MEKONG RIVER COMMISSION
For Sustainable Development

2016 LOWER MEKONG
Regional Water Quality
MONITORING REPORT

The Mekong River Commission Secretariat
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Acknowledgements

This report is based on water quality data obtained from the MRC Water Quality Monitoring Network (WQMN). The WQMN is one of the MRC's Core River Basin Management Functions and is actively being implemented by the MRC Member Countries. As such, the preparation of this report would not have been possible without the continued support of the MRC Member Countries, specifically, the national water quality laboratories of the Member Countries and the National Mekong Committee Secretariats.

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Abbreviations

AL	Guidelines for the Protection of Aquatic Life
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CODMN	Chemical Oxygen Demand Analysed using the Permanganate Oxidation Method
DO	Dissolved Oxygen
EC	Electrical Conductivity
EHM	Ecological Health Monitoring
EP	Environment Programme
HH	Guidelines for the Protection of Human Health
ISO	International Organization for Standardization
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMCs	National Mekong Committees
NMCSs	National Mekong Committee Secretariats
PDIES	Procedures for Data and Information Exchange and Sharing
PWQ	Procedures for Water Quality
QA/QC	Quality Assurance/Quality Control
TGWQ	Technical Guidelines for the Implementation of the Procedures for Water Quality
TOTN	Total Nitrogen
TOTP	Total Phosphorus
TSS	Total Suspended Solids
WQGA	MRC Water Quality Guidelines for the Protection of Aquatic Life
WQGH	MRC Water Quality Guidelines for the Protection of Human Health
WQI	Water Quality Index
WQI_{ag}	Water Quality Index for Agricultural Use
WQI_{al}	Water Quality Index for the Protection of Aquatic Life
WQI_{hh}	Water Quality Index for the Protection of Human Health
WQMN	Water Quality Monitoring Network

Executive Summary

Since its inception in 1985, the Water Quality Monitoring Network (WQMN) has provided a continuous record of water quality in the Mekong River and its tributaries. The routine water quality monitoring under the WQMN has become one of the key environmental monitoring activities at MRC, supporting the implementation of the Procedures for Water Quality. The actual monitoring of water quality is being implemented by the designated laboratories of the Member Countries.

In 2016, the Mekong River Commission, with the assistance from the Member Countries – Cambodia, Lao, Thailand, and Vietnam – conducted a routine monitoring of water quality in the Mekong River and its tributaries at 48 stations, of which 17 are located in the Mekong River, 5 in the Bassac River, and 26 in tributaries. In all stations, 18 parameters were measured in 2016, of which 12 are routine water quality parameters that are required to be measured for each sample month. The other six, major anions and major cations, be analysed for each sample taken between April and October.

The results of the monitoring showed that the water quality in the Mekong and Bassac Rivers was still of good quality with a slight improvement compared with 2015. There were only a small number of measurements of electrical conductivity, dissolved oxygen, chemical oxygen demand, nitrate-nitrite, ammonium, and total phosphorus exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. The majority of exceedances were recorded in the Delta, which is highly populated.

The assessment of the Water Quality Index for the Protection of Aquatic Life revealed that water quality in the Mekong and Bassac Rivers was still of good quality for the protection of aquatic life, with almost all stations rated as either "good" or "excellent". Of the 22 monitoring stations located in the Mekong and Bassac Rivers, 10 Monitoring Stations were rated as "excellent" while 11 were rated as "good" for the protection of aquatic life. Only one station (My Tho) was rated as "poor" quality for the protection of aquatic life. The slight impairment at My Tho Monitoring Station can be attributed to the elevated total phosphorus and nitrate-nitrite concentrations, which were recorded exceeding the target values for protection of aquatic life in 100% and 83% of the sampling occasions, respectively. The degree of water quality for the protection of aquatic life improved slightly in 2016 when compared to 2015, with eight stations received higher rating scores in 2016.

The analysis of the 2016 water quality data, using the Water Quality Index for Human Health Acceptability, reveals that water quality in the Mekong and Bassac Rivers for the protection of human health was still good with all stations rated as either "good" or "excellent". Of the 22 stations located in the Mekong and Bassac Rivers, 13 stations were rated as "excellent" while the remaining stations were rated as "good". Of the 13 stations rated as "excellent", 12 were located in Cambodia and Viet Nam, and 1 station was located in Lao PDR. From 2009 to 2016, water quality for the protection of human health did not change significantly, with ratings ranging from "moderate quality" to "excellent quality". Compared to 2015, the water quality for the protection of human health decreased slightly (lower water quality index scores) at 2 stations (My Tho and Takhmao). Improvement of water quality in terms of the protection of human health was observed in 4 stations (Kampong Cham, Neak Lou ng, Kaorm Samnor, and Koh Khel). The improvement can be attributed to the reduction in chemical oxygen demand levels, which only exceeded the guideline value of 5 mg/L in 6% of sampling occasions. For comparison, the exceedance observed at the same stations in 2015 was 11% of sampling occasions.

Except for My Tho station, with no recorded violation of the guideline values for Water Quality Indices for General Irrigation and Paddy Rice Irrigation, it can be concluded that there was no restriction for all types of agricultural use of the Mekong and Bassac River water in the upper and middle parts of the rivers. However, when using water for agriculture in the Delta of Vietnam, especially the areas around My Tho station, the water quality needs to be thoroughly examined.

The temporal analysis of data from 2000 to 2016 suggests that pH levels showed a slight decrease during the period, but were still well within the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (6-9). The average TSS concentration of the Mekong River had decreased since 2000. It was measured at about 118.7 mg/L in 2000, whereas in 2016, the average monthly concentration for TSS was measured at about 80.63 mg/L. Concentrations of nitrate-nitrite, ammonium, and dissolved oxygen remained relatively constant, while chemical oxygen demand and total phosphorous levels were slightly increased.

There is no compelling evidence of transboundary pollution in the LMB despite some observed significant differences between some pollutants at stations upstream and downstream of national boundary areas. Maximum concentrations of pollutants at national boundary stations generally did not exceed the MRC WQGH and WQGA, which is indicative of a low risk of transboundary issues.

1. Introduction

1.1 BACKGROUND

Ranked as 12th longest at about 4,880 km and 8th in terms of mean annual discharge at its mouth at about 14,500 m3/s (MRC, 2011), the Mekong River is one of the world's largest rivers. Originating in the Himalayas, the Mekong River flows southward through China, Myanmar, Lao PDR, Thailand, Cambodia, and Viet Nam. With a total catchment area of 795,000 km2, the Mekong River Basin can be divided into the Upper Mekong Basin, which comprises an area in China where the Mekong is known as the Lancang River and makes up 24% of the total Mekong Basin (190,800 km2), and the Lower Mekong Basin which comprises an area downstream of the Chinese border with Lao PDR.

The Lower Mekong Basin is functionally subdivided into four broad physiographic regions described by topography, drainage patterns and the geomorphology of river channels. These are the Northern Highlands, the Khorat Plateau, the Tonle Sap Basin, and the Delta. With a total catchment area of about 571,000 km2, the Lower Mekong Basin covers a large part of Northeast Thailand, almost the entire countries of Lao PDR and Cambodia, and the southern tip of Viet Nam (MRC, 2010a).

According to the Mekong River Commission (MRC) Planning Atlas of the Lower Mekong Basin (MRC, 2011), the Lower Mekong River is home to about 60 million people, of whom about 85% live in rural areas where many practise subsistence farming, with supplemental fish catch for livelihoods and food security. The Mekong River is also one of the most bio-diverse rivers in the world with over 850 identified fish species (MRC, 2011). The river's annual flood pulse continues to support a rich natural fishery and an extensive and unique wetland environment. This makes the rich ecology of the Basin extraordinarily important in terms of its contribution to livelihoods and sustainable development. As such, water quality monitoring is an integral part of detecting changes in the Mekong riverine environment and for maintaining good/acceptable water quality to promote the sustainable development of the Mekong River Basin.

1.2 WATER QUALITY MONITORING NETWORK

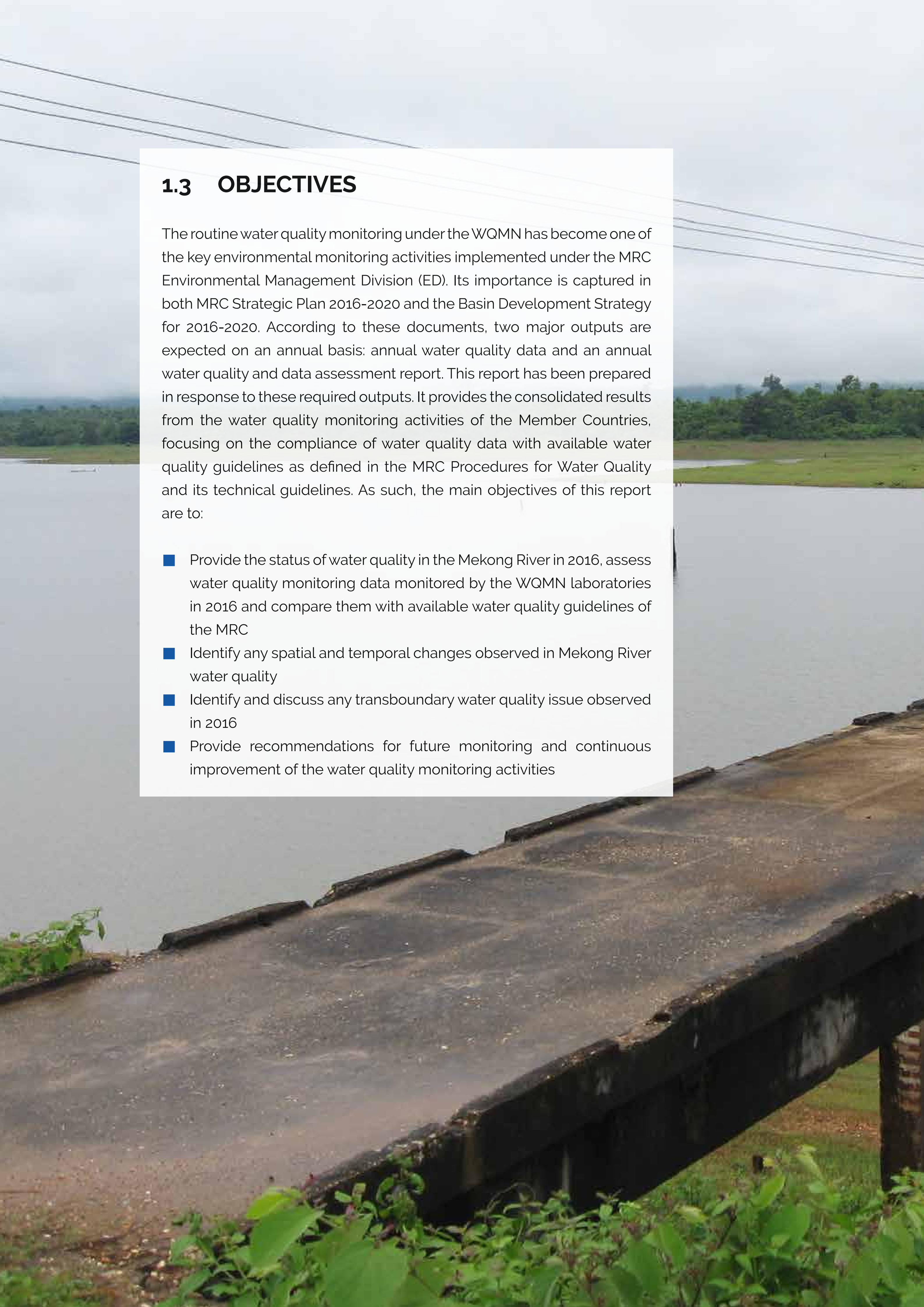
Recognising that sustainable development of water resources of the Lower Mekong River Basin will not be possible without effective management of water quality, the MRC Member Countries agreed to establish a Water Quality Monitoring Network (WQMN) to detect changes in Mekong River water quality and to take preventive and remedial action if any changes are detected. Since its inception in 1985, the WQMN has provided a continuous record of water quality in the Mekong River and its tributaries by measuring a number of different water quality parameters at different stations.

The number of stations sampled has varied over the years since the inception of the WQMN, with up to 90 stations sampled in 2005. In 2006, the MRC, led by the Environment Programme, conducted a full assessment of water quality monitoring activities in the Mekong River under the WQMN. One of the outcomes of the assessment was the need to reduce the cost of monitoring while at the same time increase its suitability. An agreement was reached for the Network to include only primary stations while the secondary stations would be monitored by individual Member Countries. Primary stations are those that are located in the mainstream and key tributaries of the Mekong River. It is noted that for Lower Mekong water quality monitoring, key tributaries include the Bassac river. In 2016, a total of 48 stations were included in the WQMN, of which 17 were located on the Mekong River, 5 on the Bassac River, and 31 in the tributaries of the Mekong River in which 5 are in the Bassac River. Out of these, there are 19 stations (6 mainstream/3 Bassac River/10 tributary) in Cambodia, 11 stations (5 mainstream/6 tributary) in Lao PDR, 8 stations (3 mainstream/5 tributary) in Thailand, and 10 (3 mainstream/2 Bassac River/5 tributary) stations in Viet Nam. These 48 stations have been classified as "primary stations" since 2005 and were designed to detect changes and capture pressures and threats to Mekong water quality. A number of these stations were also strategically selected to detect transboundary water quality problems.

The WQMN is one of the MRC's core function activities which will be fully decentralised to the Member Countries by 2020. The decentralisation of the WQMN was completed for Thailand and Viet Nam in 2016. For Cambodia and Lao PDR, the decentralisation of the WQMN will be completed by 2020. Following decentralisation, Member Countries, through their designated water quality laboratories, will be required to finance and undertake the monitoring, sampling, and analysis of Mekong water quality. At national level, each Member Country has designated a water quality laboratory to undertake the monitoring, sampling, and analysis. The designated laboratories are responsible for undertaking routine monitoring and measurements of water quality parameters. They are also responsible for analysing, assessing, and reporting water quality data on an annual basis. Their specific duties are to:

- Conduct routine monthly water quality monitoring of the Mekong River and its tributaries as defined in their Terms of Reference
- Manage water quality data in accordance with the agreed format and submit the data to the MRCS for validation and sharing through the MRC data portal
- Produce and publish an annual water quality data assessment report, outlining the results of water quality monitoring, analysis, and assessment

At regional level, the MRCS will continue to provide technical support for the monitoring of water quality and to ensure the integrity of data recorded at national level. The MRCS will also act as a central hub for regional water quality data and provide a platform for data exchange in accordance with the Procedures for Data and Information Exchange and Sharing (PDIES) and its Technical Guidelines.



1.3 OBJECTIVES

The routine water quality monitoring under the WQMN has become one of the key environmental monitoring activities implemented under the MRC Environmental Management Division (ED). Its importance is captured in both MRC Strategic Plan 2016-2020 and the Basin Development Strategy for 2016-2020. According to these documents, two major outputs are expected on an annual basis: annual water quality data and an annual water quality and data assessment report. This report has been prepared in response to these required outputs. It provides the consolidated results from the water quality monitoring activities of the Member Countries, focusing on the compliance of water quality data with available water quality guidelines as defined in the MRC Procedures for Water Quality and its technical guidelines. As such, the main objectives of this report are to:

- Provide the status of water quality in the Mekong River in 2016, assess water quality monitoring data monitored by the WQMN laboratories in 2016 and compare them with available water quality guidelines of the MRC
- Identify any spatial and temporal changes observed in Mekong River water quality
- Identify and discuss any transboundary water quality issue observed in 2016
- Provide recommendations for future monitoring and continuous improvement of the water quality monitoring activities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2. Materials and methods

2.1 MONITORING LOCATION AND FREQUENCY

Forty-eight stations were monitored by the WQMN in 2016. A breakdown of the number of stations in each Member Country is presented in Table 2-1. As can be seen in the table, of the 48 stations monitored in 2016, 11 stations are located in Lao PDR, 8 in Thailand, 19 in Cambodia and 10 in Viet Nam. Figure 2-1 illustrates their locations in the Lower Mekong Basin (17 on the Mekong River, 31 on Mekong tributaries in which 5 are on the Bassac River). The detailed list of each station, code name and coordinates can be found in Table 2-2.

