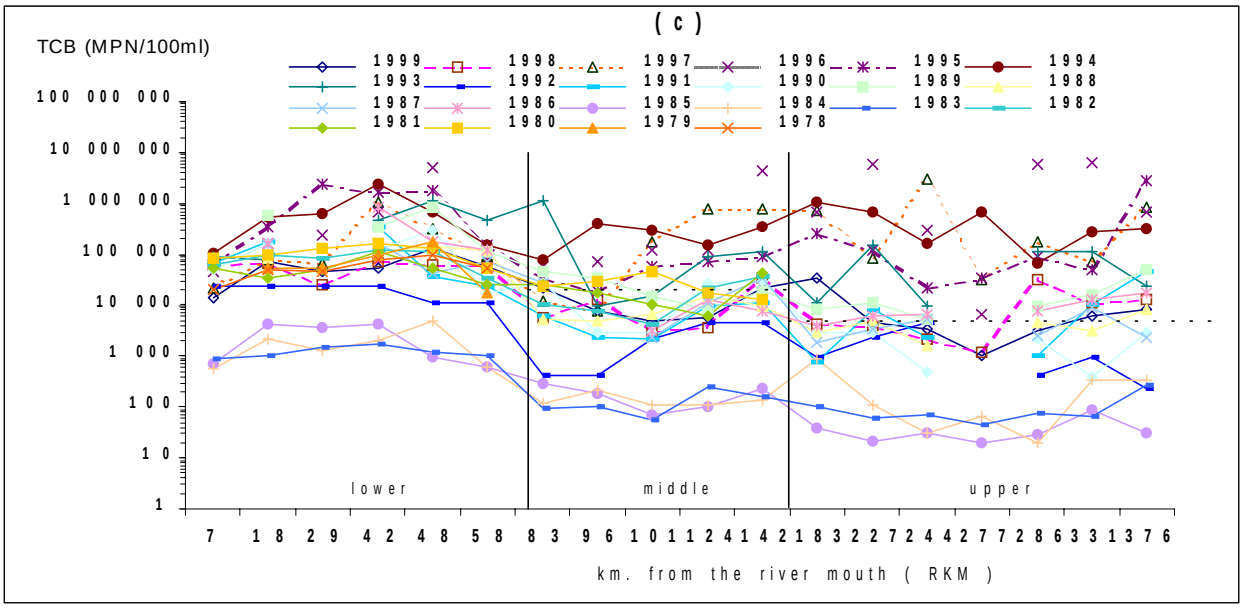
In the middle part, from Rama VI Bridge, Nonthaburi Province to Ayutthaya, the river was slightly polluted. The DO levels in most monitoring stations were slightly higher than the regulated value (not less than 4 mg/L), which were suitable for water consumption and agricultural uses. The average DO value was approximately 4.6 mg/L and the P20 value during the period was 3.9 mg/L. From Figure 2, DO values in this part were very moderately contaminated from Nonthaburi to Ayutthaya. The DO levels in almost all of the monitoring stations in year 2000 were not less than the DO standard level of the middle part of the Chao Phraya River (the observed DO values ranged from 1.0 to 2.9 mg/L). Pollution in term of average BOD was 1.5 mg/L and the P80 value was 1.9 mg/L. BOD values within this section did not exceed water quality standard (not more than 2.0 mg/L). The average TCB value was 80,000 MPN/100 mL and the P80 value was 22,000 MPN/100 mL, which was slightly higher than the regulated value (not more than 20,000 MPN/100 mL). Concentrations of TP, NH_3-N and NO_3-N in this section were averaged approximately 0.08, 0.10 and 0.63 mg/L, respectively. From table 3, FCB, TCB and turbidity are the major problem parameters by averaging 40, 36 and 36 % of most monitoring stations, respectively, during 1991 to 2000. The major contributors to pollution in this section were generated mainly from domestic and agricultural activities.

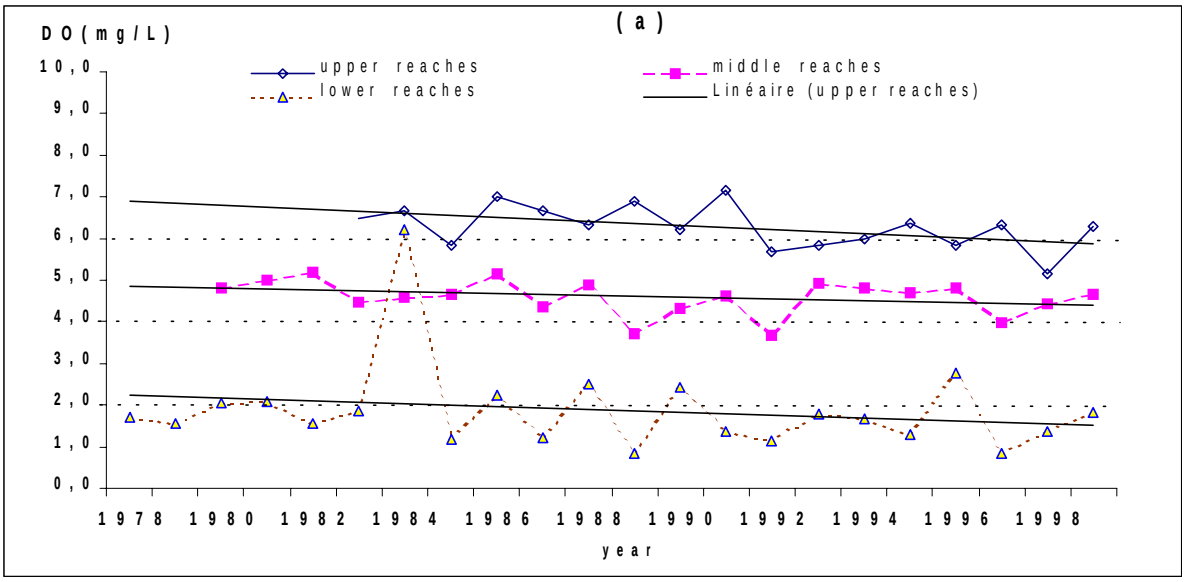
Consequently, the river water quality was in a less deteriorated state with normal DO value except in Amphoe Muang Nonthaburi, low BOD and slightly high FCB and TCB specifically in Amphoe Muang Ayutthaya. With compared to water quality since 1978, the trend of DO in this section is slightly sloped down, trend for BOD moderately slope up and TCB extremely slope up (Figure 4).

