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2013 LOWER MEKONG REGIONAL WATER QUALITY MONITORING REPORT

Report prepared by
Mekong River Commission
Environment Programme

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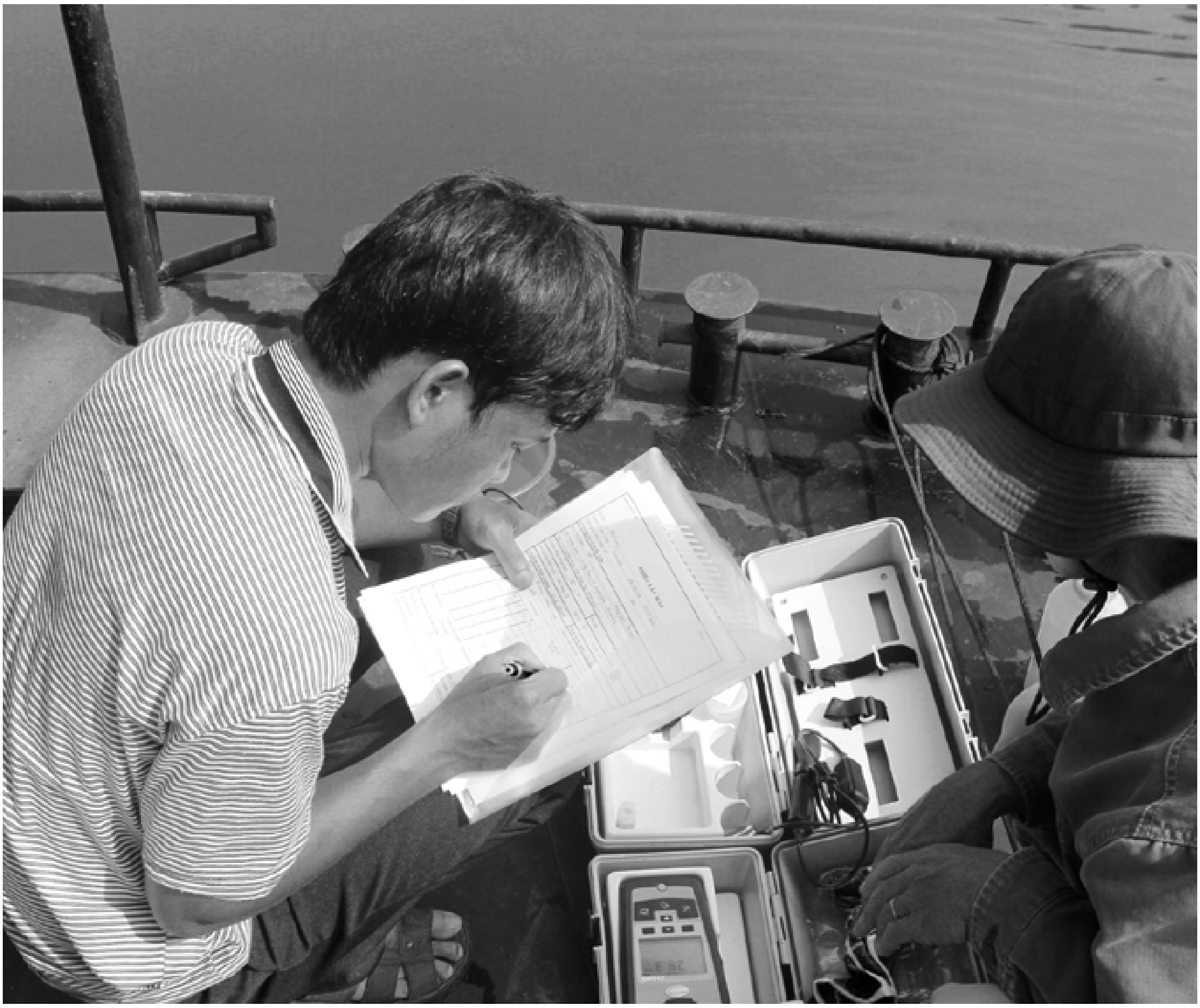