For consistency, the Member Countries have agreed to carry out the sampling and monitoring of water quality on a monthly basis between the 13th and 18th day of each month.

Table 2-1: A summary of 2016 water quality monitoring stations

Countries	No. of Stations	No. on the Mekong River	No. on tributaries		Monitoring Frequency
			No. on the Bassac River	Others	
Lao PDR	11	5	0	6	Monthly
Thailand	8	3	0	5	Monthly
Cambodia	19	6	3	10	Monthly
Viet Nam	10	3	2	5	Monthly
Total	48	17	5	26	Monthly

Table 2-2 lists the 22 mainstream stations monitored in 2016 in geographical order, from upstream to downstream, to facilitate the analysis of water quality trends along the Mekong River mainstream.

Table 2-2: Water quality monitoring stations in the Mekong and Bassac Rivers numbered in sequence from upstream to downstream and as monitored in 2016

Station No.	Name of station	Station ID	River	Countries	Latitude	Longitude
1	Houa Khong	H010500	Mekong River	Lao PDR	21.5471	101.1598
2	Chiang Saen	H010501	Mekong River	Thailand	20.2674	100.0908
3	Luang Prabang	H011200	Mekong River	Lao PDR	19.9000	102.0000
4	Vientiane	H011901	Mekong River	Lao PDR	17.9281	102.6200
5	Nakhon Phanom	H013101	Mekong River	Thailand	17.4250	104.7744
6	Savannakhet	H013401	Mekong River	Lao PDR	16.5583	104.7522
7	Khong Chiam	H013801	Mekong River	Thailand	15.3255	105.4937
8	Pakse	H013900	Mekong River	Lao PDR	15.1206	105.7837
9	Stung Treng	H014501	Mekong River	Cambodia	13.5450	106.0164
10	Kratie	H014901	Mekong River	Cambodia	12.4777	106.0150
11	Kampong Cham	H019802	Mekong River	Cambodia	11.9942	105.4667
12	Chrouy Changvar	H019801	Mekong River	Cambodia	11.5861	104.9407
13	Neak Loung	H019806	Mekong River	Cambodia	11.2580	105.2793
14	Kaorm Samnor	H019807	Mekong River	Cambodia	11.0679	105.2086
15	Tan Chau	H019803	Mekong River	Viet Nam	10.9079	105.1835
16	My Thuan	H019804	Mekong River	Viet Nam	10.2725	105.9100

17	My Tho	H019805	Mekong River	Viet Nam	10.3430	106.3505
18	Takhmao	H033401	Bassac River	Cambodia	11.4785	104.9530
19	Koh Khel	H033402	Bassac River	Cambodia	11.2676	105.0292
20	Koh Thom	H033403	Bassac River	Cambodia	11.1054	105.0678
21	Chau Doc	H039801	Bassac River	Viet Nam	10.9552	105.0867
22	Can Tho	H039803	Bassac River	Viet Nam	10.0580	105.7977

Figure 2.1: Water quality monitoring stations of the MRC WQMN in the Mekong and Bassac Rivers in 2016

2.2 SAMPLING TECHNIQUES

In an effort to standardise the sampling techniques, in 2016 MRC continued to work with the designated laboratories of the Member Countries to identify appropriate sampling techniques for collecting water samples. Through consultations, it was agreed that the water sampling, sample preservation, sample transportation and storage, would be carried out in accordance with methods outlined in the 20th edition of the Standard Methods for the Examination of Water and Wastewater (Clesceri et al., 1998) or in accordance with national standards complying with the requirements of method validation of ISO/IEC 17025-2005.

Specifically, the designated laboratories are required to:

- Collect water samples using the simple surface grab technique at the middle of the stream where free flowing water is observable
- Collect water samples at about 30 to 50 cm under the surface of the stream
- If in-situ measurement is not possible, immediately preserve samples collected with proper preservative agents (i.e. sulphuric acid for nutrients measurement) and store in a cooler to prevent further breakdown of chemicals and biological contents
- Analyse all water samples within the recommended holding time

All designated laboratories of the MRC WQMN are required to adhere to the MRC QA/QC procedures which were developed in accordance with ISO/IEC 17025-2005 and personnel safety procedures when collecting water samples and measuring water quality parameters.

2.3 LABORATORY ANALITICAL METHODS

Since its inception in 1985, the Water Quality Monitoring Network has provided data on water quality in the Mekong River and its selected tributaries by measuring a number of different water quality parameters. At its peak, the network (Table 2-2) provided a measurement of 23 water quality parameters. However, in 2016, 19 water quality parameters were measured by the MRC WQMN (Table 2-3). Of the 19 parameters measured in 2016, 13 are routine water quality parameters that are required to be measured for each sample month. The other six, major anions and major cations, are required to be analysed for each sample taken between April and October.

In addition to providing a list of parameters measured by the MRC WQMN, Table 2-3 provides a list of recommended analytical methods used for measuring water quality parameters. These methods are consistent with methods outlined in the 22nd edition of the Standard Methods for the Examination of Water and Wastewater (Clesceri et al., 1998) or nationally accepted methods, as previously agreed between the laboratories and the Mekong River Commission Secretariat.

Table 2-3: Water quality parameters and their corresponding analytical methods

Analytical parameter	Recommended analytical methods
Temperature	2550-Temp/SM
pH	4500-H+/SM
Electrical conductivity	2510-Ec/SM
Alkalinity/ Acidity	2320-A/SM
Dissolved Oxygen (DO)	4500-O/SM
Chemical Oxygen Demand (COD)	Permanganate Oxidation
Total phosphorous (T-P)	4500-P/SM
Total Nitrogen (T-N)	4500-N/SM
Ammonium (NH4-N)	4500-NH4/SM
Total Nitrite and Nitrate (NO2-3-N)	4500-NO2-3/SM
Faecal Coliform	9221-Faecal Coliform group/SM
Total Suspended Solid	2540-D-TSS-SM
Calcium (Ca)	3500-Ca-B/SM
Magnesium (Mg)	3500-Mg-B/SM
Sodium (Na)	3500-Na-B/SM
Potassium (K)	3500-K-B/SM
Sulphate (SO4)	4500- SO4 –E/SM
Chloride (Cl)	4500-Cl/SM
BOD5	521-BOD5/SM

2.4 DATA ASSESSMENT

2.4.1 STATUS AND TRENDS

The maximum, average and minimum values of each water quality parameter were analysed for each monitoring station to show the status of water quality in 2016. These values were compared to the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life to identify any exceeded values that need special attention.

Variations of key water quality parameters were assessed spatially and temporally. In analysing water quality data, a test was carried out to determine whether water quality data for each station is monotonous (water quality data for all time-series has a monotonic relationship). Therefore, a non-parametric method was used for trend analysis as this method minimises the importance of both extremes and missing values. Variations along the mainstream were assessed for data obtained in 2016. Trend analysis of water quality from 2000 to 2016 was also carried out for selected water quality parameters. Box-and-whisker plots were used to characterise water quality data for spatial and temporal analysis. A box-and-whisker plot is normally used to analyse variation and central tendency of data. It is a useful statistical tool which can be used to explore a dataset and show key statistics associated with it. In particular, when using box-and-whisker plots the following key statistical information can be drawn (Nord, 1995):

- Median value of the dataset
- Upper quartile and lower quartile or the median of all data above and below the median, respectively
- Upper and lower extremes or the maximum and minimum values of the dataset (excluding outliers), respectively

2.4.2 TRANSBOUNDARY WATER QUALITY

Transboundary water quality was assessed for six stations located at or near national borders of the Member Countries. Water quality data comparison and assessment were made for Pakse versus Stung Treng; Kaorm Samnor versus Tan Chau; and Koh Thom versus Chau Doc. Comparisons were made for two stations at a time using key pollutant monitoring data during the period 2005–2015 and 2016 for the station closest upstream and downstream of the national border, respectively. Box-and-whisker plots, using the statistical software package SPSS 23, were used to characterise water quality data. Any observed differences between the upstream and downstream stations were tested using an independent t-test, to determine whether the differences observed are statistically significant.

2.4.3 WATER QUALITY INDICES

Another way to assess water quality in the Mekong River is through the use of the MRC Water Quality Indices which combine the results of several parameters into one overall value describing the water quality. In 2013, the MRC Member Countries adopted three water quality indices taking into account requirements under Chapters 1 and 2 of the Technical Guidelines for the Implementation of the Procedures for Water Quality (TGWQ) and available water quality guidelines of the Member Countries. These indices include:

- Water Quality Index for the Protection of Aquatic Life (WQIal)
- Water Quality Index for the Protection of Human Health (WQIhh)
- Water Quality Index for Agricultural Use, which is divided into two categories (WQag): (i) general irrigation and (ii) paddy rice

Table 2-4: Parameters used for calculating the rating score of the Water Quality Index for the Protection of Aquatic Life, together with their target values

Parameters	Target Values
pH	6 – 9
EC (mS/m)	< 150
NH3 (mg/L)	0.1
DO (mg/L)	> 5
NO2-3 – N (mg/L)	0.5
T-P (mg/L)	0.13

Table 2 5: Rating systems for the Water Quality Index for the Protection of Aquatic Life

Rating Score	Class
9.5 ≤ WQI ≤10	A: High Quality
8 ≤ WQI < 9.5	B: Good Quality
6.5 ≤ WQI < 8	C: Moderate Quality
4.5 ≤ WQI < 6.5	D: Poor Quality
WQI < 4.5	E: Very Poor Quality

2.4.3.1 Water Quality Index for the Protection of Aquatic Life

The Water Quality Index for the Protection of Aquatic Life is calculated using Equation 2-1. The index has been developed as an open-ended index which would allow more parameters to be added once data becomes available (Campbell, 2014). In this annual water quality report, only six parameters are included. These parameters, together with their target values, are listed in Table 2-4. The classification system for the Water Quality Index for the Protection of Aquatic Life is summarized in Table 2-5.

$$WQI = \frac{\sum_{i=1}^{n} p_i}{M} \times 10 \quad \text{Equation 2-1}$$

Where,

- "pi" is the points scored on sample day i. If each parameter listed in Table 2-4 meets its respective target value in Table 2-6, one point is scored; otherwise the score is zero
- "n" is the number of samples from the station in the year
- "M" is the maximum possible score for the measured parameters in the year

2.4.3.2 Water Quality Index for the Protection of Human Health

With the finalization of Chapter 1 (Guidelines for the Protection of Human Health (HH)) of the Technical Guidelines for the Implementation of the Procedures for Water Quality, the Member Countries have agreed to include HH in the analysis of water quality of the Mekong River. To assist in communicating water quality information concerning the protection of human health, water quality indices and classification systems were developed, focusing on human health acceptability and human health risk.

The Human Health Acceptability Index utilizes parameters of indirect impact, as identified by the HH while the human health risk index utilizes direct impact parameters. The rating score for both indices can be calculated using Equation 2-2, which is based on the Canadian Water Quality Index (CCME 2001). It should be noted that since the monitoring of direct impact parameters has not commenced, Member Countries have agreed to adopt only the human health index. Furthermore, due to the lack of data availability at the time of the preparation of this report, of the parameters included in TGH as indirect impact parameters, total coliform, phenol, temperature, oil and grease, and biochemical oxygen demand are not included in the calculation of the rating score for the human health index. The list of the approved parameters to be included in the calculation of the rating score for the human health index, together with their target values, are listed in Table 2-6. The classification system for the Water Quality Index for the Protection of Human Health Index is summarized in Table 2-5.

$$WQI = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}\right)$$ Equation 2-2

Where, F1 is the percentage of parameters which exceed the guidelines and can be calculated by Equation 2-3.

$$F_1 = \left(\frac{\#\ of\ failed\ parameters}{Total\ \#\ of\ parameters}\right)$$ Equation 2-3

F2 is the percentage of individual tests for each parameter that exceeded the guideline, and can be calculated by Equation 2-4.

$$F_2 = \left(\frac{\#\ of\ failed\ tests}{Total\ \#\ of\ tests}\right)$$ Equation 2-4

F3 is the extent to which the failed test exceeds the target value and can be calculated using Equation 2-5.

$$F_3 = \left(\frac{nse}{0.01nse\ +\ 0.01}\right)$$ Equation 2-5

Where nse is the sum of excursions and can be calculated using Equation 2-6.

$$nse = \left(\frac{\sum excursion}{Total\ \#\ of\ tests}\right)$$ Equation 2-6

The excursion is calculated by Equation 2-7.

$$\text{excursion} = \left(\frac{failed\ test\ value}{guideline\ value}\right) - 1$$ Equation 2-7

Table 2-6: Parameters used for calculating the rating score of the Water Quality Index for the Protection of Human Health together with their target values

Parameters	Target Values
pH	6 – 9
EC (mS/m)	< 150
NH3 (mg/L)	0.5
DO (mg/L)	4
NO2-3 – N (mg/L)	5
COD (mg/L)	5
BOD (mg/L)*2	4

* BOD has been approved by the MRC Member Countries as one of the parameters to be included in the calculation of the Water Quality Index for the Protection of Human Health. However, due to the lack of BOD data at the time of the preparation of this report, the parameter is not included in the analysis of the Human Health Acceptability Index.

Table 2-7: Rating systems for the Water Quality Index for the Protection of Human Health

Rating Score	Class	Description
95 ≤ WQI ≤100	A: Excellent Quality	All measurements are within objectives virtually all of the time
80 ≤ WQI < 95	B: Good Quality	Conditions rarely depart from desirable levels
65 ≤ WQI < 80	C: Moderate Quality	Conditions sometimes depart from desirable levels
45 ≤ WQI < 65	D: Poor Quality	Conditions often depart from desirable levels
WQI < 45	E: Very Poor Quality	Conditions usually depart from desirable levels

2.4.3.3 Water Quality Index for Agricultural Use

Another index adopted by the MRC Member Countries as a means for communicating water quality monitoring information to the public is the Water Quality Index for Agricultural Use, focusing on water quality for general irrigation and paddy rice. The indices for general irrigation and paddy rice are calculated based on water quality guidelines for salinity (electrical conductivity). The electrical conductivity guidelines together with the degree of consequence for the indices for general irrigation and paddy rice are outlined in Table 2-8.

Table 2-8: Electrical conductivity guidelines and degrees of consequence for Water Quality Index for Agricultural Use – general irrigation and paddy rice.