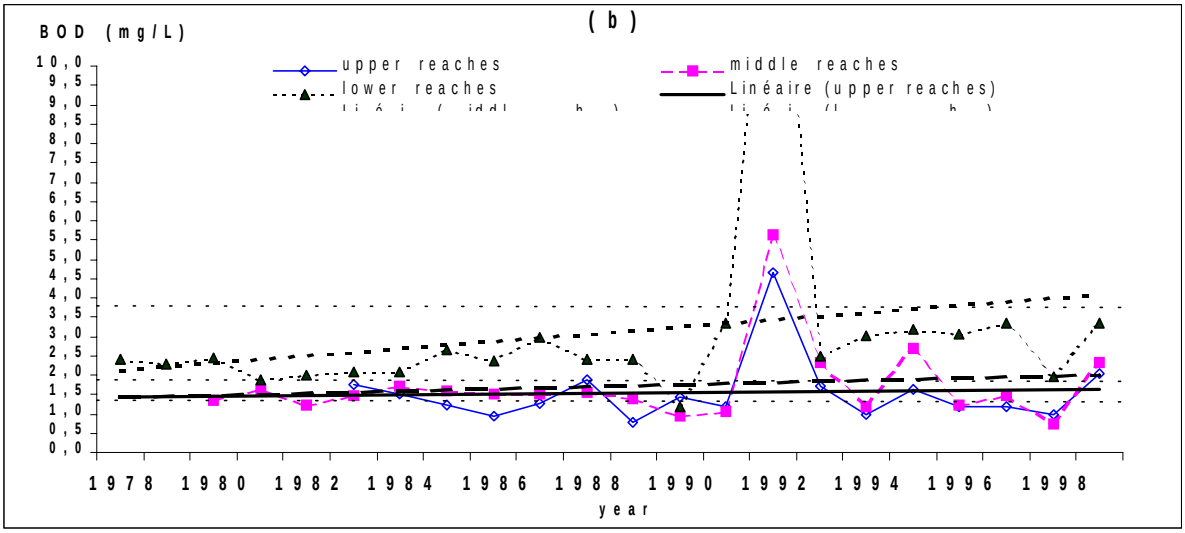
In the upper part of the river, from Amphoe Muang Ayutthaya to Amphoe Muang Nakhon Sawan, the river was less polluted. The average DO level in this section was 6.3 mg/L and the P20 value was 5.5 mg/L which was a little lower quality standard (not less than 6 mg/L). From Table 2, most DO values in this section were under the regulated standard value. The DO levels in almost all of the monitoring stations in year 2000 were higher level than the DO standard level (the observed DO values ranged from 4.0 to 7.9 mg/L) because of the dilution from flooding.


(a)
DO (mg/L)
1999 1998 1997 1996 1995 1994
1993 1992 1991 1990 1989 1988
1987 1986 1985 1983 1982 1981
1980 1979 1978
lower
middle
upper
km. From the river mouth (RKM)


(b)
BOD (mg/L)
1999 1998 1997 1996 1995 1994
1993 1991 1990 1989 1988 1987
1986 1985 1984 1983 1982 1981
1980 1979 1978
lower
middle
upper
km. From the river mouth (RKM)


(c)
TCB (MPN/100ml)
1999 1998 1997 1996 1995 1994
1993 1992 1991 1990 1989 1988
1987 1986 1985 1984 1983 1982
1981 1980 1979 1978
lower
middle
upper
km. from the river mouth (RKM)


(a)
DO (mg/L)
upper reaches
middle reaches
lower reaches
Linéaire (upper reaches)
10,0
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998
year


(b)
BOD (mg/L)
upper reaches
middle reaches
lower reaches
Linéaire (upper reaches)
10,0
9,5
9,0
8,5
8,0
7,5
7,0
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
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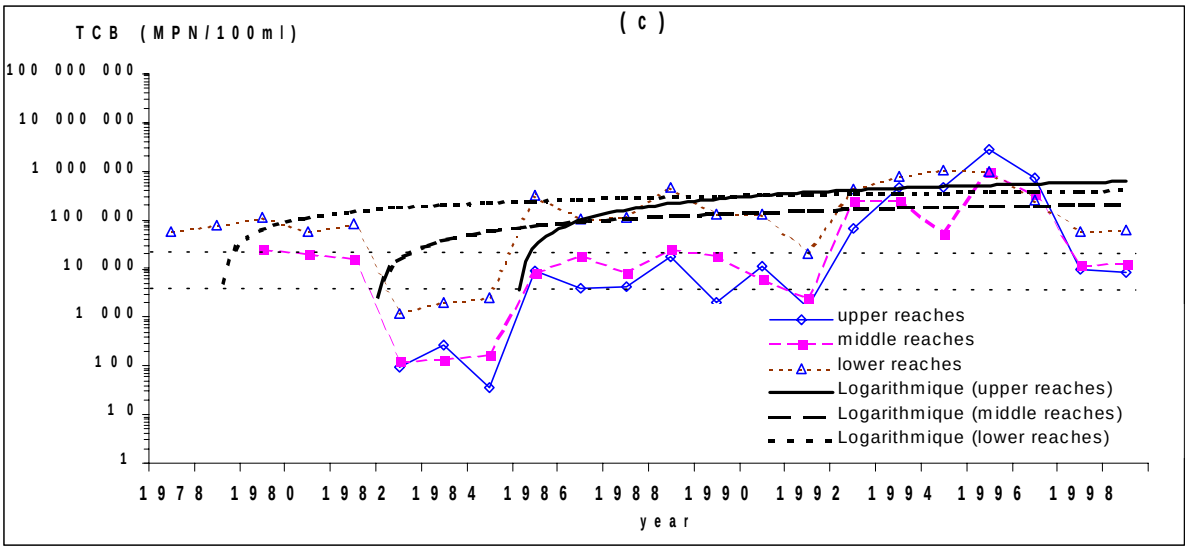
0,0
1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998
year


(c)
TCB (MPN/100ml)
100 000 000
10 000 000
1 000 000
100 000
10 000
1 000
100
10
1
upper reaches
middle reaches
lower reaches
Logarithmique (upper reaches)
Logarithmique (middle reaches)
Logarithmique (lower reaches)
1978 1980 1982 1984 1986 1988 1990 1992 1994 1996 1998
year

The average BOD value in this section was 1.5 mg/L and the P80 was 1.8 mg/L. BOD values in this section did slightly exceed the regulated value (not more than 1.5 mg/L). The average TCB was 350,000 MPN/100mL and the P80 value was 35,000 MPN/100 mL with higher than the regulated standard (not more than 5,000 MPN/100 mL). Concentrations of TP, NH_3-N and NO_3-N in this section were averaged approximately 0.07, 0.08 and 0.52 mg/L, respectively. In the upper section of the Chao Phraya River, TCB, FCB and turbidity were the major problem parameters by averaging 37, 36 and 26 % of all monitoring stations during 1991 to 2000 (Table 3). The major contributors to pollutant generation in this section were mainly from domestic and agricultural activities.

I the upper part of the river, water quality was in a natural state, and most stations was slightly lower DO values, and higher BOD, FCB and TCB values than the regulated standard. The lowest DO values in this section were found to be 4.8 mg/L at Aumphor Muang Chainat. However, the BOD values in this section were higher than the surface water quality standard especially in the river flowing via large communities. TCB values mostly exceeded over the regulated value. with Compared to water quality during 21 years (1978 – 1999), trend of DO in this section slightly sloped down, while trend of BOD slightly sloped up and trend of TCB extremely sloped up (Figure 4).

In summary, the water quality of the Chao Phraya River was “moderately clean” in the upper part, “ lightly polluted” in the middle part and “ polluted” in the lower part. DO, BOD and FCB/TCB are major problems of water quality parameters. Low DO level, and high BOD and FCB/TCB were the most alarming water quality problems in the river. However, other parameters are needed to be considered such as nutrients from agricultural non-point source pollution.

2.4 Tha Chin river

The Tha Chin River has been subdivided into three sections: lower (RKM 0 to 82), middle (RKM 82 to 202) and upper (RKM 202 to 325) based on the river water quality standard and its classification. Water quality monitoring during the last decade (1984 – 1995) showed that water quality in the upper region were better than in the middle and lower parts of the river, respectively. The first three major polluted contributors in the Tha Chin River regarding the respective parameters (Figure 5) are low DO (30 %), high FCB and TCB (47 %) and high NH_3-N (15 %). Simachaya (1999) states that organic waste in term of BOD generation in the entire Tha Chin Basin are highest from industrial sector (33 %), followed by domestic sources (30 %), pig farms (23 %), fish and shrimp farms (12 %), and duck farms (2 %).