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Acronyms

AL	Guidelines for the Protection of Aquatic Life
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EHM	Ecological Health Monitoring
EP	Environment Programme
HH	Guidelines for the Protection of the Human Health
ISO	International Standardization Organization
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMCs	National Mekong Committees
NMCSs	National Mekong Committee Secretariats
PWQ	Procedures for Water Quality
QA/QC	Quality Assurance/Quality Control
TGWQ	Technical Guidelines for the Implementation of the Procedures for Water Quality
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
WQIag	Water Quality Index for Agricultural Use
WQIal	Water Quality Index for the Protection of Aquatic Life
WQIhh	Water Quality Index for the Protection of Human Health Acceptability
WQMN	Water Quality Monitoring Network

EXECUTIVE SUMMARY

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 implemented under the MRC Environment Programme, 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 2013, the Mekong River Commission, with the assistance of the Member Countries, conducted a routine monitoring of water quality of the Mekong River and its tributaries at 48 stations, of which 17 were located in the Mekong River while five were located in the Bassac River. In all, 12 water quality parameters were monitored on a monthly basis at each station while an additional six parameters were monitored monthly during the wet season at each station (for Viet Nam, these six parameters are monitored each month).

The results of the monitoring showed that water quality of the Mekong River is still good, with only a small number of samples of pH, dissolved oxygen and chemical oxygen demand exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. The results also showed that pH and dissolved oxygen levels decreased as the Mekong River flowed from upstream to downstream while chemical oxygen demand levels exhibited opposite trends as the river flowed from upstream to downstream.

Compared to previous years, nutrient levels in the Mekong River increased slightly in 2013 with total phosphorus and ammonium levels showing slightly increasing trends from 2000 to 2013 while nitrate-nitrite levels remain relatively constant. Dissolved oxygen levels for the Mekong River remained relatively constant from 2000 to 2013 while chemical oxygen demand levels increased slightly during the same time frame. The level of total suspended solids (TSS) in the Mekong River showed a noticeable decrease between 1985 and 2013, from an average value of about 300 mg/L to about 96 mg/L. However, TSS did not show any noticeable change from 2000 (119 mg/L) to 2013 (96 mg/L).

In 2013, the results of water quality data analysis revealed no strong evidence of transboundary pollution in the LMB despite some observed significant differences between some pollutants at stations upstream and downstream of national borders.

The elevated levels of total phosphorus and nitrate-nitrite, recorded in 2013, affected

water quality for the protection of aquatic life at some monitoring stations. The analysis of the 2013 water quality data using the MRC Water Quality Index for the Protection of Aquatic Life reveals that water quality in the Mekong and Bassac Rivers ranged from "moderate" to "good" quality for the protection of aquatic life. Compared to the previous year (2012), the degree of impairment increased slightly with six monitoring stations receiving a lower rating score than the year before. The impairment can be attributed to the increased nutrient levels recorded at these stations.

The analysis of the 2013 water quality data using the MRC Water Quality Index for the Protection of Human Health (Human Health Acceptability Index) reveals that water quality of the Mekong River ranged from "good" to "excellent" quality for the protection of human health. Of the 22 stations located in the Mekong and Bassac River, 10 stations were rated as "excellent". From 2008 to 2013, water quality for the protection of human health did not change significantly and was acceptable for human health.

With the maximum recorded electrical conductivity of 72 mS/m and 24.4 mS/m in the Mekong River and Bassac River, respectively, no restriction on the use of water from the Mekong and Bassac Rivers for agricultural purposes was recorded in 2013.

Overall, it can be concluded that the Mekong and Bassac Rivers still have good water quality with respect to the protection of human health and aquatic life. However, elevated levels of some individual parameters were recorded in the past few years, which could be of concern considering the ongoing development in the Lower Mekong Basin and the utilization of water resources. As such, a number of measures should be considered to improve the management and monitoring of water quality of the Mekong and Bassac Rivers. These measures include:

- Capacity improvement for the monitoring of emerging toxic contaminants;
- Capacity improvement for the implementation of QA/QC Procedures;
- Capacity improvement for data analysis and report writing; and
- Improvement of knowledge on the relationships between water quality conditions and land use within the Lower Mekong Basin.