Irrigation Raw Water	Unit	Degree of Consequence[1]		
		None (Good)	Some (Fair)	Severe (Poor)
Electrical Conductivity				
General Irrigation	mS/m	<70	70-300	>300
Paddy Rice	mS/m	<200	200-480	>480

2.5 QUALITY ASSURANCE / QUALITY CONTROL

Recognising the need to improve the quality, precision and accuracy of the water quality data, all designated laboratories of the MRC WQMN were requested to participate in the implementation of a quality assurance and quality control (QA/QC) test for water sampling, preservation, transportation, and analysis from 2004. The goal of the implementation of the QA/QC procedures is to ensure that the designated laboratories carry out their routine water quality monitoring activities in accordance with international standard ISO/IEC 17025-2005. To date, of the four designated laboratories of the MRC WQMN, the laboratory in Lao PDR and Viet Nam have received ISO/IEC 17025-2005 certification. The certifications were given by the Bureau of Accreditation, Directorate for Standards and Quality of Viet Nam.

Other designated laboratories, while not being ISO/IEC 17025-2005 certified, have rigorously implemented the MRC WQMN QA/QC in Sampling and Laboratory Work or national QA/QC procedures that meet the requirements of the ISO/IEC 17025-2005. The MRC QA/QC procedure calls for the designated laboratories to:

- Be well prepared for each sampling event, having a sampling plan with clear sampling objectives and ensure sampling teams are equipped with appropriate sampling and safety equipment and preservative chemical reagents
- Apply quality control during sampling, which consists of taking duplicate samples and field blanks for certain parameters
- Analyse all water samples within recommended holding times
- Conduct routine maintenance and calibration of all measurement equipment
- Conduct data analysis using control chart and reliability score testing using ion balance test
- Archive raw data and any important pieces of information relating to the results of the analysis in order to make it possible to trace all data and reconfirm the results of the analysis

[1] None = 100% yield; Some = 50-90% yield; Severe = <50% yield

3. Results and Discussion

3.1 ANALYSIS OF WATER QUALITY

The key water quality parameters monitored in stations along the Mekong and Bassac Rivers are analysed spatially and temporally to reflect the status of water quality of the Lower Mekong basin in 2016 and the trend for water quality from 2000 to 2016. In addition, a comparison of the maximum, mean and minimum values of key water quality parameters between 1985-2015 and 2016 are presented in Table 3-1 and 3-2 to see if there are any parameters exceeding MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life.

3.1.1. pH

In aquatic ecosystems, pH can affect many chemical and biological processes. This is because pH affects the solubility and availability of nutrients and heavy metals in water (USGS, 2016). At extremely low pH, some toxic compounds and elements from sediments may be released into the water where they can be taken up by aquatic animals or plants, and ultimately by humans through direct contact and/or human consumption of aquatic animals or plants (USEPA, 2012). Additionally, changes in pH can also influence the availability of trace elements, iron, and nutrients, such as phosphate and ammonia in water. As such, pH is one of the key water quality parameters monitored by the MRC Water Quality Monitoring Network. In 2016, the WQMN continued to monitor pH levels at all 17 Mekong and 5 Bassac water quality monitoring stations.

Recognising the importance of pH on the Mekong riverine environment, the Member Countries have agreed to establish the technical water quality guidelines for pH levels in the Mekong River and its tributaries to protect human health and aquatic life, with the overall goal of achieving the MRC water quality objective – to maintain acceptable/good water quality to promote the sustainable development of the Mekong River Basin.

Compared to the recommended guidelines, the results of 2016 monitoring revealed that all pH values measured along the Mekong and Bassac Rivers were within the upper and lower target values of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life (pH values of 6 to 9 for both the protection of human health and aquatic life).

In 2016, the pH values recorded in the Mekong ranged from 6.3 to 8.7 with the minimum and maximum pH value recorded at Koh Thom Water Quality Monitoring Station in Cambodia, on October 23rd, 2016 and at Kampong Cham Water Quality Monitoring Station on December 21st, 2016, respectively. The average pH value of the Mekong River in 2016 was recorded at about 7.7, which was slightly higher than the average pH value recorded between 1985 to 2015 (pH of 7.5).

The spatial trend for pH in the Mekong and Bassac Rivers is shown in Figure 3.1. In general, in 2016, pH values were slightly higher in the upper part (stations located in Lao PDR and Thailand) when compared with the lower part of the river (stations located in Cambodia and Viet Nam). For example, Houa Khong Station (1), the uppermost station of the MRC WQMN, reported pH values ranging from 7.3 to 8.0 with an average value of 7.6 while Can Tho (22), the lowest station in Viet Nam, reported values ranging from 7 to 7.8 with an average value of 7.4.

Results of the temporal analysis of pH data from 2000 to 2016 are shown in Figure 3.2. Based on a visual inspection of Figure 3.2, the overall pH levels have remained relatively constant from year to year since 2000. In 2000, the average pH value was recorded at 7.6 while in 2016 the average pH value was recorded at 7.7.

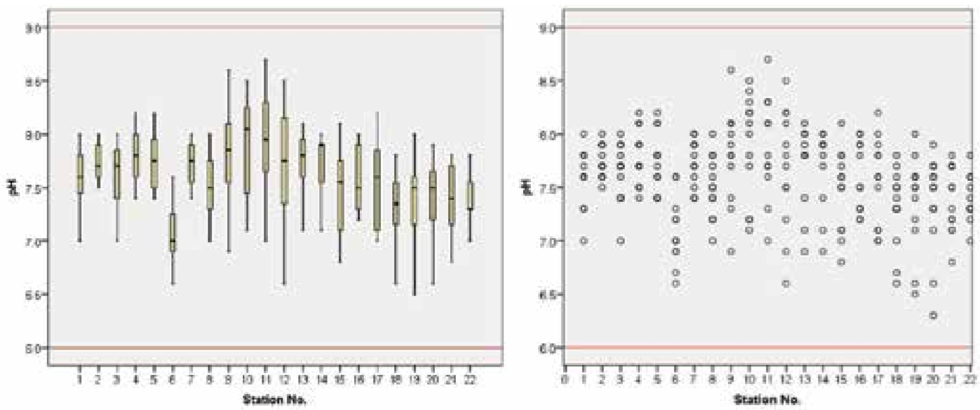


Figure 3.1: Spatial variation in pH levels along the Mekong River (Stations: 1-17) and Bassac River (Stations: 18-22) as observed in 2016 (the horizontal lines at 6.0 and 9.0 represent lower and upper pH limits of the MRC Water Quality Guidelines for the Protection of Aquatic Life and Protection of Human Health)

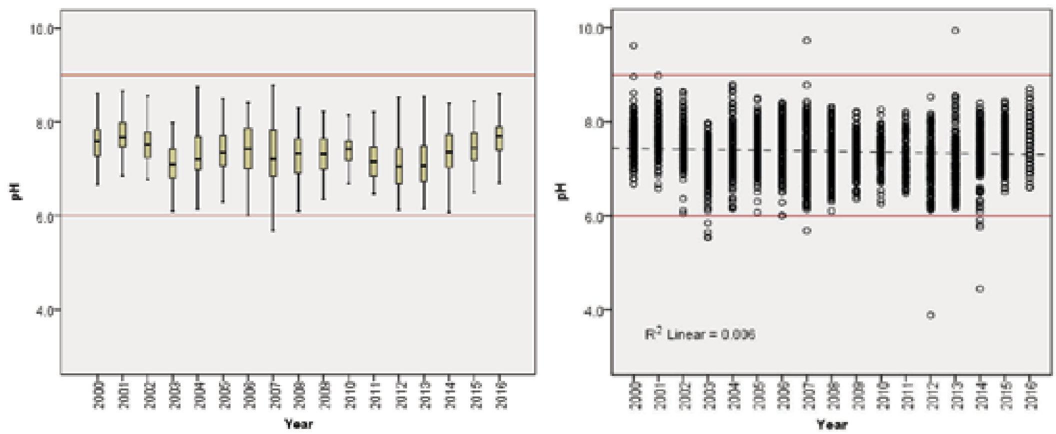


Figure 3.2: Temporal variation in pH levels in the Mekong River from 2000 - 2016 (the horizontal lines at 6.0 and 9.0 represent lower and upper pH limits of the MRC Water Quality Guidelines for the Protection of Aquatic Life and Protection of Human Health)

Table 3-1: Comparison of water quality data in the Mekong River between 1985-2015 and 2016 (yellow colour marks non-compliance with WQGH or WQGA)

Parameters	Unit	Water Quality Guidelines		1985-2014				2015			
		Protection of Human Health (WQGH)	Protection of Aquatic Life (WQGA)	Max	Mean	Min	Stdev	Max	Mean	Min	Stdev
Temp	-	Natural	Natural	38.00	27.07	13.00	3.07	35.90	27.61	17.10	2.90
pH	-	6 – 9	6 – 9	9.94	7.49	3.78	0.51	8.70	7.65	6.60	0.40
TSS	mg/L	-	-	5716.00	151.84	0.10	265.24	593.00	80.63	2.33	86.34
EC	mS/m	70 - 150	-	841.00	20.60	1.20	27.62	385.00	23.05	10.00	29.20
NO32	mg/L	5	5	1.42	0.24	0.00	0.17	1.08	0.29	0.01	0.23
NH4N	mg/L	-	-	2.99	0.05	0.00	0.11	0.70	0.06	0.01	0.08
TOTN	mg/L	-	-	4.89	0.58	0.00	0.38	2.81	0.58	0.06	0.54
TOTP	mg/L	-	-	2.20	0.10	0.00	0.12	0.34	0.09	0.01	0.08
DO	mg/L	≥ 6	> 5	13.85	7.23	2.25	1.09	10.16	7.09	4.27	1.04
COD	mg/L	5	-	65.00	2.24	0.00	2.00	9.14	2.34	0.00	1.74

Table 3-2: Comparison of water quality data in the Bassac River between 1985-2015 and 2016 (yellow colour marks non-compliance with WQGH or WQGA)

Parameters	Unit	Water Quality Guidelines		1985-2015				2016			
		Protection of Human Health (WQGH)	Protection of Aquatic Life (WQGA)	Max	Mean	Min	Stdev	Max	Mean	Min	Stdev
Temp		Natural	Natural	34.0	28.98	23.50	1.82	32.30	28.73	25.10	2.27
pH	-	6 -- 9	6 – 9	9.36	7.15	3.80	0.39	8.03	7.36	6.27	0.37
TSS	mg/L	-	-	939.0	76.96	0.10	85.02	247.0	52.87	8.00	49.37
EC	mS/m	70 - 150	-	1050.0	19.95	1.30	57.53	27.50	15.83	7.50	5.12
NO32	mg/L	5	5	3.02	0.26	0.00	0.22	0.80	0.29	0.03	0.20
NH4N	mg/L	-	-	3.04	0.07	0.00	0.15	0.50	0.09	0.01	0.09
TOTN	mg/L	-	-	4.03	0.76	0.03	0.45	2.27	0.75	0.15	0.60
TOTP	mg/L	-	-	1.78	0.14	0.00	0.14	0.52	0.13	0.02	0.08
DO	mg/L	≥ 6	> 5	12.25	6.39	1.79	1.05	9.27	6.45	4.12	1.04
COD	mg/L	5	-	13.06	3.30	0.04	1.82	5.84	2.40	0.28	1.23

3.1.2 ELECTRICAL CONDUCTIVITY (EC)

Electrical conductivity is another useful water quality indicator monitored by the MRC WQMN. It provides a valuable baseline that has been used to identify any emerging effects of development on water quality in the Mekong River. Under normal circumstance and in areas that are not affected by saline intrusion, the Mekong and Bassac Rivers, similar to other waterbodies, have constant ranges of conductivity, and therefore, any sudden and significant change in electrical conductivity can be an indicator of water pollution. Wetzel (2001) states that pollution from agricultural runoff or sewage leaks can increase electrical conductivity levels while Murphy (2007) reported that a spill of organic compounds, such as oil, can reduce electrical conductivity levels.

Except for My Tho station, which had values of high conductivity of 91.5 and 103.3 mS/m in February and April 2016, respectively, all EC levels were recorded to fall outside the recommended range of the MRC Water Quality Guidelines for the Protection of Human Health of 70-150mS/m. It should be noted, however, that the Mekong River mainstream and

Bassac River are naturally low-salinity rivers with electrical conductivity values rarely exceeding 50 mS/m. High electrical conductivity has been observed in the Delta (Vietnam's stations) during high tide due to the intrusion of sea water, and has been recorded with a maximum value of 841.0 mS/m. This maximum value was recorded at My Tho Water Quality Monitoring Station in April 1998. In 2016, all samplings in the Delta, for both the Mekong River and the Bassac Rivers, were carried out during low tide, which may explain the low levels of electrical conductivity recorded.

Spatial and temporal trends for electrical conductivity in the Mekong and Bassac Rivers are illustrated in Figures 3.3 and 3.4, respectively. The Mekong and Bassac Rivers can be generally characterised as rivers with low conductivity values, with average historical values from 1985 to 2015 of about 20.6 and 20 mS/m, respectively (Tables 3-1 and 3-2)[2]. In 2016, electrical conductivity of the Mekong river was slightly increased compared to historical values with the mean value of 23.1 mS/m. This increase was partly contributed to by the very high conductivity values between January and April 2016 at My Tho station, ranging from 91.5 to 385 mS/m. For the Bassac River, the conductivity continued to be relatively low with values ranging from 7.5 to 27.5 mS/m with a mean value of 15.8 mS/m, which is a slight decrease compared to historical values (Table 3-1).

Spatially, conductivity levels in the Mekong River in 2016 exhibited a bow shape characteristic as shown in Figure 3.3, where the conductivity levels were highest in the upper part and lower part of the Lower Mekong River but lowest in the middle part of the river. For example, Houa Khong Station (1), the uppermost station of the MRC WQMN, reported electrical conductivity values ranging from 20.4 to 33.6 mS/m with an average value of 27.1 mS/m and My Tho Station (17) – the last station in the Mekong River before the river enters the East Sea - reported values ranging from 14.1 to 385 mS/m with an average value of 76.6 mS/m, while Chrouy Changvar (12) – the station located in the middle part of the Lower Mekong River – reported values ranging from 11.9 to 21.7 mS/m with an average value of 17.6 mS/m. When compared to 2015, the electrical conductivity levels recorded at My Tho Water Quality Monitoring Station (17) were highly variable and elevated. In 2015, electrical conductivity levels at this station were reported to range from 12.1 to 42.5 mS/m with an average value of 24.7 mS/m. It should be noted, however, that My Tho Water Quality Station is the lowest station monitored as part of the WQMN and may have been affected by sea water intrusion.

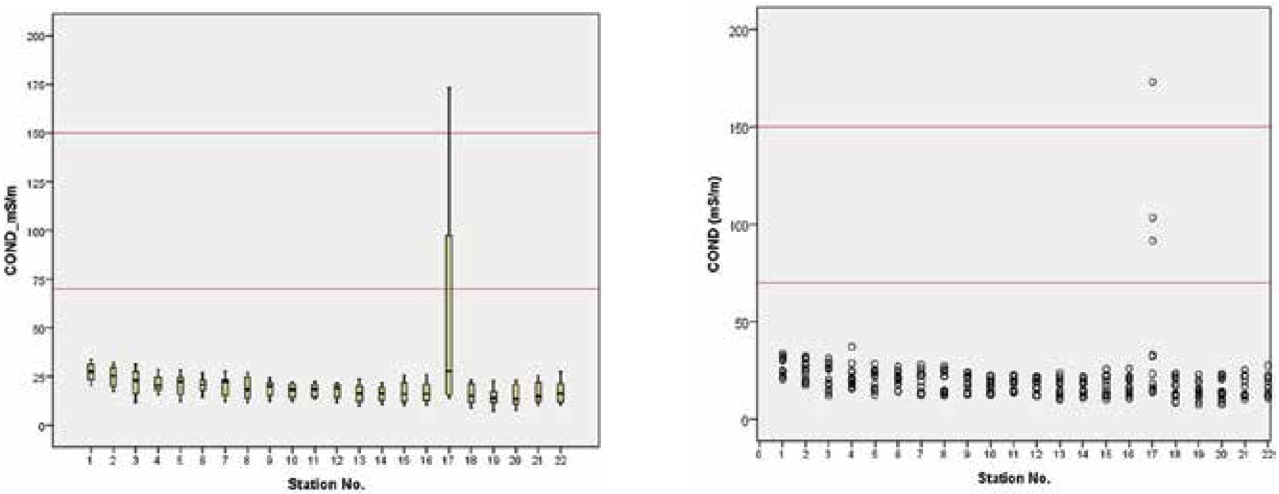


Figure 3.3: Spatial variation in Electrical Conductivity levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2016 (the horizontal lines at 70 and 150 represent lower and upper EC limits of the MRC Water Quality Guidelines for the Protection of Human Health)

[2] These average values are based on measurements taken during low tide. Electrical conductivity values for stations located in the Delta generally can reach up to more than 5,000 mS/m during high tide.