In the lower part, from the river mouth Samut Sakhon Province (RKM 0) to the Nakhon Chaisi District in the Nakhon Pathom Province (RKM 82), the river was seriously polluted with organic waste contamination. The most alarming water quality problem in this part was the low concentrations of dissolved oxygen (DO) during the dry period. DO levels almost every monitoring stations were lower than the regulated value of the established water quality standard for industrial use (not less than 2 mg/L). The average DO value in this section since 1982 was 1.2 mg/L and the P20 value during that time was 0.5 mg/L (Table 4). From figure 6, DO values in this part are very low especially from the river mouth to Nakhon Chaisi

District. The DO levels in most monitoring stations in year 2000 were lower than the regulated standard value (the observed DO values ranged from 0.0 to 0.9 mg/L). BOD levels in this section were mostly below the established water quality standard (not more than 4 mg/L). The average BOD value was 2.6 mg/L and the P80 value was 3.5 mg/L. TCB values were found as follows, the maximum as 24,000,000 MPN/100 mL, average as 350,000 MPN/100 mL and P80 as 170,000 MPN/100 mL. Concentrations of TP, NH_3-N and NO_3-N in this section were approximately 0.22, 0.68 and 0.85 mg/L, respectively. In the lower part of the Tha Chin River, DO, FCB, TCB, and NH_3-N were the major problem parameters by averaging 95, 69, 67 and 62 %, respectively, of all monitoring stations during 1991 - 2000 (Table 5). However, TS and BOD could be the potential problem's parameters in this section. The major contributors to water pollution in this section were generated mainly from domestic and industrial activities and pig farms.

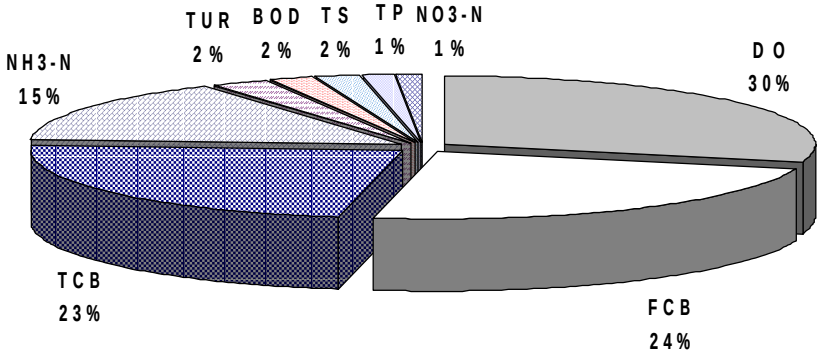


FIGURE 5 PROBLEM'S PARAMETERS IN THE THA CHIN RIVER 1991-2000

TABLE 4 THE MOST ALARMING WATER QUALITY PARAMETER OF THE THA CHIN RIVER 1982 - 1999

	DO		BOD		TCB	
River Reaches	Average	P20	Average	P80	Average	P80
Lower	1.2	0.5	2.6	3.5	350,000	170,000
Middle	2.5	1.2	2.4	3.0	700,000	220,000
Upper	5.2	4.4	1.8	2.1	650,000	120,000

TABLE 5 PERCENTAGE OF WATER – QUALITY PARAMETER PROBLEMS OF THE THA CHIN RIVER 1991-2000

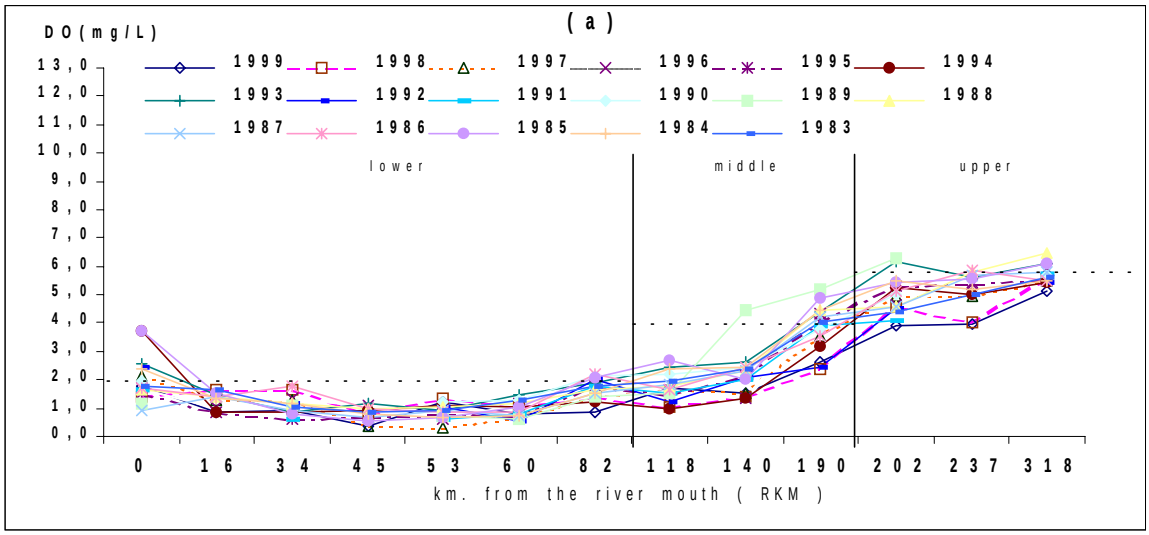
River Reaches	Tur.	DO	BOD	FCB	TCB	NH_3-N	TP	TS
Lower	0	95	6	69	67	62	5	11
Middle	4	73	5	49	49	23	1	0
Upper	28	3	3	45	43	3	0	0

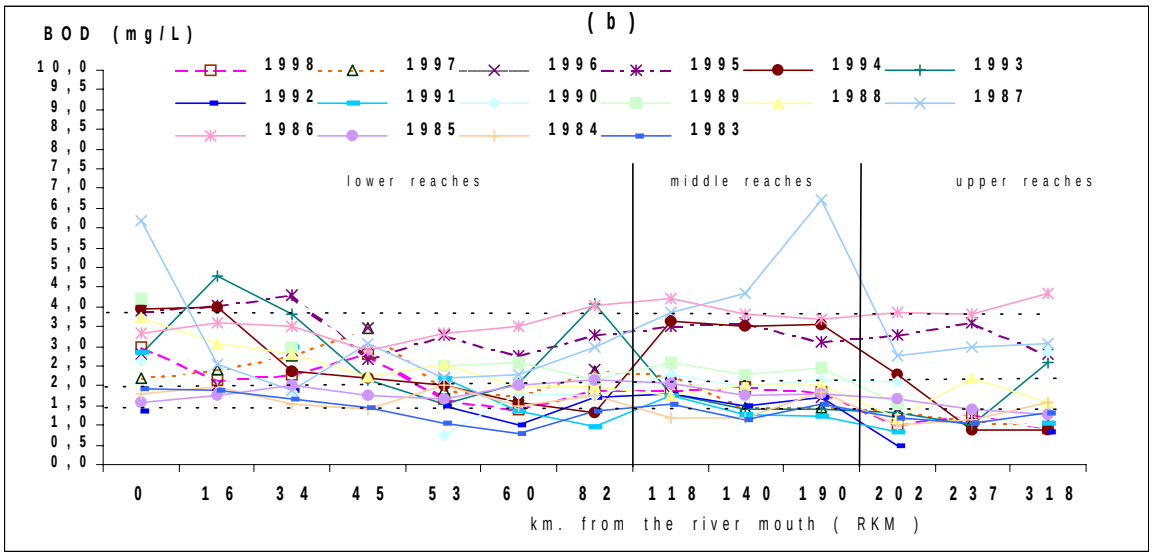
In the lower part, there were many canals in Nakhon Pathom and Samut Sakhon joining and delivering wastewater from domestic and industrial sources. Form Figure 7, water quality during 16 years (1982 – 1999) has trend of DO slightly sloped down and trend of BOD and TCB extremely sloped up.