1. INTRODUCTION

1. INTRODUCTION

1.1 BACKGROUND

Ranked as 12th longest river at about 4,880 km and 8th in terms of mean annual discharge at the mouth at about 14,500 m^3/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 km^2 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 km^2), 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, Khorat Plateau, Tonle Sap Basin and the Delta. With a total catchment area of about 571,000 km^2, 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 fish species identified (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 the 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. For 2013, a total of 48 stations were included in the WQMN, of which 17 were located on the Mekong River and 5 were located on the Bassac River. The other 26 stations were located in the tributaries of the Mekong River. These 48 stations have been classified as “primary stations” since 2005 and were designed to detect changes and capture pressures and threats to the Mekong water quality. A number of these stations were also strategically selected to detect trans-boundary water quality problems.

The WQMN is one of the MRC’s core function activities which are going to be decentralised to the Member Countries. At regional level, the overall management of the WQMN is under the MRC Environment Programme (EP). Over the years, the EP has provided both technical and financial support to the WQMN. The WQMN is co-financed by the MRCS (25%) and the Member Countries (75%). At national level, each Member Country has designated a water quality laboratory to undertake the monitoring, sampling, and analysis of the Mekong water quality. The designated laboratories are responsible for undertaking routine monitoring and measurement of water quality parameters. They are also responsible for analysing, assessing and reporting water quality data on an annual basis. Their specific duties include:

- Conduct routine (monthly or bi-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; and
- Produce and publish annual water quality data assessment report, outlining the results of water quality monitoring, analysis and assessment.

1.3 OBJECTIVES

The routine water quality monitoring under the WQMN has become one of the key environmental monitoring activities implemented under the MRC EP. Its importance is captured in both the EP Document 2011-2015 and the EP Implementation Plan for 2011-2015. According to these documents, two major outputs are expected on an annual basis, including 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 of the water quality monitoring activities from 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 the 2013 water quality of the Mekong River, assessing water quality monitoring data monitored by the WQMN laboratories in 2013 and comparing them with available water quality guidelines of the MRC;

- Identify any spatial and temporal changes observed in the Mekong River water quality;
- Identify and discuss any transboundary water quality issue observed in 2013; and
- Provide recommendations for future monitoring and continuous improvement of the water quality monitoring activities.

2. METHODOLOGY FOR MONITORING AND DATA ASSESSMENT

2. METHODOLOGY FOR MONITORING AND DATA ASSESSMENT

2.1 MONITORING LOCATION AND FREQUENCY

Forty-eight stations were monitored by the WQMN in 2013. 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 2013, 11 stations are located in Lao PDR, 8 are located in Thailand, 19 are located in Cambodia and 10 are located in Viet Nam. Figure 2-1 illustrates their locations in the Lower Mekong Basin (17 on the Mekong River, 5 on the Bassac River and 26 on the Mekong tributaries). 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 the month.

Table 2-2 lists the 22 mainstream stations monitored in 2013. The table lists the mainstream stations in geographical order, from upstream to downstream, to facilitate in the analysis of water quality trends along the Mekong River mainstream.

For consistency, the Member Countries also agreed to carry out the sampling and monitoring of water quality between the 13th and 18th of the monitoring month.

Table 2-2 lists the 22 mainstream stations monitored in 2012. The table lists the mainstream stations in geographical order, from upstream to downstream, to assist in the analysis of water quality trend along the Mekong River mainstream.

2.2 SAMPLING TECHNIQUES

In an effort to standardise the sampling techniques, the EP has 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 simple surface grab technique at the middle of the stream where free flowing water is observable;
- Collect water sample at about 30 to 50 cm under the surface of the stream;

Table 2-1. A summary of 2013 water quality monitoring stations

Countries	No. of Stations	No. on the Mekong River	No. on the Bassac River	No. on tributaries	Monitoring Frequency
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. Water quality monitoring stations in the Mekong and Bassac Rivers numbered in sequence from upstream to downstream and as monitored in 2013

Station No.	Name of station	Station ID	River	Country	Latitude	Longitude
1	Houa Khong	H010500	Mekong River	Lao PDR	21.5471	101.1598
2	Chaing Sean	H010501	Mekong River	Thailand	20.2731	100.0917
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	17.3983	104.8033
6	Savannakhet	H013401	Mekong River	Lao PDR	16.5583	104.7522
7	Khong Chiam	H013801	Mekong River	Thailand	15.3183	105.5000
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	Krom Samnor	H019807	Mekong River	Cambodia	11.0679	105.2086
15	Tan Chau	H019803	Mekong River	Viet Nam	10.9036	105.5206
16	My Thuan	H019804	Mekong River	Viet Nam	10.8044	105.2425
17	My Tho	H019805	Mekong River	Viet Nam	10.6039	104.9436
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	10.8253	105.3367
22	Can Tho	H039803	Bassac River	Viet Nam	10.7064	105.1272

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

- 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; and
- 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 LABORATORIES ANALYSES

2.3.1 Water Quality and Analytical 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 2013, 18 water quality parameters were measured by the MRC WQMN (Table 2-3). Of the 18 parameters measured in 2013, 12 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 (the wet season).