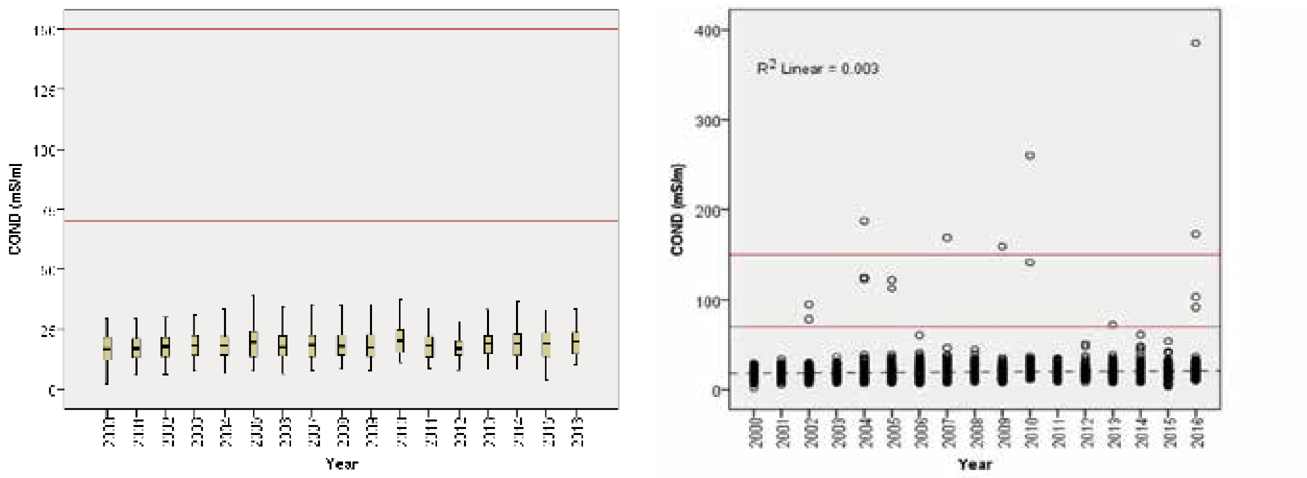


Figure 3.4: Temporal variation in Electrical Conductivity levels in the Mekong River as observed from 2000 to 2016 (the horizontal lines at 70 and 150 represent lower and upper EC limits of the MRC Water Quality Guidelines for the Protection of Human Health)

3.1.3 TOTAL SUSPENDED SOLIDS (TSS)

In the Mekong River, Total Suspended Solids (TSS) are influenced by both natural and anthropogenic activities in the Basin, including urban runoff, industrial effluents, and natural and/or human induced (i.e. agriculture, forestry, or construction) soil erosion (MRC, 2008). The method used by the MRC WQMN to sample TSS does not reflect the sediment concentration in the whole water column2, but currently provides an indication of long-term trends for sediment content in the Mekong River.

In 2016, the TSS concentrations observed along the Mekong River continued to be highly variable, with values ranging from 2.3 to 593 mg/L. The average TSS concentration was about 80.6 mg/L (Table 3-1). TSS concentrations along the Bassac River, on the other hand, were less variable compared to the range observed along the Mekong River. Along the Bassac River, TSS concentrations ranged from 8.0 to 247 mg/L, with an average value of 52.9 mg/L (Table 3-2).

Spatially, the highest TSS levels were observed in the upper part of the Lower Mekong River. TSS levels at stations located in this part of the river were also highly variable as can be seen in Figure 3.5. The maximum TSS concentration of 593 mg/L recorded in 2016 was observed at Vientiane station (4) in September 2016. This may be explained by the construction of the roads near the sampling sites as the soil from the roads was washed into the river.

For both rivers, the lowest TSS concentrations were observed during the dry season (November to April). In general, the Lower Mekong River receives very little to no rainfall during the dry season which causes the dry season TSS concentrations to be lower than those generally observed during the wet season. Along the Mekong River, the average dry season TSS concentration was recorded at about 36.9 mg/L. The highest dry season concentration for TSS was recorded at 362 mg/L at Nakhon Phanom Water Quality Monitoring Station (5) in November 2016 while the lowest concentration was recorded at 4.0 mg/L at Kampong Cham Water Quality Monitoring Station (11) in April 2016.

Along the Bassac River, dry season TSS concentrations ranged from 8.0 to 85.0 mg/L, with the highest dry season concentration recorded at Takhmao (18) in November 2016 and the lowest concentration recorded at Chau Doc (21) in April 2016. The average dry season TSS concentration for the Bassac River was recorded at about 28.4 mg/L.

[2] Water samples are taken approximately 30 cm below the water surface.

During the wet season, the average concentration for the Mekong River was recorded at about 124 mg/L, with values ranging from 2.3 to 593 mg/L. The lowest wet season TSS concentration was recorded in Houa Khong (1) in May 2016, while the highest concentration was recorded at Vientiane (4) in September 2016. With values ranging from 9.0 to 247 mg/L, wet season TSS concentrations along the Bassac River were less variable compared to those recorded along the Mekong River. The highest wet season TSS concentration along the Bassac River was recorded at Takhmao (18) in June 2016, while the lowest concentration was recorded at both Koh Khel (19) and Koh Thom (20) in October 2016.

The temporal analysis of data from 2000 to 2016 suggests that TSS levels in the Mekong River have decreased since 2000 (Figure 3.6). The average TSS concentration in the Mekong River in 2000 was measured at about 118.7 mg/L, whereas in 2016, the average monthly concentration for TSS was measured at about 80.6 mg/L. This figure is, however, slightly elevated compared to the figure recorded in 2015. In 2015, the average TSS concentration for the Mekong River was recorded at 80.2 mg/L.

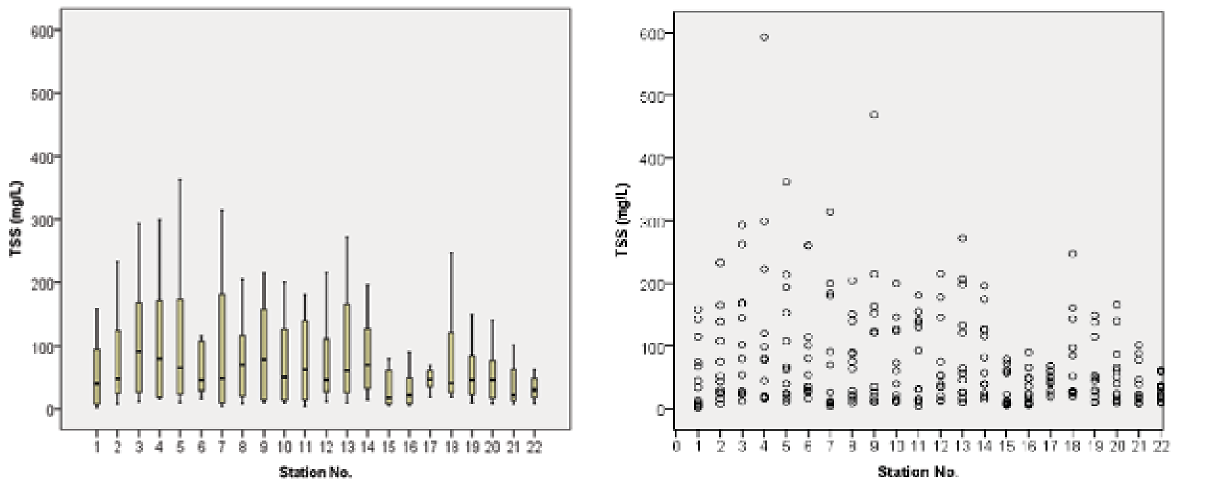


Figure 3.5: Spatial variation in TSS concentrations along the Mekong River (1-17) and Bassac River (18-22) as observed in 2016

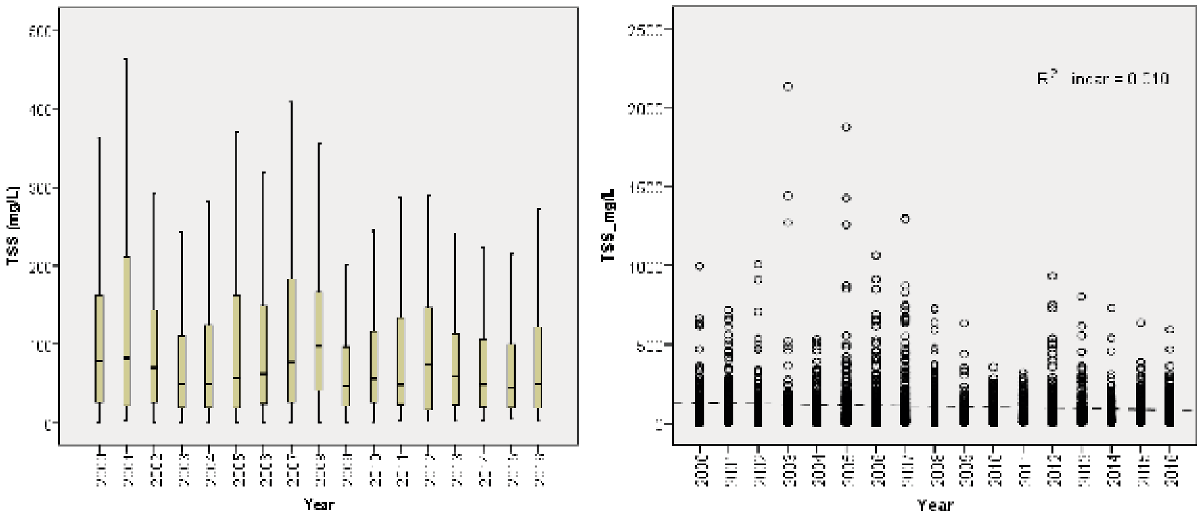


Figure 3.6: Temporal variation in TSS concentrations along the Mekong River as observed from 2000 to 2016

3.1.4 NUTRIENTS

3.1.4.1 Nitrogen

The MRC WQMN designated laboratories continued to monitor concentrations of nitrite-nitrate, ammonium, and total phosphorus as part of nutrient monitoring in 2016. Concentrations of nutrients at all mainstream stations in the Mekong River and Bassac River remained well below the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life (Table 3.1).

The spatial analysis of water quality data shows that in 2016, nitrate-nitrite concentrations were highly variable at a number of stations. The stations located in the upper-most part of the Lower Mekong River, including Houa Khong (1) and Chiang Saen (2) and a number of stations located in the Mekong Delta Tan Chau (15), My Thuan(16), My Tho(17), Chau Doc(21), and Can Tho(22) had higher nitrate-nitrite concentrations compared to other stations. At these stations, the highest concentrations of nitrate-nitrite were observed at My Tho station in March 2016 at a concentration of 1.08mg/l, which was well below the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (5 mg/L).

Temporal analysis of nitrate-nitrite concentrations from 2000 to 2016 reveals that nitrate-nitrite concentrations in the Mekong River remained relatively constant (Figure 3.8). For the Mekong River, the average nitrate-nitrite concentration (measured as N) in 2000 was recorded to be about 0.23 mg/L while the average concentration for nitrate-nitrite in 2016 was recorded to be about 0.29 mg/L.

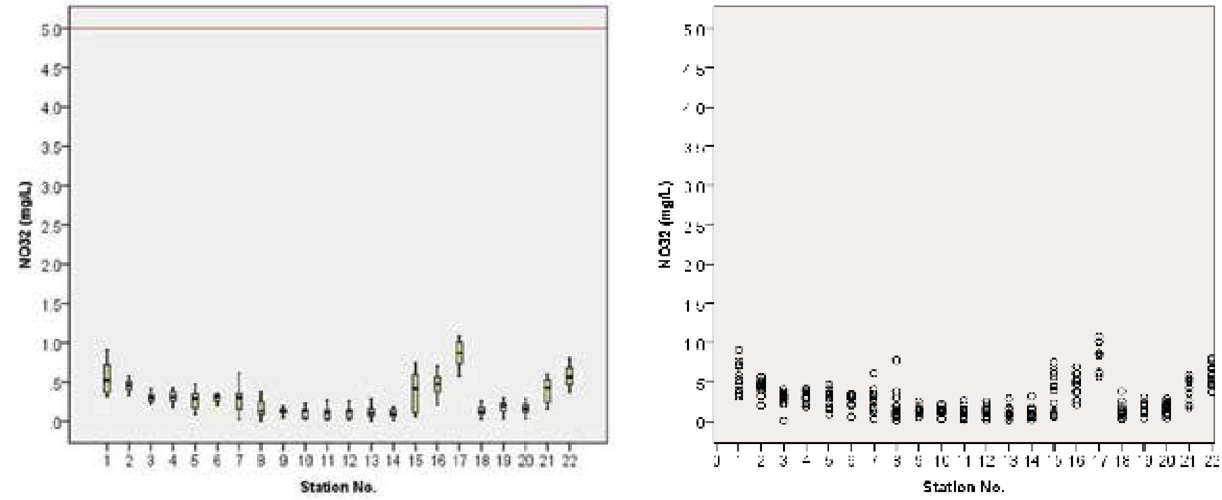


Figure 3.7: Spatial variation in nitrate-nitrite concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2016 (the horizontal lines at 5.0 represent nitrate-nitrite limits of the MRC Water Quality Guidelines for the Protection of Human Health)

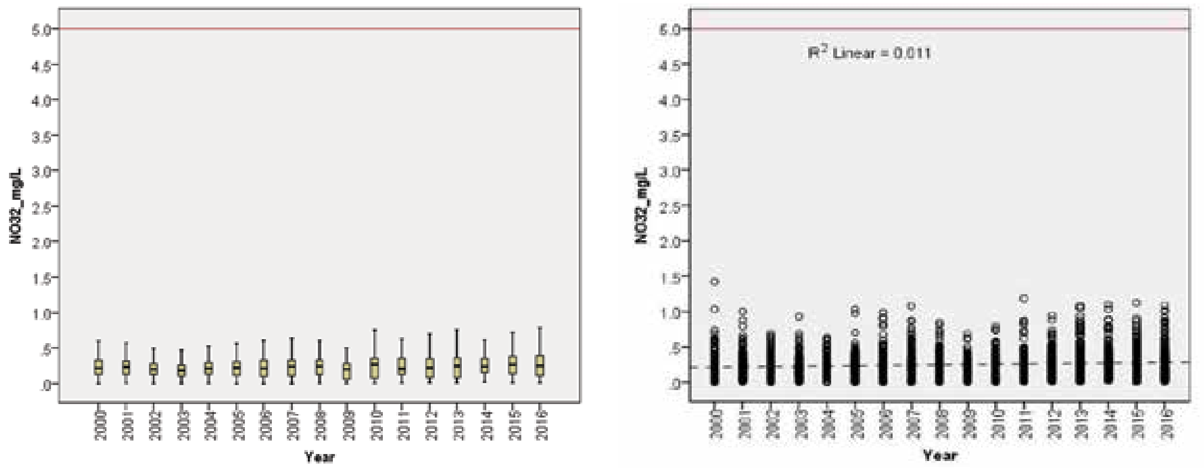


Figure 3.8: Temporal variation in nitrate-nitrite concentrations in the Mekong River as observed from 2000 to 2016 (the horizontal lines at 5.0 represent nitrate-nitrite limits of the MRC Water Quality Guidelines for the Protection of Human Health)

Although there was a slight increase in the concentration of ammonium in 2016 compared to 2015 (0.06mg/l compared to 0.04 mg/l), concentrations of ammonium remained relatively low in 2016 (Figure 3.9). The highest concentrations were measured at My Tho Station (17) with the value of 0.7mg/l. At this station, ammonium levels were highly variable with values (measured as N) ranging from 0.06 to 0.7 mg/L. The values of ammonium concentration at this station exceeded the threshold value used for calculating Water Quality Index for Human Impact (0.05 mg/L) (Table 2-4). It is unclear what caused the high ammonium levels at My Tho station. Spatially, ammonium levels recorded at stations located in the upper parts of the Lower Mekong River were low and less variable when compared to those recorded at stations located in the Mekong Delta.