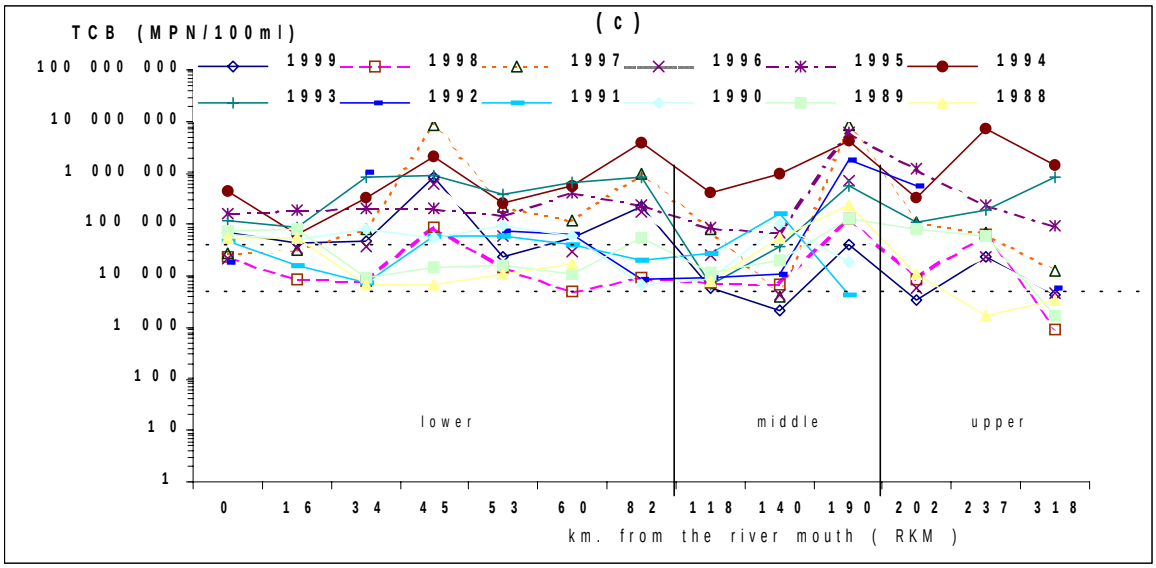
In the middle part, from Nakhon Chaisi District to the Phopraya Regulator in SuphanBuri Province the river was moderately polluted. The DO levels in almost all of the monitoring stations were lower than the regulated value for consumption and agricultural use (not less than 4 mg/L). The average DO value was 2.5 mg/L and the P20 value during that period was 1.2 mg/L. From Figure 6, DO values in this part was very seriously contaminated from domestic wastewater discharges between Nakhon Chaisi District and Muang Suphanburi. The DO levels of most monitoring stations in year 2000 were lower level than the DO standard level of Class 3 (the observed DO values ranged from 1.0 to 3.9 mg/L. Concentration of BOD was 2.4 mg/L and the P80 value was 3.0 mg/L. BOD values in this section did exceed water quality standard (not more than 2.0 mg/L). The average TCB was 700,000 MPN/100 mL and the P80 value was 220,000 MPN/100 mL, which was higher than Class 3 of the Surface Water Quality Standard (not more than 20,000 MPN/100 mL). Concentrations of TP, NH_3-N and NO_3-N in this section were averaged approximately 0.10, 0.31 and 0.50 mg/L, respectively. In the Tha Chin River, concentrations of DO, FCB and TCB were major problem parameters by averaging 73, 49 and 49%, respectively, of all monitoring stations during 1991 - 2000 (Table 5). Additionally, NH_3-N and turbidity could be the potential problem's parameters in this section. The major pollution sources in this sector were from domestic and agricultural activities.

The middle part of the Tha Chin's water quality was in a moderately deteriorated state with low DO values specifically in Nakhon Pathom Province and high BOD and very high FCB/TCB especially in the river flowing in Nakhon Pathom Province. with Compared to water quality since 1982, the trend of DO in this section slightly sloped down, while the trend of BOD slightly sloped up and TCB extremely sloped up (Figure 7).

In the upper part of the river, from the Phopraya Regulator to the Polthep Regulator, the river is less polluted. The average DO level in almost all of this section was 5.2 mg/L and the P20 value was 4.4 mg/L lower than the water quality standard (not less than 6 mg/L). From Figure 6, DO values in this part is less contaminated. The DO levels in almost all of the monitoring stations in year 2000 were higher level than the DO standard level of the upper reaches of the Tha Chin River (the observed DO values ranged from 0.0 to 0.9 mg/L). The average BOD value in this section was 1.8 mg/L and the P80 value was 2.1 mg/L. BOD values in this section did exceed the regulated value (not more than 1.5 mg/L). The average TCB was 650,000 MPN/100mL and the P80 value was 120,000 MPN/100 mL (not more than 5,000 MPN/100 mL). Concentrations of TP, NH_3-N and NO_3-N in this section were averaged approximately 0.07, 0.10 and 0.88 mg/L, respectively. FCB, TCB, and turbidity are the major problem parameters by averaging 45, 43 and 28 % of monitoring stations during 1991 - 2000 (Table 5). The major contributors to pollution in this section were generated mainly from domestic and agricultural activities.


(a)
DO (mg/L)
1999 1998 1997 1996 1995 1994
1993 1992 1991 1990 1989 1988
1987 1986 1985 1984 1983
lower
middle
upper
13,0 12,0 11,0 10,0 9,0 8,0 7,0 6,0 5,0 4,0 3,0 2,0 1,0 0,0
0 16 34 45 53 60 82 118 140 190 202 237 318
km. from the river mouth (RKM)


(b)
BOD (mg/L)
1998 1997 1996 1995 1994 1993
1992 1991 1990 1989 1988 1987
1986 1985 1984 1983
lower reaches
middle reaches
upper reaches
10,0 9,5 9,0 8,5 8,0 7,5 7,0 6,5 6,0 5,5 5,0 4,5 4,0 3,5 3,0 2,5 2,0 1,5 1,0 0,5 0,0
0 16 34 45 53 60 82 118 140 190 202 237 318
km. from the river mouth (RKM)