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

Analytical parameter	Recommended Analytical Methods
Temperature	2550-Temp/SM
pH	4500-H+/SM
Conductivity (Salinity)	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 (NH_4-N)	4500-NH4/SM
Total Nitrite and Nitrate (NO_{2-3-}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 (SO_4)	4500- SO_4 –E/SM
Chloride (Cl)	4500-Cl/SM

Table 2-3, in addition to providing a list of parameters measured by the MRC WQMN, also 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.

2.4 DATA ASSESSMENT

2.4.1 Descriptive Statistical Analysis

The maximum, average and minimum values of each water quality parameter were analysed for each monitoring station for 2013. 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.

2.4.2 Trends Analysis

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 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 2013. Trend analysis of water quality from 2000 to 2013 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; and
- Upper and lower extremes or the maximum and minimum values of the dataset (excluding outliers), respectively.

2.4.3 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; Krom 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 of 2005–2012 and 2013 for the station closest upstream and downstream of the national border, respectively. Box-and-whisker plots, using the statistical software package SPSS 16, 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.

2.4.4 Water Quality Indices

Another way to assess the water quality of 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 2006, the MRC Member Countries adopted three water quality indices (MRC, 2008). These indices have been used to express overall water quality of the Mekong River and its tributaries at specific locations and time based on several water quality parameters. The indices are:

- Water quality index for the protection of aquatic life (WQIal)
- Water quality index for human impact on water quality (WQIhi)
- Water quality index for agricultural use (WQIag), which is divided into three categories: (i) general irrigation, (ii) irrigation of paddy rice, (iii) livestock and poultry.

These indices were developed based on the reviews of scientific literature and statistical characteristics of available water quality data obtained through the MRC WQMN. The target values used for classifying water quality under different indices, for instance, were established as temporary measures based on a combination of target values established by international organizations and target values of some Member Countries. Additionally, the numbers and types of water quality parameters used for each index were based on the availability of data at the time the index was conceived.

Since the adoption of the Water Quality Indices in 2006, the MRC Member Countries have collaboratively adopted the Procedures for Water Quality (PWQ) with an objective of establishing "a cooperative framework for the maintenance of acceptable/good water quality to promote the sustainable development of the Mekong River Basin." With the adoption of the PWQ, Member Countries have also developed the Technical Guidelines for Implementation of the Procedures for Water Quality (TGWQ), which consist of five chapters. Chapter 1 and Chapter 2 of the TGWQ, which focus on the protection of human health and the protection of aquatic life, respectively, were finalized by the Member Countries in 2010. These two chapters call for the Member Countries to commence the monitoring of a number of direct and indirect impact parameters on human health and aquatic life. The chapters also provide target values for each direct and indirect impact parameter to protect human health and aquatic life. In addition to the finalization of the chapters, some Member Countries have developed and updated target values for a number of water quality parameters for different types of water use (e.g. drinking water, protection of aquatic life, recreation and contact, industrial discharge, etc.).

The review of the MRC Water Quality Indices was initiated in 2013 taking into account requirements under Chapters 1 and 2 of the TGWQ and available water quality guidelines of the Member Countries. Following the review, the Member Countries have agreed to adopt the following water quality indices, as tools for interpreting the results of the MRC WQMN data, turning the complex data into information that can be understood by the public:

- Water Quality Index for the Protection of Aquatic Life (WQIal).
- Water Quality Index for the Protection of Human Health with a focus on Human Acceptability (WQIha).
- Water Quality Index for Agricultural Use, which is divided into two categories: (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
NH_3 (mg/L)	0.1
DO (mg/L)	> 5
$NO_{2\text{-}3}$ – 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

2.4.4.1 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.

$$WQI = \frac{\sum_{i=1}^{n} p_i}{M} \times 10$$

- **Equation 2.1**

Where,

- "*pi*" is the points scored on sample day i. If each of the parameters listed in Table 2-4 meets its respective target value in Table 2-6, its corresponding weighting factor 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.