Temporal analysis of data from 2000 to 2016 for the Mekong River reveals that ammonium concentrations remain relatively constant (Figure 3.10). The average monthly ammonium concentrations in the Mekong River were recorded to be 0.05 mg/L in 2000 and about 0.06 mg/L in 2016.

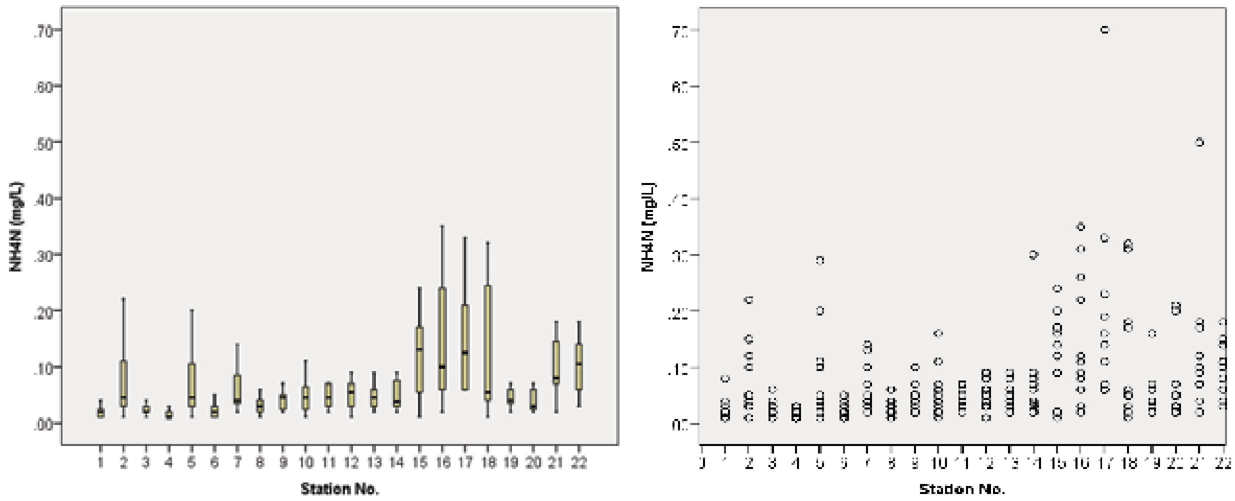


Figure 3.9: Spatial variation in ammonium concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2016

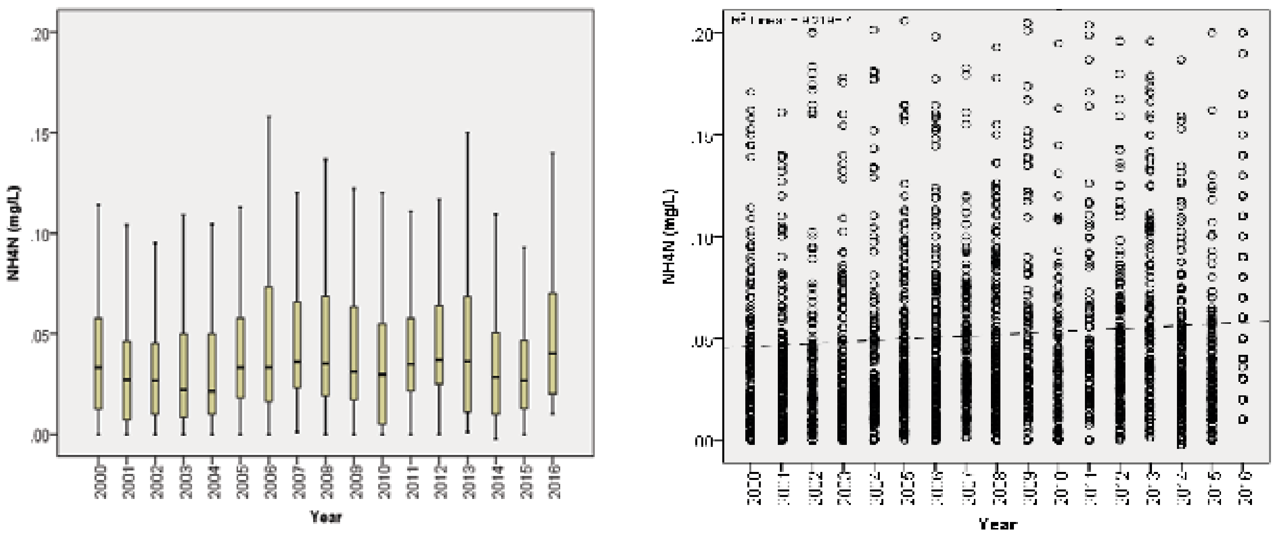


Figure 3.10: Temporal variation in ammonium concentrations in the Mekong River as observed from 2000 to 2016

3.1.4.2 Phosphorus

In 2016, total phosphorus concentrations were highly variable among stations. While the highest concentrations of total phosphorus were recorded at Neak Loung and My Thuan stations with the values of 0.34 and 0.32 mg/l in July 2016, the lowest concentration was observed at 0.01mg/l. Compared to the threshold value used for calculating Water Quality Index for the Protection of Aquatic Life (0.13 mg/L) (Table 2-4), elevated concentrations of total phosphorus were observed at all monitoring stations on at least one monitoring occasion except for stations 1, 3, 4, 6, and 8.

In the Bassac River, the highest total phosphorus concentration was measured at Chau Doc station (21) in May 2016. At this station, total phosphorus levels ranged from 0.02 to 0.52 mg/L. Of the twelve measurements recorded in Chau Doc, five were reported to exceed the threshold value used for calculating Water Quality Index for the Protection of Aquatic Life (0.13 mg/L). The exceedances were recorded mainly during the wet season between April and October 2016.

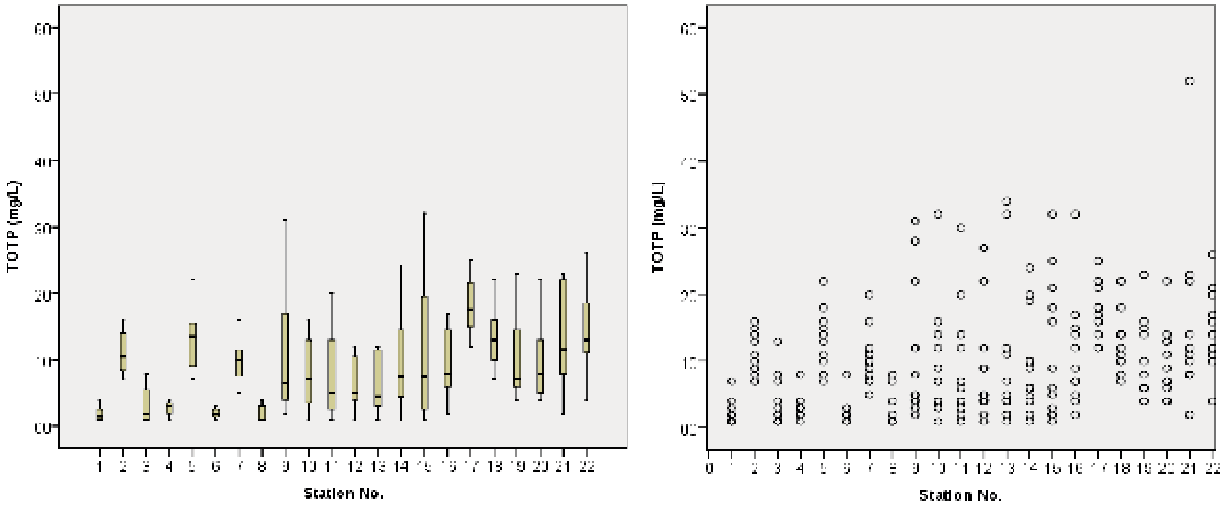


Figure 3.11: Spatial variation in total phosphorus concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2016

Between 2000 and 2016, total phosphorus concentrations in the Mekong River increased slightly, from a mean concentration of about 0.058 mg/L in 2000 to about 0.09 mg/L in 2016 (Figure 3.12). A result of increased human activities, such as agricultural runoff and municipal wastewater discharge in the downstream part of the basin, was the likely reason for this trend. However, the concentration of total phosphorous in 2016 decreased compared to 2015 (0.09mg/l compared to 0.15mg/l).

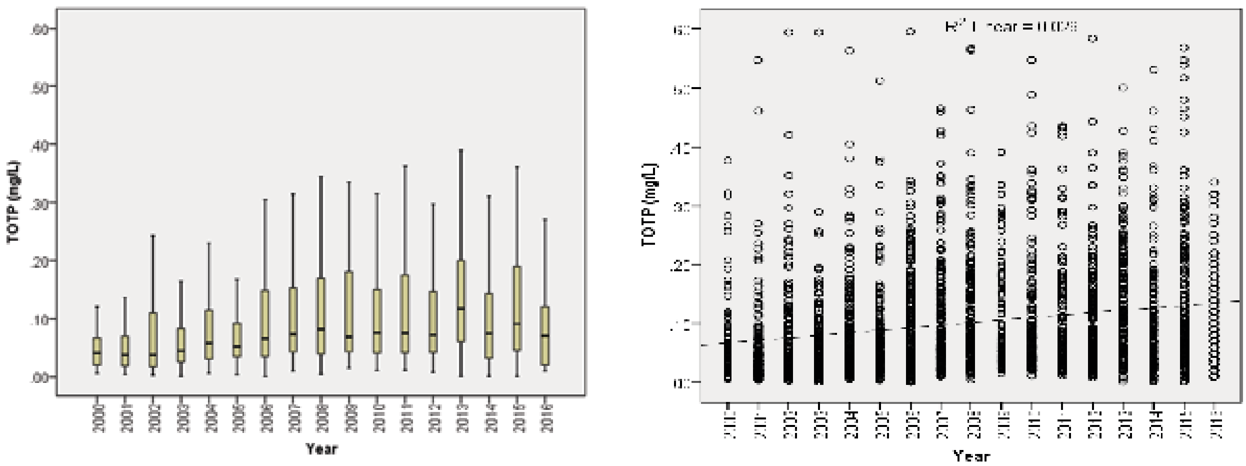


Figure 3.12: Temporal variation in total phosphorus concentrations in the Mekong River as observed from 2000 to 2016

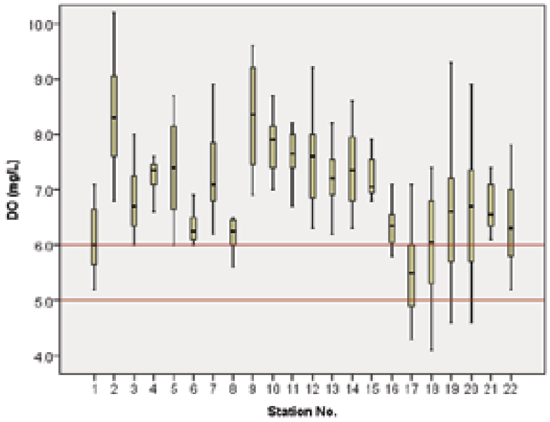
3.1.5 DISSOLVED OXYGEN (DO)

Dissolved oxygen (DO) is one of the key water quality parameters monitored routinely by the MRC Water Quality Monitoring Network. To maintain acceptable/good water quality, an adequate concentration of dissolved oxygen is necessary. This is because oxygen is required for all life forms, including those that live in a river ecosystem. Prolonged reduction in dissolved oxygen levels can lead to fish kill, and can affect other water quality indicators, including biochemical and aesthetic indicators, such as odour, clarity, and taste (National Geographic Society, n.d.). Recognising that dissolved oxygen is an integral component for determining the water quality of the Mekong River, the MRC member countries have jointly established target values for the protection of human health (WQGH) (≥ 6mg/L) and aquatic life (WQGA) (> 5 mg/L).

The 2016 dissolved oxygen data was compared with the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. Of the 22 water quality monitoring stations located in the Mekong and Bassac Rivers, 10 stations recorded dissolved oxygen levels below the MRC Water Quality Guidelines for the Protection of Human Health at least once in the year (≥ 6 mg/L). Of the 10 stations that recorded dissolved oxygen levels below the MRC Water Quality

Guidelines for the Protection of Human Health in 2016, 3 stations are located in Lao PDR, 1 station in Thailand while the other stations are located in the Delta, including 3 stations in Vietnam (16,17, 22) and 3 stations in Cambodia (18, 19, 20). In comparison, 17 stations recorded DO levels below the MRC Water Quality Guidelines for the Protection of Human Health in 2015. This indicates a slight improvement in the concentrations of dissolved oxygen in the mainstream of the Mekong and Bassac Rivers.

In addition to violating the MRC WQGH, My Tho station in Vietnam and three stations in Cambodia (18, 19, 20), recorded dissolved oxygen levels lower than the MRC Water Quality Guidelines for the Protection of Aquatic Life (WQGA) (> 5 mg/L), at one time or another.



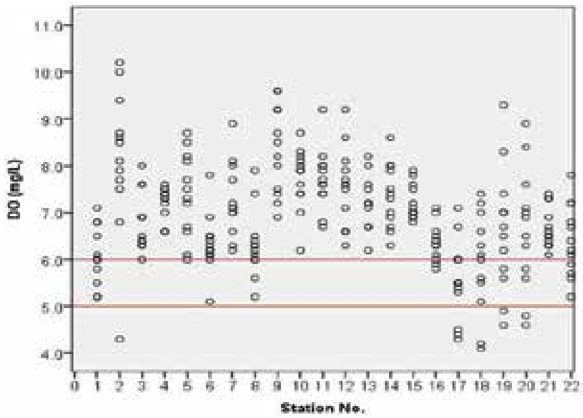


Figure 3.13: Spatial variation in dissolved oxygen (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2016 (the horizontal lines at 5.0 and 6.0 represent DO target values of the MRC Water Quality Guidelines for the Protection of Human Health and Protection of Aquatic Life respectively)

At My Tho Water Quality Monitoring Station (17), 66% of dissolved oxygen values were recorded to be lower than the MRC WQGH of 6 mg/L which may reflect faulty equipment or systematic error in the way dissolved oxygen was measured. Further investigations will need to be carried out to identify potential causes for non-compliance.