(c)
TCB (MPN/100ml)
1999 1998 1997 1996 1995 1994
1993 1992 1991 1990 1989 1988
100 000 000
10 000 000
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1 000
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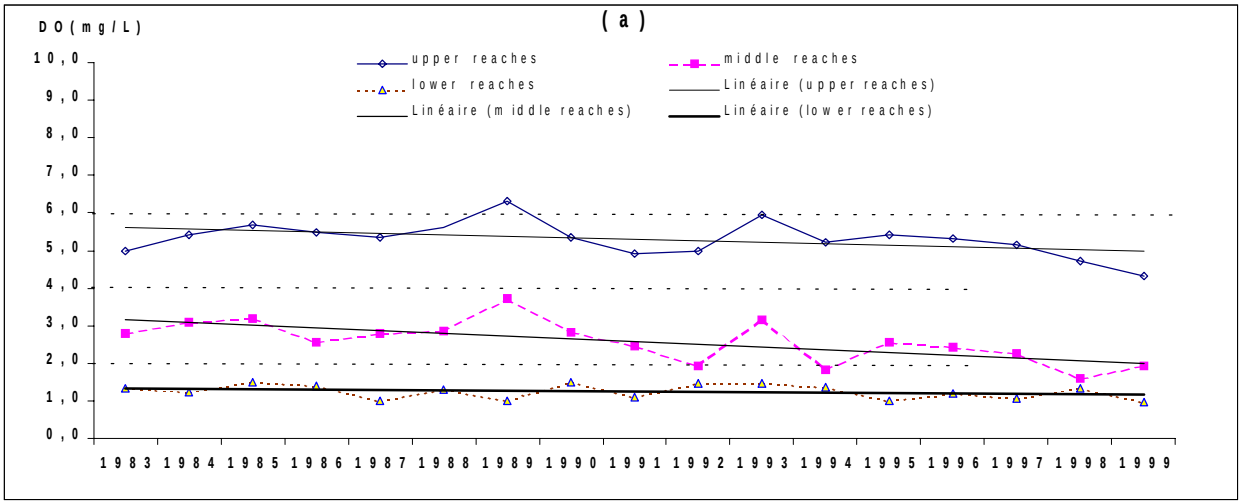
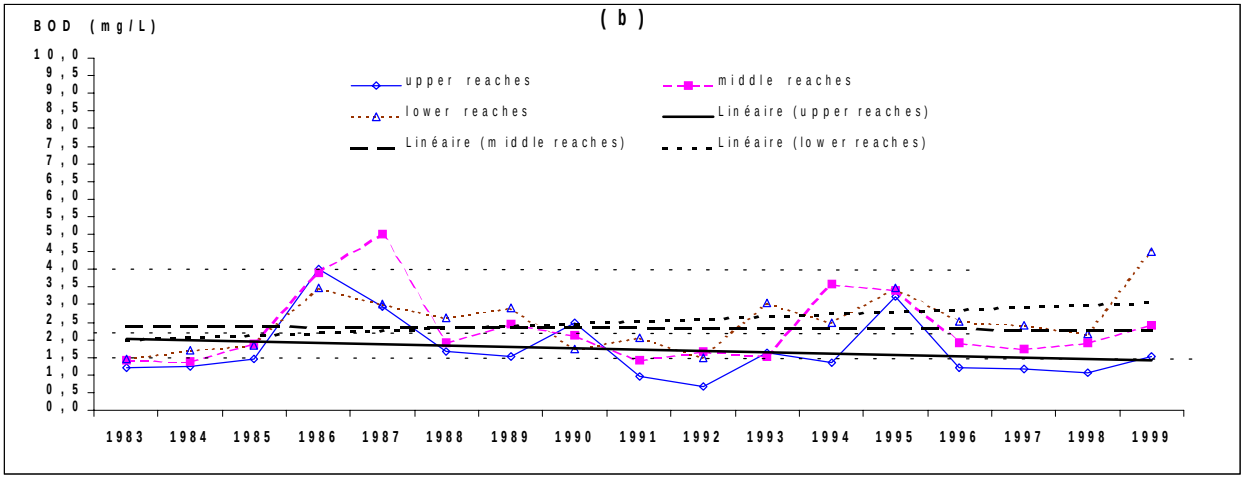
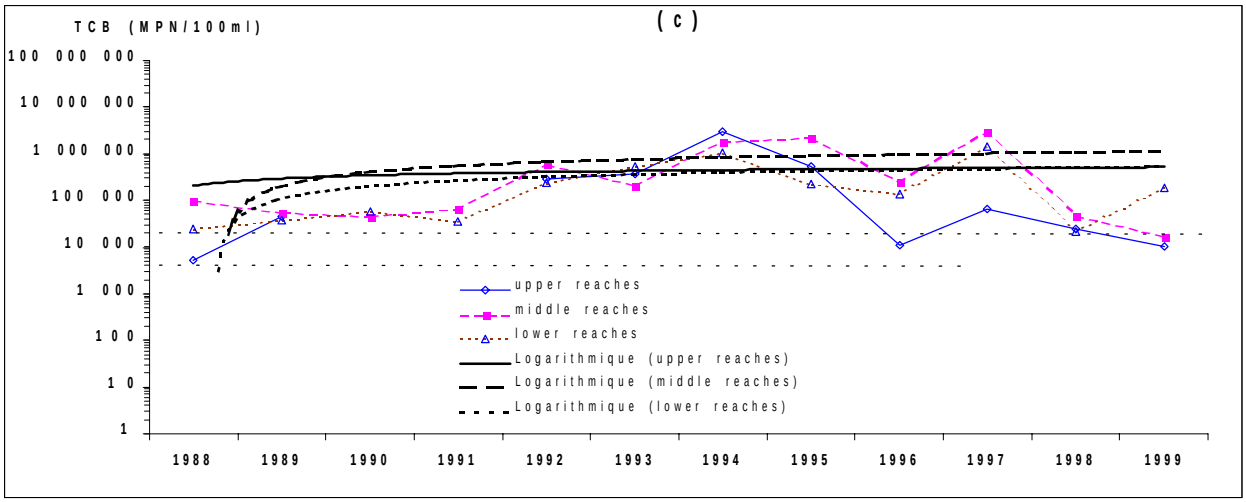
1
lower
middle
upper
0 16 34 45 53 60 82 118 140 190 202 237 318
km. from the river mouth (RKM)


(a)
DO (mg/L)
10,0
9,0
8,0
7,0
6,0
5,0
4,0
3,0
2,0
1,0
0,0
upper reaches
middle reaches
lower reaches
Linéaire (upper reaches)
Linéaire (middle reaches)
Linéaire (lower reaches)
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999


(b)
BOD (mg/L)
10,0
9,5
9,0
8,5
8,0
7,5
7,0
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
upper reaches
middle reaches
lower reaches
Linéaire (upper reaches)
Linéaire (middle reaches)
Linéaire (lower reaches)
1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999


(c)
TCB (MPN/100ml)
100 000 000
10 000 000
1 000 000
100 000
10 000
1 000
100
10
1
upper reaches
middle reaches
lower reaches
Logarithmique (upper reaches)
Logarithmique (middle reaches)
Logarithmique (lower reaches)
1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999

In summary, the river water quality in the ThaChin River was in a natural state, and almost every stations in the upper reaches have slightly lower DO values, and higher BOD and TCB than the regulated standard. DO value in this section has the lowest value in Samchuk District within 4.8 mg/L of the P20 value. However, the BOD values this section were higher than the Surface Water Quality Standard in the river sections which large communities are located. On the other hand, the TCB values were mostly exceeded over the regulated value. When compared to water quality during 16 years (1982 – 1999), trend of DO in this section slightly sloped down, trend of BOD slightly sloped up and trend of TCB extremely sloped up (Figure 7).

During late April to early May 2000, water quality along the 150-kilometer length of the Tha Chin River from Song Phi Nong District in Suphan Buri Province, Nakhon Pathom Province, and down to Muang District in Samut Sakorn Province, was completely polluted. The watercolor became black with very bad smell. Concentrations of DO in the river measured during May 3-7, 2000 became zero. The water river quality became worse when it flowed through Nakhon Pathom and Samut Sakhon Provinces because of discharge of a large amount of wastewater from industries, communities, and pig farms. However, DO concentrations of the river have never been reached zero. Large number of fish and other aquatic organisms died after the mass of high polluted water flowed through. The effect of this disaster was investigated from the opportunity losses on water usage, water supply, and aquatic system. The aquatic ecosystem in the river and estuary was destroyed. The major pollution source of this disaster was from the discharged wastewater from Song Phi Nong Sub-delta (132,000 rai) because the paddy fields were flooded and decayed just before harvesting period (high carbohydrate content) (Pollution Control Department, 2000b).