2.4.4.2 Water Quality Index for the Protection of Human Health – Human Health Acceptability Index

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 MRC Member Countries have agreed to include the 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 acceptability 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 biological oxygen demand are not included in the calculation of the rating score for human health acceptability index. The list of the approved parameters to be included in the calculation of the rating score for human health acceptability 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 – Human Acceptability 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**

Table 2 6. Parameters used for calculating the rating score of the Water Quality Index for the Protection of Human Health – Human Health Acceptability Index, together with their target values

Parameters	Target Values
pH	6 – 9
EC (mS/m)	< 150
NH_3 (mg/L)	0.5
DO (mg/L)	4
NO_{2-3} – N (mg/L)	5
COD (mg/L)	5
BOD (mg/L)[2]	4

[2] The MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life have been finalised by the MRC Technical B 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 – Human Health Acceptability Index. 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 Aquatic Life

Rating Score	Class	Description
95 ≤ WQI ≤100	A: High 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 level
45 ≤ WQI < 65	D: Poor Quality	Conditions often depart from desirable levels
WQI < 45	E: Very Poor Quality	Conditions usually depart from desirable levels

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[3]		
		None (Good)	Some (Fair)	Severe (Poor)
Electrical Conductivity				
General irrigation	mS/m	<70	70-300	>300
Paddy Rice	mS/m	<200	200-480	>480

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

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.

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

- **Equation 2.7**

2.4.4.3 Water Quality Index for Agricultural Use

Another index adopted by the MRC Member Countries as a mean 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.

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 in 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 Viet Nam has received ISO/IEC 17025-2005 certification. The certification was first gained in 2007 and was 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.

3. RESULTS AND DISCUSSIONS

3. RESULTS AND DISCUSSIONS

3.1 ANALYSIS OF WATER QUALITY

3.1.1 Descriptive Statistical Analysis

A comparison of the maximum, mean and minimum values of key water quality parameters monitored in stations along the Mekong and Bassac Rivers are presented in Table 3.1 and 3.2 below. These data are also assessed against the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life . As can be seen in the tables, exceedances of the 2013 water quality data were observed against both MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life.

Of the key water quality parameters measured for the Mekong River in 2013 (Table 3-1), four parameters had some or all measured values not complying with the MRC water quality guidelines. These included:

- A maximum pH value of 9.9 was recorded at Vientiane Water Quality Monitoring Station, Lao PDR. Based on the assessment of the 2013 water quality data, no station reported a pH value of lower than the lower limit of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life (pH of 6).
- Other than one data point recorded at My Tho Monitoring Station in Viet Nam (72.0 mS/m), all Electrical Conductivity (EC) levels were recorded to be less than the suggested lower limit of the water quality for the protection of human health of 70 mS/m. It should be noted, however, that the Mekong River mainstream is naturally a low-salinity river with the average electrical conductivity rarely exceeding 20 mS/m. High electrical conductivity can be observed in the Delta during high tide due to the intrusion of sea water, and had been recorded with a maximum value of 841.0 mS/m. In 2013, all samplings in the Delta, for both the Mekong River and the Bassac Rivers, were carried out during low tide which explains the low levels of electrical conductivity recorded.
- In 2013, dissolved oxygen (DO) levels were observed to be lower than the recommended MRC values for the protection of human health of 6 mg/L and for the protection of aquatic life of 5 mg/L. Of the 17 stations located in the Mekong River, 7 stations reported DO values of less than 6 mg/L on at least one occasion. These stations include Houa Khong, Luang Prabang, Vientiane and Pakse in Lao PDR, and Tan Chau, My Thuan, and My Tho in Viet Nam. Of the listed stations, Houa Khong and Luang Prabang recorded at

[4] The MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life have been finalised by the MRC Technical Body for Water Quality, but have not been officially adopted by the MRC Member Countries. The MRC Joint Committee, however, has recommended that these guidelines be used as part of the implementation of Chapters 1 and 2 of the Technical Guidelines for the Implementation of the Procedures for Water Quality.

least one DO value of less than 5 mg/L, the threshold value recommended by the MRC for the protection of aquatic life. Compared to historical DO data (1985 – 2012) from the same stations, mean dissolved oxygen concentration in the Mekong River in 2013 was the same as the mean level recorded from 1985 – 2012.