The analysis of the spatial variation of 2016 dissolved oxygen data along the mainstream reveals that on average dissolved oxygen concentrations tended to be higher in the upper and middle section of the Mekong River (Figure 3.13). In 2016, the highest dissolved oxygen value in the Mekong River was observed at Chiang Saen (2) monitoring station (10.2 mg/L) in August 2016 while the lowest was observed at My Tho monitoring station (4.3 mg/L) in January 2016. Along the Bassac River, the highest dissolved oxygen concentration was recorded in Koh Khel (19) at 9.3 mg/L in April 2016 while the lowest dissolved oxygen value was recorded at Takhmao monitoring station (18) at 4.1 mg/L in July 2016.

A temporal analysis of dissolved oxygen in the Mekong River from 2000 to 2016 reveals that dissolved oxygen concentrations in the mainstream did not change significantly during the time period. Based on the visual inspection of Figure 3.14, no significant difference in the median and mean values of dissolved oxygen between 2000 and 2016 were observed.

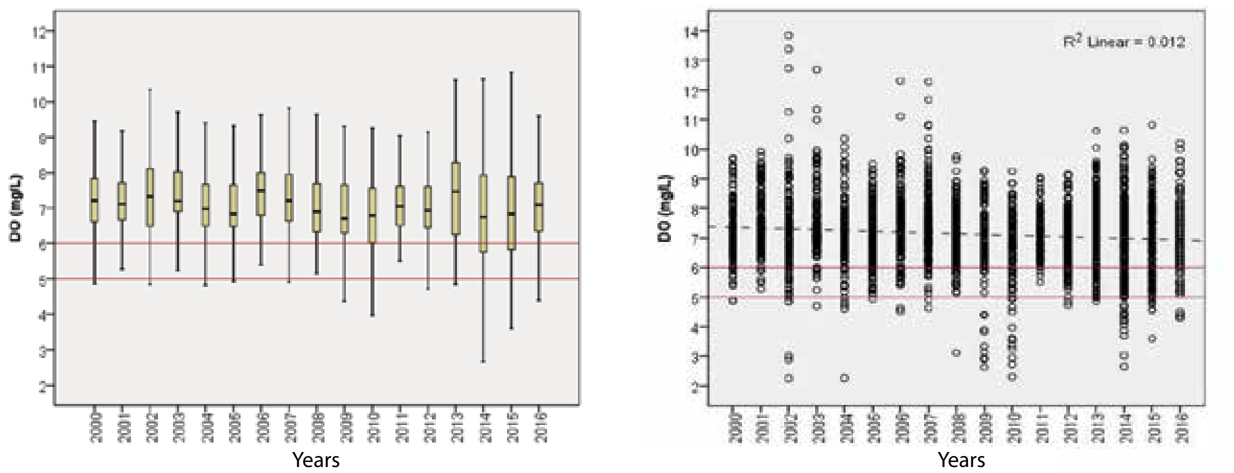


Figure 3.14: Temporal variation in dissolved oxygen (mg/L) in the Mekong River as recorded from 2000 to 2016 (the horizontal lines at 5.0 and 6.0 represent DO target values of the MRC Water Quality Guidelines for the Protection of Human Health and Protection of Aquatic Life respectively)

3.1.6 CHEMICAL OXYGEN DEMAND (COD)

The amount of oxygen needed to oxidise organic and inorganic material is called Chemical Oxygen Demand (COD), but in most cases organic components predominate and are of the greater interest (American Society for Testing and Materials, 1995).

In the Mekong River, in 2016, the maximum COD concentration was recorded at 9.1 mg/L at Nakhon Phanom Water Quality Station in September 2016; this is higher than the recommended MRC Water Quality Guidelines for the Protection of Human Health (5 mg/L). At this station, COD concentrations were highly variable in 2016, ranging from 1.6 to 9.1 mg/L with a mean concentration of about 3.9 mg/L. The mean COD concentration, however, was recorded at 2.34 mg/L, which was slightly higher than the historical mean COD concentration of 2.24 mg/L from 1985 to 2015.

The mean COD concentration in the Bassac River in 2016 was 2.4 mg/L, which was slightly lower than the mean COD value recorded in 2015 (2.6 mg/L). This value is also lower than the historical mean value of 3.3 mg/L from 1985 to 2015. The maximum COD concentration of 5.84 mg/L was recorded at Takhmao, Cambodia in December 2016.

Figure 3.15 shows spatial variations in COD along the Mekong and Bassac Rivers in 2016. As can be seen in Figure 3.15, COD concentrations fluctuate as the river runs from upstream to downstream, with the lowest and less variable concentrations recorded in the middle section of the river (where, accordingly, dissolved oxygen was found to be highest). Individually, a number of stations recorded COD values exceeding the MRC Water Quality Guidelines for the Protection of Human Health of 5 mg/L at least once in 2016. These stations include Chiang Saen (2), Luang Prabang (3), Vientiane (4), Nakhon Phanom (5), Savannakhet (6), Khong Chiam (7), Pakse (8), and Takhmao (18). In comparison, the analysis of 2015 COD data reveals that 9 water quality monitoring stations reported COD values higher than the threshold value of the MRC WQGH (5 mg/L), meaning there was a slight improvement in COD values at the monitoring stations. No COD threshold value has been set for the MRC Water Quality Guidelines for the Protection of Aquatic Life (WQGA).

Figure 3.16 reveals that COD concentrations in the Mekong River increased slightly from 2000 to 2016. For comparison, the mean COD concentration for the 17 Mekong Stations was about 1.9 mg/L in 2000, while the mean COD concentration for the same stations was about 2.5 mg/L in 2015 and 2.3 mg/l in 2016.

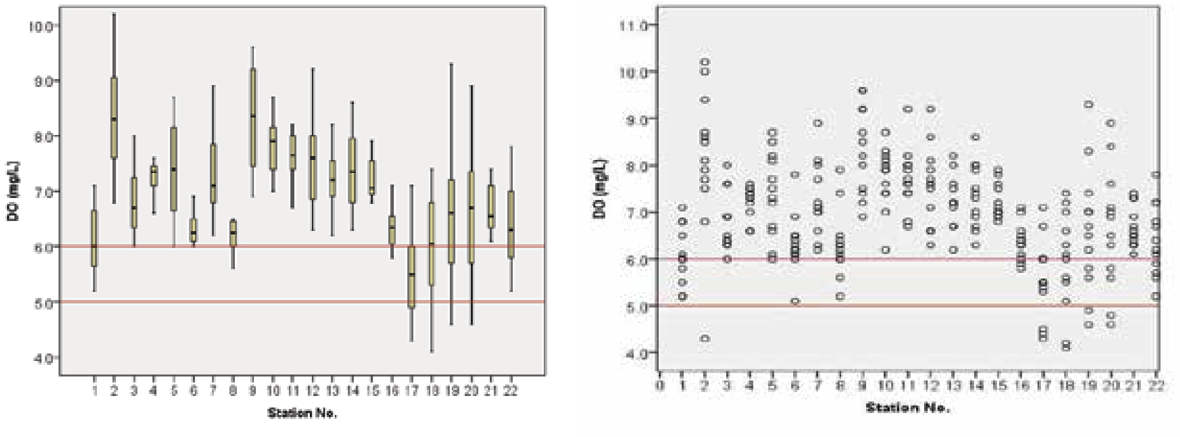


Figure 3.15: Spatial variation in COD (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2016 (the horizontal lines at 5.0 represent COD target value of the MRC Water Quality Guidelines for the Protection of Human Health)

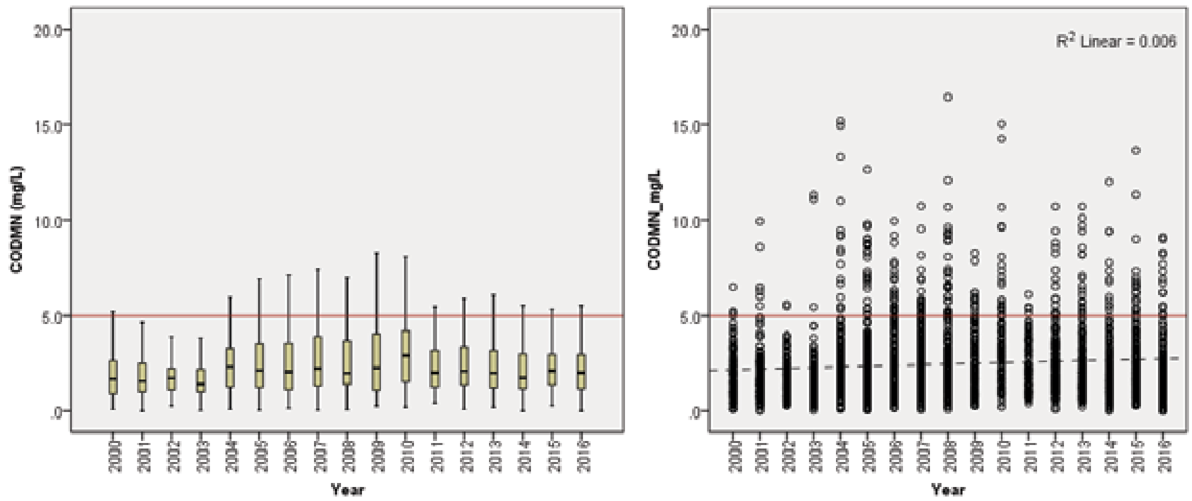


Figure 3.16: Temporal variation in COD (mg/L) in the Mekong River as recorded from 2000 to 2016 (the horizontal lines at 5.0 represent COD target value of the MRC Water Quality Guidelines for the Protection of Human Health)

3.2 TRANSBOUNDARY WATER QUALITY

The Mekong River Commission (2008), in its Technical Paper No. 19, identified five main transboundary areas along the Mekong River for assessing transboundary water quality in the Mekong and Bassac Rivers. These are:

1. People's Republic of China/Lao PDR — a water quality monitoring station was established in Houa Khong in 2004 to monitor the boundary between the Upper and Lower Mekong Basin.
2. Lao PDR/Myanmar — no water quality station exists in this part of the river since it is remote and sparsely populated.
3. Thailand/Lao PDR — a number of monitoring stations exist along this stretch of the Mekong River, including those located in the vicinity of urban areas such as Vientiane, Nakhon Phanom and Savannakhet. However, none of the stations can be referred to as transboundary stations since they receive run-off from both countries and water is normally sampled in the middle of the river.
4. Lao PDR/Cambodia — while not located directly at the border of the two countries, Pakse and Stung Treng monitoring stations have, in the past, been considered as transboundary stations. Data from these stations have been used to assess transboundary effects on water quality.

5. Cambodia/Viet Nam — both the Mekong and the Bassac Rivers have stations that can be used to capture transboundary effects on water quality. On the Mekong side, Kaorm Samnor station in Cambodia and Tan Chau in Viet Nam are located not too far from the Cambodian/Vietnamese border. Similarly, Koh Thom station in Cambodia and Chau Doc station in Viet Nam, which are located on the Bassac River, can be considered as transboundary stations due to their proximity to the Cambodian/Vietnamese border.

3.2.1 PAKSE VS. STUNG TRENG

A comparison of water quality at Pakse and Stung Treng Stations was carried out to examine potential transboundary water quality issues in the Mekong River between Lao PDR and Cambodia. For this purpose, six key parameters were selected based on the availability of data to support the assessment. These parameters are nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen, and chemical oxygen demand.

Figure 3.17 provides a summary of the comparison of 2016 water quality between the two stations. As can been seen in the figure, generally higher concentrations of ammonium were observed in Stung Treng than at Pakse. The average values of ammonium at Pakse and Stung Treng were M = 0.03 mg/L (Std. = 0.02) and M = 0.04 mg/L (Std. = 0.02). These conditions indicate that transboundary water quality issues associated with these parameters might be of potential concern. However, the average values of nitrate-nitrite and total nitrogen at Pakse was higher than that at Stung Treng. The average values of nitrate-nitrite at Pakse and Stung Treng were M = 0.2 mg/L (Std. = 0.21) and M = 0.13 mg/L (Std. = 0.05) and the average values of total nitrogen were 0.49 mg/l (Std.= 0.74) and 0.27 mg/l (Std.= 0.12). This indicates that there was likely no transboundary water quality issue of nitrogen between the two stations in 2016.

Independent t-test was carried out to determine whether the difference observed in mean concentrations of nitrate-nitrite, ammonium, and total nitrogen between the two stations was statistically significant. The results of an independent t-test reveal that the difference in mean concentrations of nitrate-nitrite, ammonium, and total nitrogen at Pakse was not statistically significant with P values of 0.28, 0.11, and 0.32 respectively.

Unlike conditions observed for nitrate-nitrite, ammonium and total nitrogen, the P values for total phosphorus, DO and COD at Parke and Stung Treng are 0.01 and 0.00. These values indicate that there was significant difference among the mean concentrations of those parameters at the two stations. The average concentration of Phosphorous at Stung Treng was recorded at about 0.11 mg/L (Std. = 0.1) compared to 0.02 mg/L (Std. = 0.03) recorded at Pakse, which further indicates that there was likely a transboundary water quality issue between the two stations in 2016.

Dissolved oxygen levels observed at the two stations further reveal the potential of transboundary water quality issues, with higher concentrations generally observed at Stung Treng than Pakse, M=8.33 mg/L (Std. = 0.95) compared to 6.31 mg/L (Std. = 0.72). In contrast, the average concentration of COD at Stung Treng was recorded at about 1.03 mg/L (Std. = 0.59) compared to 2.92 mg/L (Std. = 1.69) at Pakse, which further indicates that there was likely no transboundary water quality issue between the two stations in 2016 regarding COD.