In general, the water quality of the Tha Chin River is “clean” in the upper reaches, “moderately polluted” in the middle reaches and “ polluted” in the lower one. DO, BOD and FCB/TCB are main parameters of the river water quality. Low DO level, and high BOD and FCB/TCB are the most alarming water quality problems in the river. However, other parameters are needed to consider as well as the three major parameters. Thus, use of all parameters has been increased to improve this paper in order to investigate the main effect from most activities in the Tha Chin River Basin.

2.5 Meklong River

The Meklong River is classified in class 3 of the Surface Water Quality Standard. There are 10 water-quality sampling stations in the river. Water quality monitoring results during the last decade (1984 – 1995) were to be fair and good water quality. The first three major polluted contributors in the Meklong River regarding the respective parameters (Figure 8) are high FCB and TCB (79 %), high TS (8 %) and high turbidity (6 %).

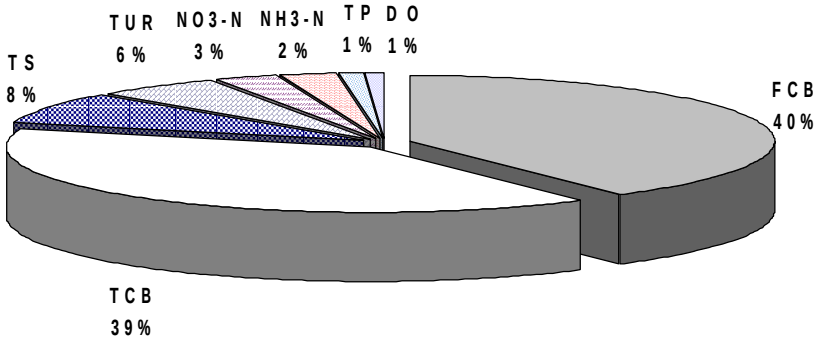
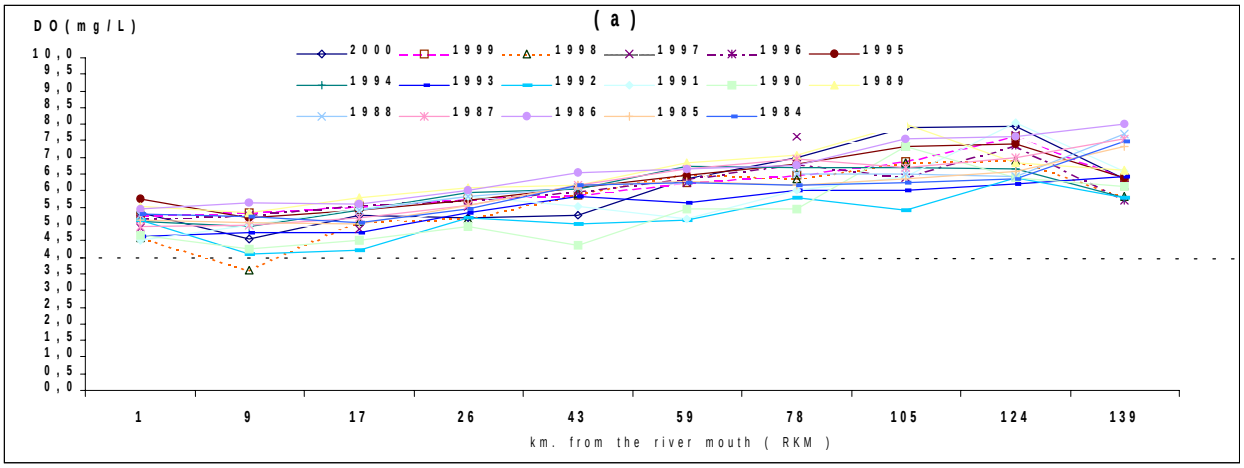


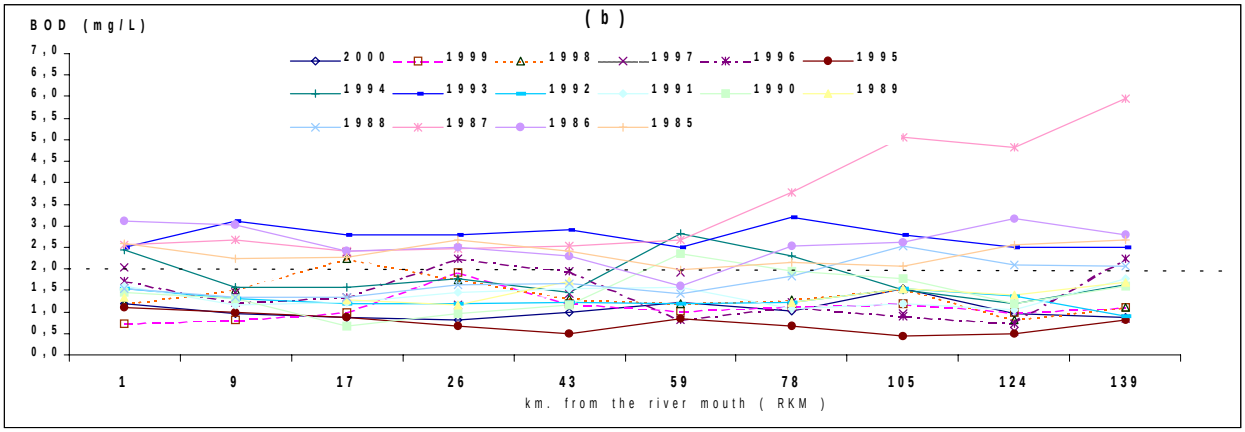
Figure 8 Problem's Parameters in the Meklong River 1992-2000

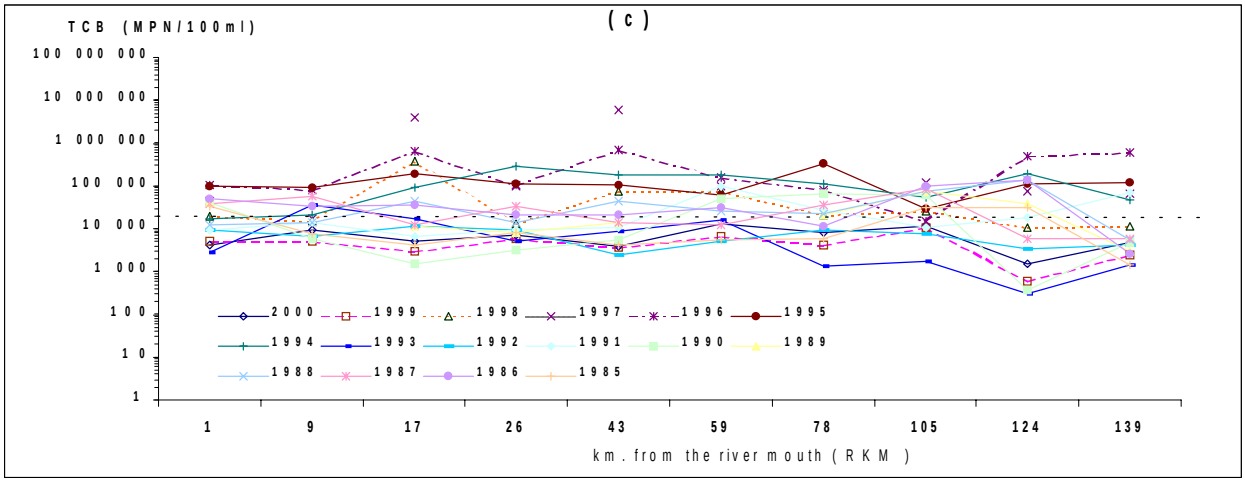
The Meklong River is less polluted. The most alarming water quality problem in this part is the low concentrations of dissolved oxygen (DO) during the dry period in certain years. However, DO levels almost every monitoring stations were higher than the regulated value in the established water quality standard for industrial use (not less than 4 mg/L). The average DO value in this section since 1978 to 1999 was 6.0 mg/L and the P20 value during those period of time was 5.1 mg/L (Table 6), which was within the Class 3 of the Surface Water Quality Standard. From Figure 9, most DO values in the river were higher than the standard value especialy from Dumnensaduk District, Rachaburi Province to Kanchanaburi Province. BOD levels in this section were mostly below established water quality standard (not more than 2 mg/L) with averaging 1.7 mg/L and the P80 value 2.3 mg/L. TCB values were found to be high with the maximum as 16,000,000 MPN/100 mL, average as 200,000 MPN/100 mL and P80 as 160,000 MPN/100 mL, which was higher than the standard value (not more than 20,000 MPN/100 mL). Concentrations of TP, NH_3-N and NO_3-N in the river were averaged 0.05, 0.14 and 0.31 mg/L, respectively. For the lower part of the Meklong River, FCB and TCB are the major problem parameter by averaging 44 and 43 % of all monitoring stations during 1991 to 2000 (Table 7). The major contributors to pollution in this section were generated mainly from domestic and industrial activities.