- Chemical oxygen demand (COD) concentration of eight stations in the Mekong River slightly exceeded the MRC Water Quality Guidelines for the Protection of Human Health of 5 mg/L. These stations were Houa Kong, Vientiane and Pakse in Lao PDR; Chiang Saen, Nakhone Phanom and Khong Chiam in Thailand, and My Thuan and My Tho in Viet Nam. In 2012, a similar number of stations reported COD concentration that exceeded the MRC Water Quality Guidelines for the Protection of Human Health. Mean COD concentration in the Mekong River for 2013 was 2.5 mg/L compared to a historical mean COD concentration of 2.2 mg/L between 1985 and 2012.

For the Bassac River, similar noncompliance was observed for pH, EC, DO and COD. In particular, the following observations can be made regarding the noncompliance parameters:

- A minimum pH value of 3.8 was recorded in Koh Khel Water Quality Monitoring Station, Cambodia. The mean pH value for the Bassac River was recorded to be about 6.9, which was slightly lower than the mean pH value observed from 1985 to 2012. Based on the 2013 water quality data, no station reported a pH value higher than the upper limit of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life (pH of 9).
- All EC values recorded in 2013 were outside the range of the MRC Water Quality Guidelines for the Protection of Human Health (70 – 150 mS/m). Similar to the Mekong River, the Bassac River is naturally a low-salinity river with the average electrical conductivity rarely exceeding 30 mS/m during the low tide. In 2013, the maximum EC value was recorded at 24.4 mS/m. Historically, high electrical conductivity values have been recorded in the Delta during high tide due to the intrusion of sea water. In 2013, all samplings in the Delta, for both the Mekong and Bassac Rivers, were carried out during low tide, which explains the low levels of electrical conductivity recorded.
- The mean DO concentration for stations along the Bassac River remained good with a value of 6.6 mg/L, but slightly decreased when compared to the mean DO concentration recorded in 2012 (7 mg/L). However, when compared to the historical mean from 1985 to 2012 (6.4 mg/L), the 2013 mean DO concentration improved slightly. Based on the results of the 2013 water quality monitoring, all five stations recorded DO concentrations of less than the recommended guidelines for the protection of human health (6 mg/L) at one time or more. No station reported DO concentrations of less than 5 mg/L, the value recommended for the protection of aquatic life in 2013.

Table 3-1. Comparison of water quality data in the Mekong River between 1985-2012 and 2013 (orange colour marks non-compliance with WQGH or WQGA).

Parameters	Unit	Water Quality Guidelines		1985-2012				2013			
		Protection of Human Health (WQCH)	Protection of Aquatic Life (WQGA)	Max	Mean	Min	St Dev	Max	Mean	Min	St Dev
Temp	°C	Natural	Natural	38.0	27.0	13.0	3.1	32.2	27.5	19.9	2.8
pH	-	6 – 9	6 – 9	9.7	7.5	3.8	0.5	9.9	7.1	6.2	0.6
TSS	mg/L	-	-	5716	163	0	282	802	96	2	114
EC	mS/m	70 - 150	-	841	21	1	30	72	19	8	7
NO_{3-2}-N	mg/L	5	5	1.4	0.23	0.00	0.16	1.08	0.27	0.01	0.21
NH_4-N	mg/L	-	-	3.00	0.05	0.00	0.11	0.53	0.06	0.00	0.07
TOT-N	mg/L	-	-	4.9	0.59	0.00	0.39	2.96	0.51	0.01	0.37
TOT-P	mg/L	-	-	2.1	0.09	0.00	0.11	0.69	0.14	0.00	0.10
DO	mg/L	≥ 6	> 5	13.9	7.3	2.3	1.0	10.6	7.3	4.9	1.3
COD	mg/L	5	-	16.4	2.2	0.0	1.7	10.7	2.5	0.2	1.9

Table 3-2. Comparison of water quality data in the Bassac River between 1985-2012 and 2013 (orange colour marks non-compliance with WQGH or WQGA).