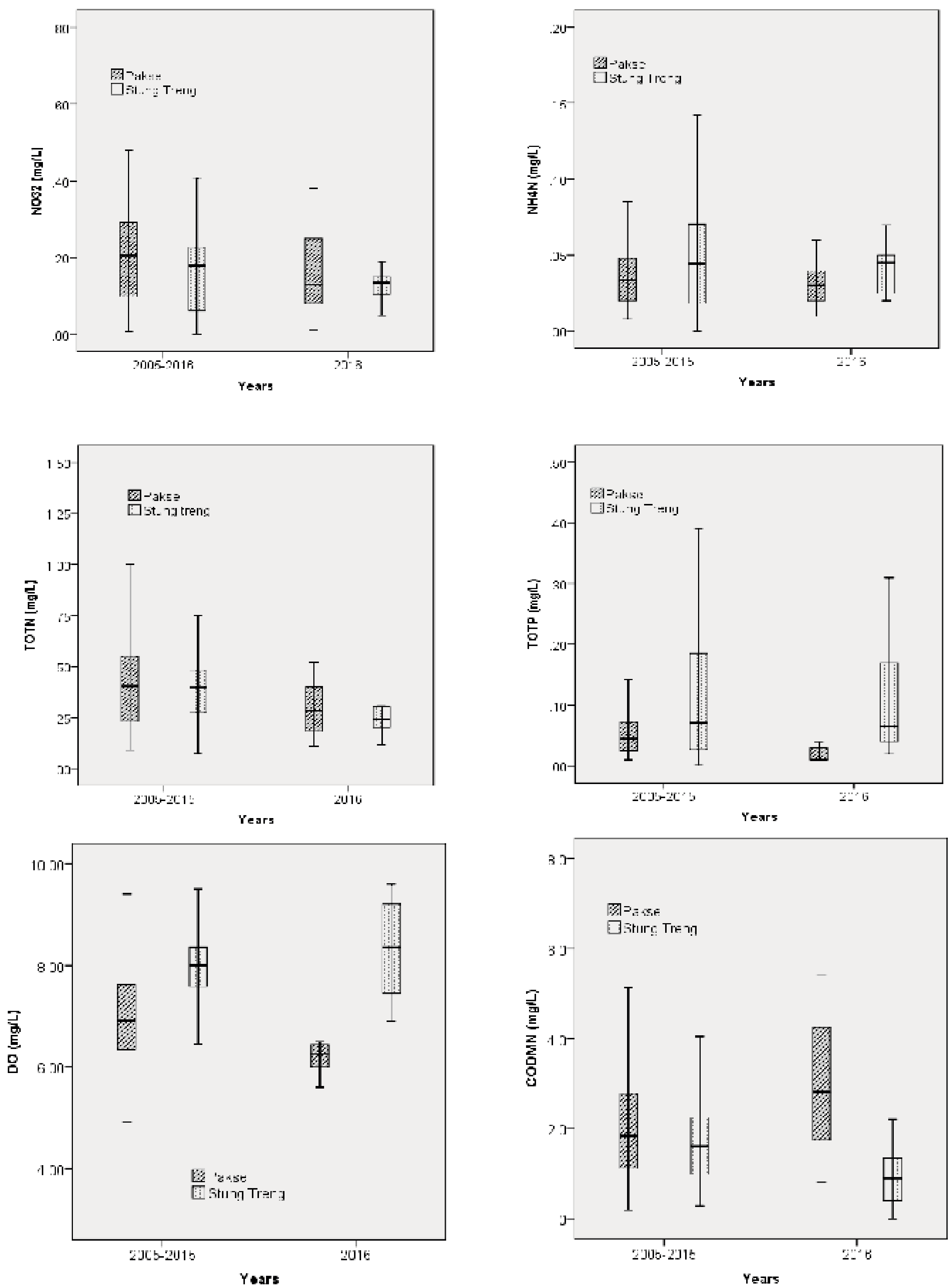


Figure 3.17: Comparisons of water quality data at Pakse and Stung Treng

3.2.2 KAORM SAMNOR VS. TAN CHAU

Kaorm Samnor and Tan Chau monitoring stations are located on the Mekong River, with Kaorm Samnor on the Cambodian side and Tan Chau on the Vietnamese side. To assess potential transboundary water quality issues at these two stations, a comparison was made of a number of key water quality parameters, including nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen, and chemical oxygen demand. The outcomes of these analyses are illustrated in Figure 3.18.

In general, water quality in the Mekong River in 2016 was more degraded in Tan Chau than in Kaorm Samnor, which may reflect transboundary water quality issues in relation to these parameters (nitrate-nitrite, ammonium, total nitrogen, total phosphorous, and COD). For instance, in 2016, generally higher levels of nitrate-nitrite, ammonium, total nitrogen, total phosphorous, and chemical oxygen demand concentrations were observed at Tan Chau than at Kaorm Samnor. Statistically, Independent t-tests revealed the significant difference in concentrations of nitrate-nitrite, total nitrogen, and COD at the two stations with the P value of 0.00.

In contrast, an independent t-test showed that there was not any significant difference between mean concentrations of ammonium, Total Phosphorous, and DO concentrations. The mean concentrations of Ammonium were M = 0.07 mg/ (Std = 0.08) at Kaorm Samnor and M = 0.12 mg/L (Std = 0.08) at Tan Chau with a P value of 0.1. The mean concentrations of DO were M = 7.36 mg/L (Std = 0.68) at Kaorm Samnor and M = 7.22 mg/L (Std = 0.36) at Tan Chau with a P value of 0.53. And the mean concentrations of Total Phosphorous were M = 0.09 mg/ (Std = 0.08) at Kaorm Samnor and M = 0.11 mg/L (Std = 0.1) at Tan Chau with a P value of 0.59.

Concentrations of those parameters were higher in the downstream station compared to the upstream one, which indicates the possibility of transboundary water issues. However, maximum concentrations did not exceed the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life in 2016.

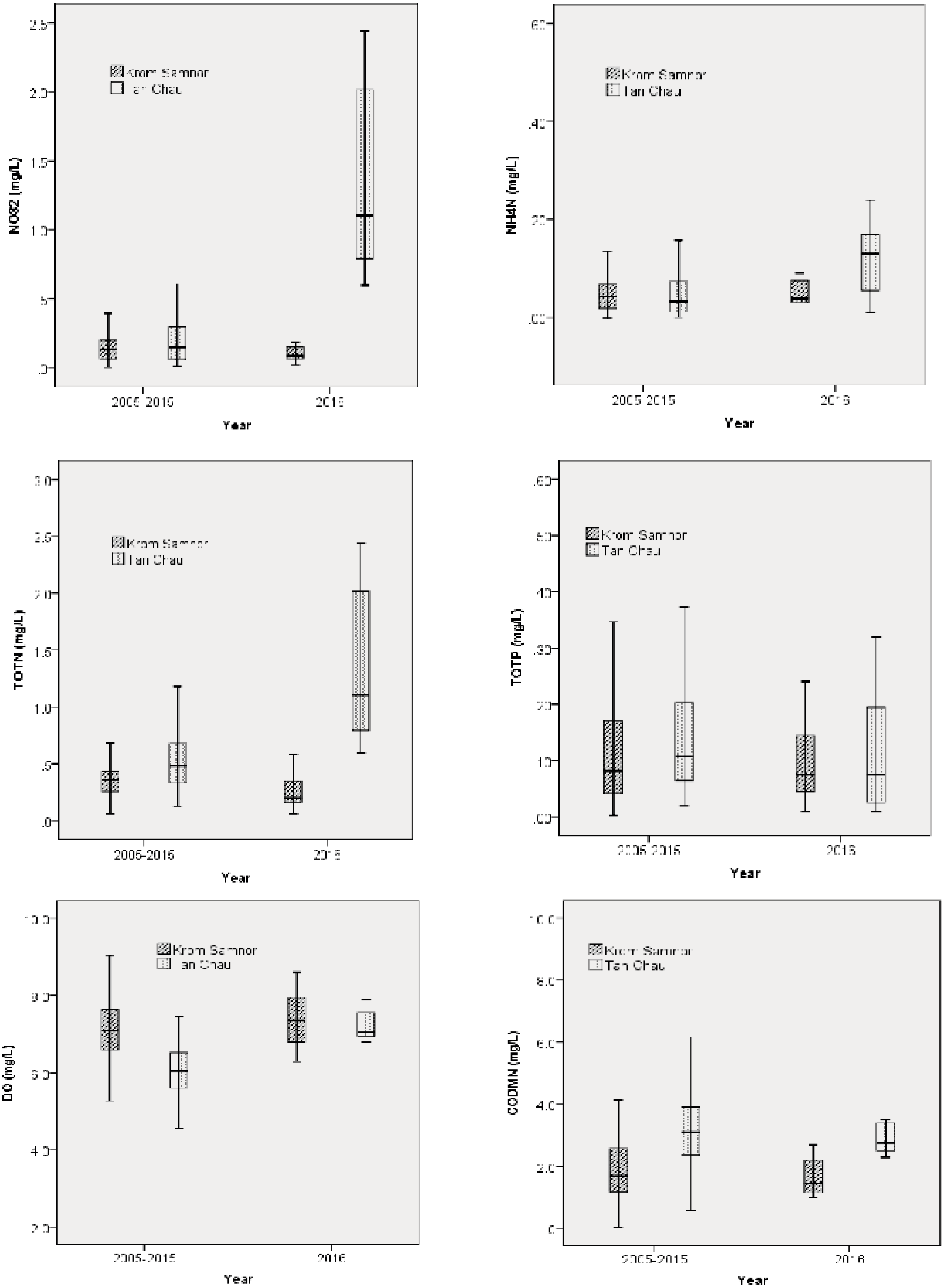


Figure 3.18: Comparisons of water quality data at Kaorm Samnor and Tan Chau

3.2.3 KOH THOM VS. CHAU DOC

Similar analysis was carried out for Koh Thom (on the Cambodian side of the river) and Chau Doc (on the Vietnamese side of the river) water quality monitoring stations on the Bassac River to assess potential transboundary water quality issues. Figure 3.19 illustrates comparisons of the concentrations of nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen, and chemical oxygen demand recorded at Koh Thom and Chau Doc monitoring stations in 2016, and from the period 2005-2015.

In terms of pollutant levels, Figure 3.19 shows that concentrations of nitrate-nitrite, ammonium, total nitrogen, total phosphorous, and chemical oxygen demand were generally higher in the downstream station (Chau Doc) than the upstream station (Koh Thom) in both 2016 and from the period 2005 to 2015. This potentially reflects pollution discharges between the two stations.

The analysis of individual pollutants in 2016 for both stations revealed that the observed difference in the mean concentrations of all pollutants was statistically significant, with a P value of about 0. Mean nitrate-nitrite concentrations for Koh Thom and Chau Doc were estimated to be 0.16 mg/L (Std = 0.07) and 0.40 mg/L (Std = 0.15), respectively. However, with the maximum concentrations recorded at 0.29 and 0.59 mg/L for Koh Thom and Chau Doc, respectively, nitrate-nitrite levels at these two stations were still well below the recommended MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (5 mg/L).
In the case of total nitrogen, the result of an independent t-test for both stations revealed that the observed difference in the mean concentrations of total nitrogen was statistically significant, with a P value of about 0. Mean total nitrogen concentrations for Koh Thom and Chau Doc were estimated to be 0.29 mg/L (Std = 0.12) and 1.25 mg/L (Std = 0.58), respectively.

The observed difference in the mean concentrations of chemical oxygen demand between Koh Thom (M = 1.71 mg/L, Std = 1.08) and Chau Doc (M = 3.27 mg/L, Std = 0.96) was statistically significant with a P value of about 0. However, the maximum COD concentrations at the two stations (3.77 mg/L for Koh Thom and 4.50 mg/L for Chau Doc) were still below the MRC WQGH (5 mg/L), indicating that there is no transboundary issue.
Dissolved oxygen concentrations at Chau Doc were recorded to be generally higher than those recorded at Koh Thom, which indicates there is no transboundary issue. A comparison of mean dissolved oxygen concentrations between the two stations revealed that the difference is statistically significant, with a P value of about 0. Mean dissolved oxygen concentrations for Koh Thom and Chau Doc were estimated at 6.64 mg/L (Std = 1.31) and 6.68 mg/L (Std = 0.44), respectively.

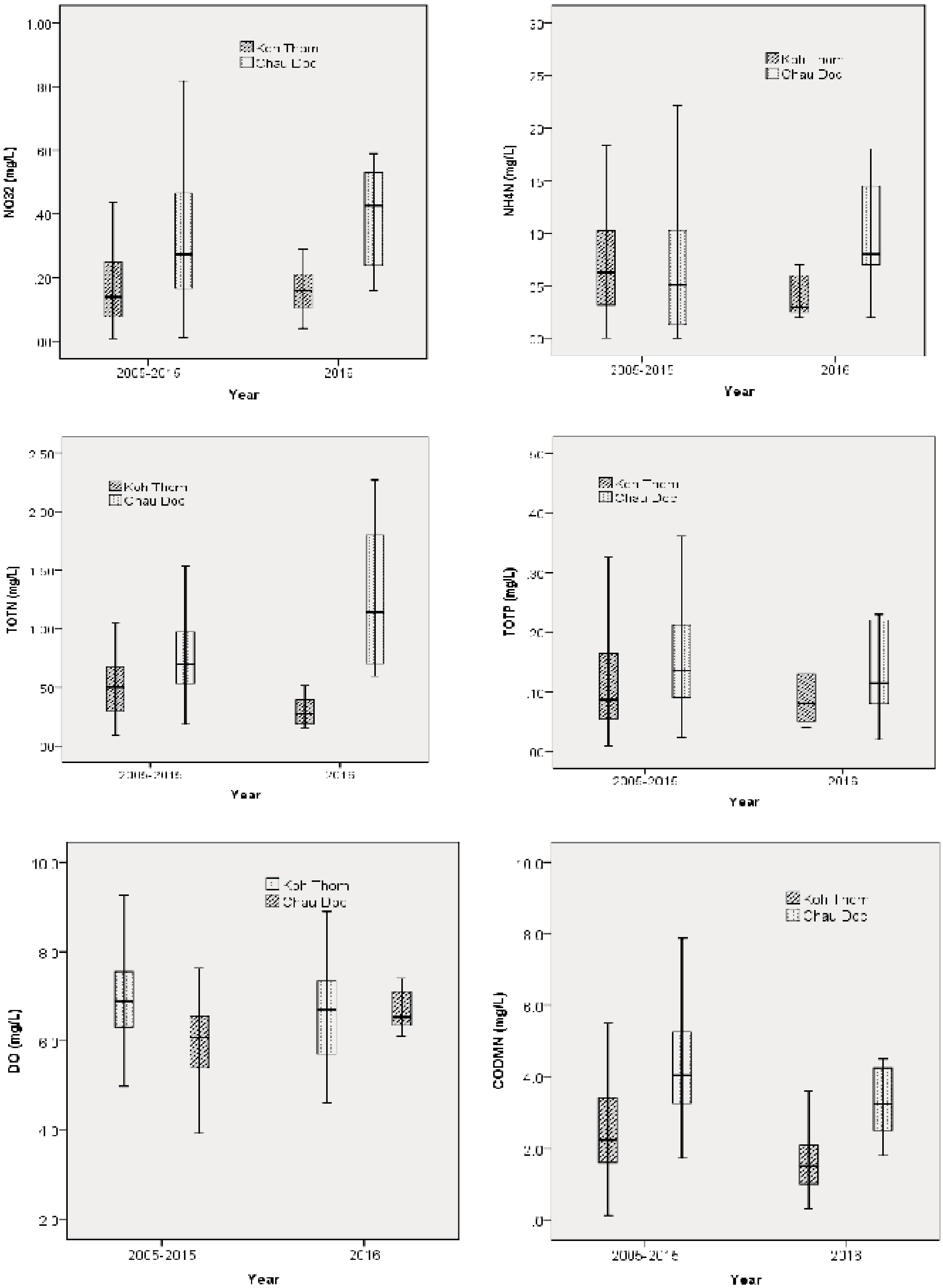


Figure 3.19: Comparisons of water quality data at Koh Thom and Chau Doc

3.3 WATER QUALITY INDICES

3.3.1 WATER QUALITY INDEX FOR THE PROTECTION OF AQUATIC LIFE

In 2016, except for My Tho station, which has water quality classified as "Poor", water quality of the Mekong and Bassac Rivers was classified from "good" to "excellent" for the protection of aquatic life (Table 3-3). Of the 17 monitoring stations located in the Mekong River, 10 Monitoring Stations (Vientiane, Nakhon Phanom, and Khong Chiam) were rated as "excellent" for the protection of aquatic life while 6 were rated as "good quality". My Tho was the only monitoring station to receive a rating of "poor" for the protection of aquatic life. The slight impairment at My Tho Monitoring Station can be attributable to the elevated total phosphorus and nitrate-nitrite concentrations, which were recorded as exceeding the target values for protection of aquatic life in 100% and 83% of sampling occasions, respectively.