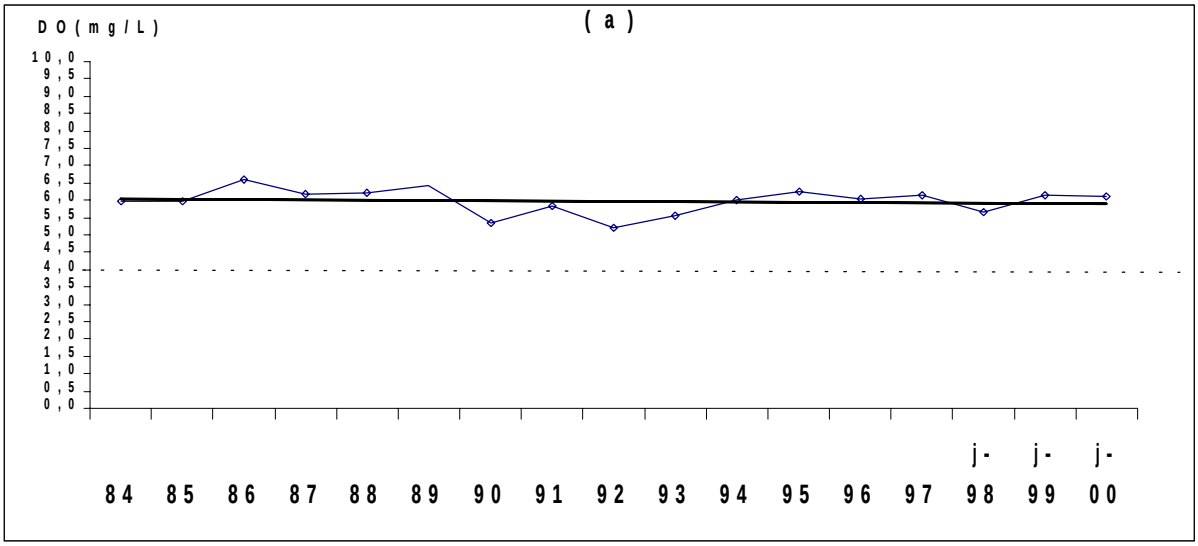
TABLE 6 THE MOST ALARMING WATER QUALITY PARAMETERS OF THE MEKLONG RIVER 1978 - 1999

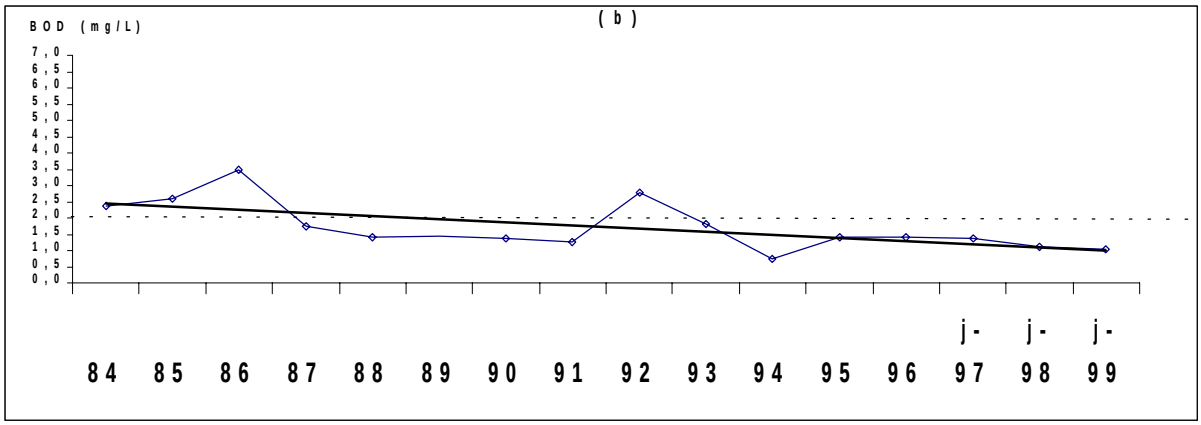
	DO		BOD		TCB	
	Average	P20	Average	P80	Average	P80
River Reaches	6.0	5.1	1.7	2.3	200,000	160,000


(a)
DO (mg/L)
2000 1999 1998 1997 1996 1995
1994 1993 1992 1991 1990 1989
1988 1987 1986 1985 1984
10,0 9,5 9,0 8,5 8,0 7,5 7,0 6,5 6,0 5,5 5,0 4,5 4,0 3,5 3,0 2,5 2,0 1,5 1,0 0,5 0,0
1 9 17 26 43 59 78 105 124 139
km. from the river mouth (RKM)


(b)
BOD (mg/L)
2000 1999 1998 1997 1996 1995
1994 1993 1992 1991 1990 1989
1988 1987 1986 1985
7,0 6,5 6,0 5,5 5,0 4,5 4,0 3,5 3,0 2,5 2,0 1,5 1,0 0,5 0,0
1 9 17 26 43 59 78 105 124 139
km. from the river mouth (RKM)


(c)
TCB (MPN/100ml)
100 000 000
10 000 000
1 000 000
100 000
10 000
1 000
100
10
1
2000 1999 1998 1997 1996 1995
1994 1993 1992 1991 1990 1989
1988 1987 1986 1985
1 9 17 26 43 59 78 105 124 139
km. from the river mouth (RKM)


(a)
DO (mg/L)
10,0
9,5
9,0
8,5
8,0
7,5
7,0
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
j- j- j-
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00


(b)
BOD (mg/L)
7,0
6,5
6,0
5,5
5,0
4,5
4,0
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
j- j- j-
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