Parameters	Unit	Water Quality Guidelines		1985-2012				2013			
		Protection of Human Health (WQCH)	Protection of Aquatic Life (WQGA)	Max	Mean	Min	St Dev	Max	Mean	Min	St Dev
Temp	°C	Natural	Natural	34.0	28.9	23.5	1.9	32.7	29.3	25.4	1.8
pH	-	6 -- 9	6 – 9	9.4	7.2	6.1	0.4	7.5	6.9	3.8	0.5
TSS	mg/L	-	-	939	80	0	87	230	58	6	48
EC	mS/m	70 - 150	-	1050	21	1	62	24	14	7	5
NO_{3-2}-N	mg/L	5	5	3.02	0.25	0.00	0.23	1.03	0.31	0.03	0.22
NH_4-N	mg/L	-	-	3.04	0.07	0.00	0.16	0.55	0.10	0.00	0.11
TOT-N	mg/L	-	-	4.03	0.76	0.03	0.45	1.64	0.68	0.17	0.33
TOT-P	mg/L	-	-	1.78	0.13	0.00	0.14	0.47	0.16	0.02	0.08
DO	mg/L	≥ 6	> 5	12.3	6.4	1.9	1.0	9.8	6.6	5.1	1.1
COD	mg/L	5	-	13.1	3.4	0.0	1.9	5.3	2.8	0.8	1.1

- Despite all five stations recording non-compliance of DO concentration at least once during the monitoring period in 2013, COD levels above the guidelines were recorded at only two stations (Takhmao and Koh Khel). The mean COD concentration in the Bassac River in 2013 was 2.8 mg/L compared to the historical mean value of 3.4 mg/L from 1985 to 2012. The maximum COD concentration of 5.2 mg/L was recorded at Koh Khel, Cambodia.

3.1.2 Individual Trends Analysis

3.1.2.1 pH

In aquatic ecosystems, pH can affect the dynamics of the water body, influencing the physiology of aquatic organisms. For example, at 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. 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 2013, 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 water quality guidelines for pH levels in the Mekong River and its tributaries to protect human health and aquatic life, with an 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 water quality guidelines (Table 3-1), the results of the 2013 monitoring revealed that, other than one pH measurement of 9.9 recorded at Luang Prabang, the pH values along the Mekong River were within the water quality guideline for pH (pH values of 6 to 9 for both the protection of human health and the protection of aquatic life). In 2013, the lowest pH measurement was observed at Chiang Sean monitoring station (pH = 6.2) while the highest pH measurement was observed at Luang Prabang monitoring station (pH = 9.9).

The spatial trend for pH in the Mekong and Bassac Rivers is shown in Figure 3-1. As can be seen in the figure, pH values in the upper part of the Lower Mekong River fluctuate, with pH values at all mainstream stations monitored in the Lao PDR (Stations 1 – Houa Khong, 3 – Luang Prabang, 4 - Vientiane, 6 - Savannakhet and 8 - Pakse) higher than the neutral level (pH = 7), while pH values recorded in the Thai part of the Mekong River (Stations 2 – Chiang Sean, 5 – Nakhon Phanom and 7 – Khong Chiam) were lower than the neutral level. This could indicate, for example, an issue with calibration of monitoring equipment. The pH levels of the Mekong and Bassac Rivers in Cambodia and Viet Nam were relatively constant in 2013, with all monitoring stations recording median pH values just above or below 7.

Figure 3.1. Spatial variation in pH levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2013 (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 Human Health and the Protection of Aquatic Life)