In the Bassac River, all stations monitored in 2016 were rated as "good quality" for the protection of aquatic life. Water quality data recorded at these monitoring stations reveal slightly elevated total phosphorus levels with exceedance observed in 40% and elevated nitrate-nitrite levels with exceedance observed in 20% of the total sampling occasions.

Between 2009 and 2016, water quality of the Mekong and the Bassac Rivers remains relatively unchanged and suitable for all aquatic life with only a minor degree of threat or impairment observed. Compared to 2015, the degree of water quality impairment for the protection of aquatic life increased slightly with 8 stations (Vientiane, Savannakhet, Pakse, Kratie, Kampong Cham, Chrouy Changvar, Neak Loung, and Kaorm Samnor) recording higher degrees of impairment (higher water quality index scores) compared to the previous year. This indicates the improvement of water quality for protection of aquatic life in the Mekong River.

Table 3-3: Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of aquatic life 2009-2016

No.	Station Names	Rivers	Countries	Class								
				2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Houa Khong	Mekong	Laos	A	A	A	A	B	B	B	B	B
2	Chiang Saen	Mekong	Thailand	A	B	B	A	B	B	A	B	B
3	Luang Prabang	Mekong	Laos	A	A	B	A	A	B	B	B	A
4	Vientiane	Mekong	Laos	A	A	A	A	A	B	B	A	A
5	Nakhon Phanom	Mekong	Thailand	B	A	B	A	B	B	A	A	B
6	Savannakhet	Mekong	Laos	A	A	A	A	A	B	B	B	A
7	Khong Chiam	Mekong	Thailand	B	A	A	A	A	B	A	A	A
8	Pakse	Mekong	Laos	A	A	A	A	A	B	B	B	A
9	Stung Trieng	Mekong	Cambodia	B	B	B	B	B	B	B	B	B
10	Kratie	Mekong	Cambodia	B	B	B	B	B	B	B	B	A
11	Kampong Cham	Mekong	Cambodia	B	B	B	B	B	B	A	B	A
12	Chrouy Changvar	Mekong	Cambodia	B	B	B	B	B	B	B	B	A
13	Neak Loung	Mekong	Cambodia	B	B	B	B	B	B	B	B	A
14	Krom Samnor	Mekong	Cambodia	B	B	B	B	B	B	B	B	A
15	Tan Chau	Mekong	Viet Nam	B	B	B	B	B	B	B	B	B
16	My Thuan	Mekong	Viet Nam	B	B	B	B	B	B	B	B	B
17	My Tho	Mekong	Viet Nam	C	C	C	C	B	C	C	C	D
18	Takhmao	Bassac	Cambodia	B	B	B	B	B	B	B	B	B
19	Koh Khel	Bassac	Cambodia	B	B	B	B	B	B	B	B	B
20	Koh Thom	Bassac	Cambodia	B	B	B	B	B	B	A	B	B
21	Chau Doc	Bassac	Viet Nam	B	B	B	B	B	B	B	B	B
22	Can Tho	Bassac	Viet Nam	B	C	C	C	C	C	B	B	B

A: High; B: Good; C: Moderate; D: Poor; E: Very Poor

3.3.2 WATER QUALITY INDEX FOR THE PROTECTION OF HUMAN HEALTH

An analysis of the 2016 water quality data, using the Water Quality Index for Human Health Acceptability, reveals that water quality of the Mekong and Bassac Rivers for the protection of human health is still of good quality, with all stations rated as either "good" or "excellent". Of the 22 stations located in the Mekong and Bassac Rivers, 13 were rated as "excellent" in 2016 while the remaining stations were rated as "good". Of the 13 stations rated as "excellent", 12 were located in Cambodia and Viet Nam, and 1 station was located in Lao PDR.

From 2009 to 2016, water quality for the protection of human health did not change significantly, with ratings ranging from "moderate quality" to "excellent quality". Compared to 2015, the degree of impairment for the protection of human health decreased slightly (lower water quality index scores) at 2 stations (My Tho and Takhmao).

Improvement of water quality in terms of the protection of human health was observed in 4 stations (Kampong Cham, Neak Loung, Kaorm Samnor, and Koh Khel). The improvement can be attributed to the reduction in chemical oxygen demand levels which only exceeded the guideline value of 5 mg/L in 6% of sampling occasions. For comparison, the exceedance observed at the same stations in 2015 was in 11% of sampling occasions.

Table 3-4: Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of human health 2009-2016

No.	Station Names	Rivers	Countries	Class								
				2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Houa Khong	Mekong	Lao PDR	A	A	B	A	B	B	C	A	A
2	Chiang Saen	Mekong	Thailand	B	B	B	A	B	B	B	B	B
3	Luang Prabang	Mekong	Lao PDR	A	A	B	A	B	A	B	B	B
4	Vientiane	Mekong	Lao PDR	A	A	B	A	B	B	B	B	B
5	Nakhon Phanom	Mekong	Thailand	B	B	B	B	B	B	B	B	B
6	Savannakhet	Mekong	Lao PDR	A	A	A	A	B	B	C	B	B
7	Khong Chiam	Mekong	Thailand	B	B	B	A	B	B	B	B	B
8	Pakse	Mekong	Lao PDR	B	A	A	A	A	B	A	B	B
9	Stung Trieng	Mekong	Cambodia	B	A	A	A	A	A	A	A	A
10	Kratie	Mekong	Cambodia	B	A	A	A	A	A	A	A	A
11	Kampong Cham	Mekong	Cambodia	B	A	A	A	A	A	A	B	A
12	Chrouy Changvar	Mekong	Cambodia	B	A	A	A	A	A	A	A	A
13	Neak Loung	Mekong	Cambodia	B	A	A	A	A	A	A	B	A
14	Krom Samnor	Mekong	Cambodia	B	A	A	A	B	A	A	B	A
15	Tan Chau	Mekong	Viet Nam	B	C	B	B	A	A	A	A	A
16	My Thuan	Mekong	Viet Nam	B	B	C	A	A	B	A	A	A
17	My Tho	Mekong	Viet Nam	B	C	C	B	B	B	B	A	B
18	Takhmao	Bassac	Cambodia	B	A	A	A	A	B	C	A	B
19	Koh Khel	Bassac	Cambodia	A	A	B	A	B	B	A	B	A
20	Koh Thom	Bassac	Cambodia	B	A	A	A	B	B	A	A	A
21	Chau Doc	Bassac	Viet Nam	B	C	C	B	B	A	A	A	A
22	Can Tho	Bassac	Viet Nam	B	B	C	B	A	A	A	A	A

A: Excellent; B: Good; C: Moderate; D: Poor; E: Very Poor

3.3.3 WATER QUALITY INDEX FOR AGRICULTURAL USE

The level of impairment of water quality for agricultural use was assessed using the MRC Water Quality Indices for Agricultural Use. While two indices were adopted by the MRC to assess the level of impairment of water quality for general irrigation and paddy rice irrigation, all indices for agricultural use can be assessed against threshold values for electrical conductivity (Table 2-8).

An analysis of electrical conductivity data from 2016 reveals that except for My Tho station, which had the values of EC higher than 70mS/m between January and April 2016, all electrical conductivity values fell within the guideline value for Water Quality Index for General Irrigation Use of 70 mS/m. At My Tho station, the maximum EC was recorded at 385 mS/m in March 2016, which is classified as a "Severe restriction" condition. However, the average value of electrical conductivity at this station was 76.6 mS/m and was classified as "some restriction" for general irrigation. It is unclear about the reasons for the very high EC at My Tho station from January to April 2016. However, high electrical conductivity had been observed in the Delta (Vietnam's stations) during high tide due to the intrusion of sea water, and had been recorded with a maximum value of 841.0 mS/m at My Tho station in April 1998.

Except for My Tho station, with no recorded violation of the guideline values for Water Quality Indices for General Irrigation and Paddy Rice Irrigation, it can be concluded that there was no restriction for all types of agricultural use of Mekong and Bassac River water in the upper part of the river. However, when using water for agriculture in the Delta of Vietnam, especially the areas around My Tho station, it is necessary to thoroughly examine the water quality. The level of impairment of the Mekong and Bassac Rivers' water quality for agricultural use is summarised in Table 3-5.

Table 3-5: Water quality class of the Mekong River (1-17) and Bassac River (18-22) for agricultural use for 2009-2016

No.	Station Name	Rivers	Countries	Class							
				2009	2010	2011	2012	2013	2014	2015	2016
1	Houa Khong	Mekong	Lao PDR	A	A	A	A	A	A	A	A
2	Chiang Saen	Mekong	Thailand	A	A	A	A	A	A	A	A
3	Luang Prabang	Mekong	Lao PDR	A	A	A	A	A	A	A	A
4	Vientiane	Mekong	Lao PDR	A	A	A	A	A	A	A	A
5	Nakhon Phanom	Mekong	Thailand	A	A	A	A	A	A	A	A
6	Savannakhet	Mekong	Lao PDR	A	A	A	A	A	A	A	A
7	Khong Chiam	Mekong	Thailand	A	A	A	A	A	A	A	A
8	Pakse	Mekong	Lao PDR	A	A	A	A	A	A	A	A
9	Stung Treng	Mekong	Cambodia	A	A	A	A	A	A	A	A
10	Kratie	Mekong	Cambodia	A	A	A	A	A	A	A	A
11	Kampong Cham	Mekong	Cambodia	A	A	A	A	A	A	A	A
12	Chrouy Changvar	Mekong	Cambodia	A	A	A	A	A	A	A	A
13	Neak Loung	Mekong	Cambodia	A	A	A	A	A	A	A	A
14	Kaorm Samnor	Mekong	Cambodia	A	A	A	A	A	A	A	A
15	Tan Chau	Mekong	Viet Nam	A	A	A	A	A	A	A	A
16	My Thuan	Mekong	Viet Nam	A	A	A	A	A	A	A	A
17	My Tho	Mekong	Viet Nam	A	A	A	A	A	A	A	B
18	Takhmao	Bassac	Cambodia	A	A	A	A	A	A	A	A
19	Khos Khel	Bassac	Cambodia	A	A	A	A	A	A	A	A
20	Khos Thom	Bassac	Cambodia	A	A	A	A	A	A	A	A
21	Chau Doc	Bassac	Viet Nam	A	A	A	A	A	A	A	A
22	Can Tho	Bassac	Viet Nam	A	A	A	A	A	A	A	A

A: No restriction; B: Some restriction; C: Severe restriction

4. Conclusions and Recommendations

4.1 CONCLUSIONS

Based on the results of the 2016 water quality monitoring survey, it can be concluded that the water quality of the Mekong and Bassac Rivers is still of good quality with a slight improvement compared to 2015. There were only a small number of measurements of dissolved oxygen, chemical oxygen demand, nitrate-nitrite, and total phosphorus exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (Tables 3-1 and 3-2). The majority of exceedances were recorded in the Delta, which is highly populated, especially at My Tho station (17) in Vietnam.

Additionally, electrical conductivity levels were recorded to be well below the lowest allowable limit of the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (70-150 mS/m), except for My Tho Station, where the EC from January to April was quite high with a maximum value of 385 mS/m. However, it should be noted that the Mekong River is generally characterised as a low saline river with average electrical conductivity rarely exceeding 40 mS/m. When compared to 2015 data, water quality of the Mekong and Bassac Rivers improved slightly in 2016.

The temporal analysis of data from 2000 to 2016 suggests that pH levels showed a slight decrease during the period but were still well within the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (6-9). The average TSS concentration of the Mekong River has decreased since 2000. It was measured at about 118.7 mg/L in 2000, whereas in 2016, the average monthly concentration for TSS was measured at about 80.63 mg/L. Concentrations of nitrate-nitrite, ammonium, and dissolved oxygen remained relatively constant, while chemical oxygen demand and total phosphorous levels increased slightly.

There is no compelling evidence for transboundary pollution in the LMB despite some observed significant differences between some pollutants at stations upstream and downstream of national boundary areas. Maximum concentrations of pollutants at national boundary stations generally do not exceed the MRC WQGH and WQGA, which is indicative of a low risk of transboundary issues.

The assessment of the Water Quality Index for the Protection of Aquatic Life revealed that water quality of the Mekong and Bassac Rivers for the protection of aquatic life ranged from good quality, with most stations rated as either "good" or "excellent". Of the 22 stations located in the Mekong and Bassac Rivers, 10 stations were rated as "excellent" in 2016 while the remaining stations were rated as "good". Of the 10 stations rated as "excellent", 5 were located in Cambodia, 4 in Lao PDR, and 1 in Thailand. Only one station (My Tho) was rated as "poor" quality for the protection of aquatic life. The slight impairment at My Tho Monitoring Station can be attributable to the elevated total phosphorus, and nitrate-nitrite concentrations which were recorded as exceeding the target values for protection of aquatic life in 100% and 83% of sampling occasions, respectively. The degree of water quality for the protection of aquatic life improved slightly in 2016 when compared to 2015, with eight stations receiving higher rating scores in 2016.

The analysis of the 2016 water quality data, using the Water Quality Index for Human Health Acceptability, reveals that water quality of the Mekong and Bassac Rivers for the protection of human health was still good with all stations rated as either "good" or "excellent". Of the 22 stations located in the Mekong and Bassac Rivers, 13 stations were rated as "excellent" in 2016 while the remaining stations were rated as "good". Of the 13 stations rated as "excellent", 12 were located in Cambodia and Viet Nam and 1 station in Lao PDR. From 2009 to 2016, water quality for the protection of human health did not change significantly, with ratings ranging from "moderate quality" to "excellent quality". Compared to 2015, the degree of impairment for the protection of human health decreased slightly (lower water quality index scores) at 2 stations (My Tho and Takhmao). Improvement of water quality in terms of the protection of human health was observed in 4 stations (Kampong Cham, Neak Loung, Kaorm Samnor, and Koh Khel). The improvement can be attributed to the reduction in chemical oxygen demand levels, which only exceeded the guideline value of 5 mg/L in 6% of the sampling occasions. For comparison, the exceedance observed at the same stations in 2015 was 11% of the sampling occasions.

Except for My Tho station, with no recorded violation of the guideline values for Water Quality Indices for General Irrigation and Paddy Rice Irrigation, it can be concluded that there was no restriction for all types of agricultural use of the Mekong and Bassac Rivers' water in the upper and middle parts of the rivers. However, when using water for agriculture in the Delta of Vietnam, especially the areas around My Tho station, the water quality needs to be thoroughly tested.

4.2 RECOMMENDATIONS

MRC Member Countries' efforts to maintain acceptable/good water quality of the Mekong and Bassac Rivers requires monitoring to closely follow the TGWQ in the Mekong and Bassac Rivers. The TGWQ provides a number of additional water quality indicators for monitoring in the near future. These indicators have been added to take into account emerging threats to water quality, including population growth, intensive agriculture and aquaculture, navigation, hydropower, and industrialisation, which can often lead to increased inputs of chemicals and ultimately affect aquatic ecosystems and human health.

Considering the potential changes in the future monitoring of water quality, the following measures are recommended for the sustainable implementation of routine water quality monitoring under the MRC WQMN:

- Improve and update water quality monitoring knowledge and skills for national laboratories by providing training programs
- Make an assessment on the status of equipment used for water analysis in the laboratories
- Find solutions to improve sampling processes, especially in remote areas (e.g. close to Lao-Myanmar border and possibly Lao-Chinese border)
- Monitor more parameters mentioned in water quality indicators listed in Chapters 1 and 2 of the TGWQ, including heavy metals as well as persistent and non-persistent organic substances
- Make plans/proposals to install automatic monitoring stations at selected stations to obtain more updated information on water quality

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