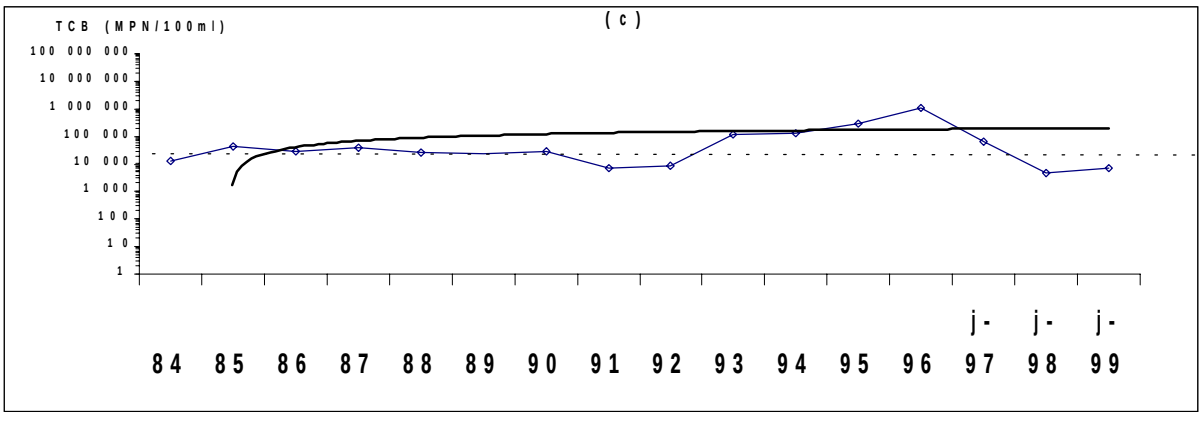

(c)
TCB (MPN/100ml)
100 000 000
10 000 000
1 000 000
100 000
10 000
1 000
100
10
1
j- j- j-
84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99

TABLE 7 PERCENTAGE OF PROBLEMS OF EACH WATER QUALITY PARAMETER OF THE MEKLONG RIVER 1991-2000

	Tur	DO	BOD	FCB	TCB	NH_3-N	NO_3-N	TS
River Reaches	8	1	0	44	43	3	3	9

In summary, the Meklong River's water quality was still in good condition with high DO and low BOD values. However, some parts of the river especially in the urban areas, TCB and FCB were very high and sometimes higher that the value of the water quality standard. The river 's water quality during 14 years (1985 – 1999) has slightly sloped down trend of DO (Figure 10) and slightly sloped up trend of BOD and extremely sloped up trend of TCB.

3 Water quality management

As mentioned earlier, there are three major pollution sources: domestic, industrial, and agricultural wastewater. The contributions of waste loads from those sources are different from place to place. For examples, the major source of pollutant in the Chao Phraya River from domestic wastewater, while agricultural sources (especially pig farms) and industrial activities are major wastewater sources for the Tha Chin River. Various management approaches have been applied to tackle water pollution problems in the Chao Phraya Delta such as:

- Establish receiving water quality standards and classification based on existing beneficial uses and loading reduction policies
- Set up effluent standards for major pollution sources such as building, industry, pig farm, etc.
- Construct central treatment plants of major municipalities
- Monitor receiving water quality an effluent from point-source pollution
- Implement public awareness program
- Set up the restricted zone for protection the source of water supply (cabinet resolution) Such as limitation of industrial expansion especially that factories produce toxic substances and high organic matter discharges
- Set up Wastewater Management Authority for the region.

4 Conclusion

The most alarming water quality problem in the delta is the low concentrations of DO and high concentrations of coliform bacteria especially during the dry period. DO concentrations were found to be less than 1 mg/L and coliform bacteria were found in densities of up to 10 times the standard levels. It can be concluded that the pollution in the lower parts of the

Chao Phraya and Tha Chin Rivers has reached a critical status compared to the established water quality standards. However, water quality of Meklong River has been in good condition due to less amount of waste loading and high water quantity. Thus, the treatment of wastewater effluent to acceptable standards before discharging into receiving waters is highly required. In general, the first priority concern is the risk to human health and aquatic life. However, the importance of the waterbody for recreation, aesthetic, and economic purposes, and the fragility of any specific environments such as aquatic habitat and wetlands should also be concerned.

RECOMMENDATIONS

1. Since the water quality of the Chao Phraya Delta is becoming worse every year especially in the lower parts of the Chao Phraya and Tha Chin Rivers, appropriate investment in wastewater treatment facilities in these sections should be prioritized based upon assimilative capacity of receiving waters, budget availability, and prioritized projects within basin-wide approach. Simple wastewater system based on natural conditions are also being addressed such as wet land applications, stabilization ponds, and crop irrigation systems.

2. Waste minimization which is included wastewater recycle and reuse, should be applied in the delta for reducing waste and maintain water quantity in main streams especially for land application and agricultural fields. Some factories have used treated water in the cooling system. However, there is recently no enforcement of this aspect. Only campaign and reinforcement are practicing. The term of “cleaner production” encompasses all phase of production process and product life cycle should also be considered. As agriculture (mainly paddy fields) is a dominant land use in the delta and is thus an important source of water pollution, it is recommended that measure and policy of best management practices (BMPs) should be developed and applied as a tool for water quality management especially for non-point source pollution controls.

3. Database system for the delta should be developed such as geographic information system (GIS), water quality and quantity database, and development projects. The system should be made available for public.

4. Once water quality problems have been identified, it is necessary to develop targets for restoration especially the planning exercise in a basin-wide basis.

5. Water quality management planning should be developed regarding the information of community health risk potential, proximity to water supply sources, magnitude of the pollutant loading discharged to the receiving water, carrying capacity of the stream to absorb pollutants, water quality criteria, and distance of pollutant source from the stream.

6. In Thailand, there are more than 30 agencies within 8 different ministries that are directly and indirectly concerned with water quality and quantity. Thus, a national planning on water resources management should be developed under appropriate institutional and legal frameworks. Watershed committee in each basin or sub-basin should also be set up to handle and manage water resources in the basin.

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Appendix

THE SURFACE WATER QUALITY STANDARD IN THAILAND

Parameter	Units	Statistic	Standard Value for Class***				
			1	2	3	4	5
1. Colour, Odour and Taste	-	-	N	N	N	N	-
2. Temperature	oC	-	N	N'	N'	N'	-
3. pH value	-	-	N	5-9	5-9	5-9	-
4. Dissolved Oxygen	mg/l	P20	N	6.0	4.0	2.0	-
5. BOD (5 days, 20 oC)	mg/l	P80	N	1.5	2.0	4.0	-
6. Coliform Bacteria							
- Total coliform	MPN/100ml	P80	N	5000	20000	-	-
- Fecal coliform	"	"	N	1000	4000	-	-
7. NO_3 -N	mg/l	Max.	N	5.0			-
8. NH_3 -N	"	allowance	N	0.5			-
9. Phenols	"	"	N	0.005			-
10. Cu	"	"	N	0.1			-
11. Ni	"	"	N	0.1			-
12. Mn	"	"	N	1.0			-
13. Zn	"	"	N	1.0			-
14. Cd	"	"	N	0.005*, 0.05**			-
15. Cr (hexavalent)	"	"	N	0.05			-
16. Pb	"	"	N	0.05			-
17. Hg (total)	"	"	N	0.002			-
18. As	"	"	N	0.01			-
19. CN	"	"	N	0.005			-
20. Radioactivity							
- Gross α	Becqurel/l	"	N	0.1			-
- Gross β	"	"	N	1.0			-
21. Pesticides(total)	mg/l	Max.	N	0.05			-
- DDT	μg/l	allowance	N	1.0			-
- α BHC	"	"	N	0.02			-
- Dieldrin	"	"	N	0.1			-
- Aldrin	"	"	N	0.1			-
- Heptachlor & Heptachlor Epoxide	"	"	N	0.2			-
- Endrin	"	"	N	none			-

Remark: P = Percentile value; N = naturally; N' = naturally but changing not more than 3 oC
* = when water hardness not more than 100 mg/l as CaCO3
** = when water hardness more than 100 mg/l as CaCO3
*** = Water Classification

Source: Pollution Control Department (2000a), National Environment Board Notification No.8 published in the Royal Goverment Gazette, vol. 111, No.16, dated February 4, B.E. 2537 (1994).