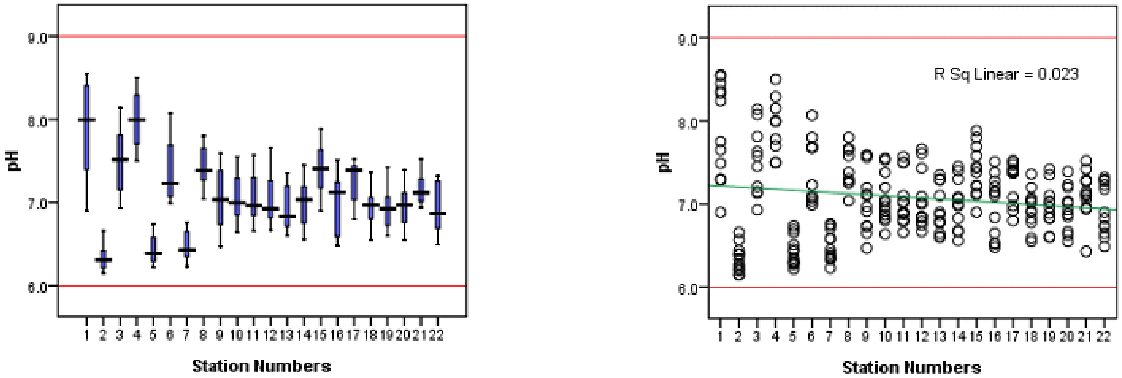
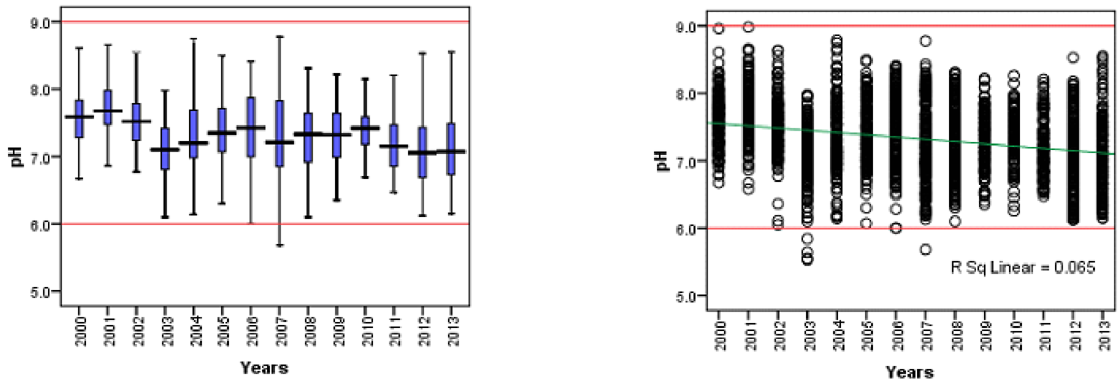


Figure 3.2. Temporal variation in pH levels in the Mekong River from 2000 - 2013 (the horizontal lines at 6.0 and 9.0 represent lower and upper pH limits of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life)



Results of the temporal analysis of pH data from 2002 to 2013 are shown in Figure 3-2. Based on the visual inspection of Figure 3.1, it can be seen that the overall pH levels decrease slightly from year to year since 2000. This is possibly a reflection of increased industrial development and urbanisation in the Lower Mekong River Basin, which has led to increased industrial and municipal effluents lowering the pH of the Mekong River.

3.1.2.2 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 of the Mekong River.

Spatial and temporal trends for electrical conductivity in the Mekong and Bassac Rivers are illustrated in Figures 3.3 and 3.4, respectively. As can be seen in Figure 3.4, the Mekong and Bassac Rivers can be generally characterised as rivers with low conductivity values, with average historical values of about 20.8 mS/m (Tables 3-1 and 3-2)[5]. In 2013, electrical conductivities

Figure 3.3. Spatial variation in Electrical Conductivity levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2013

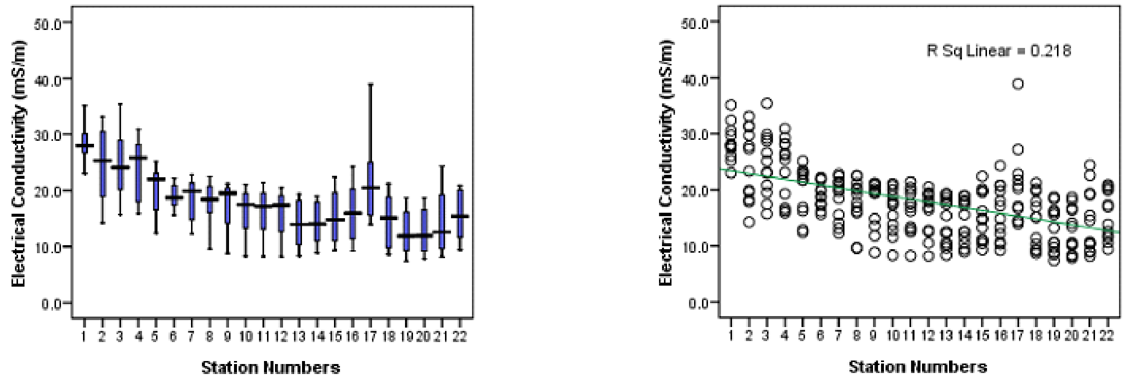
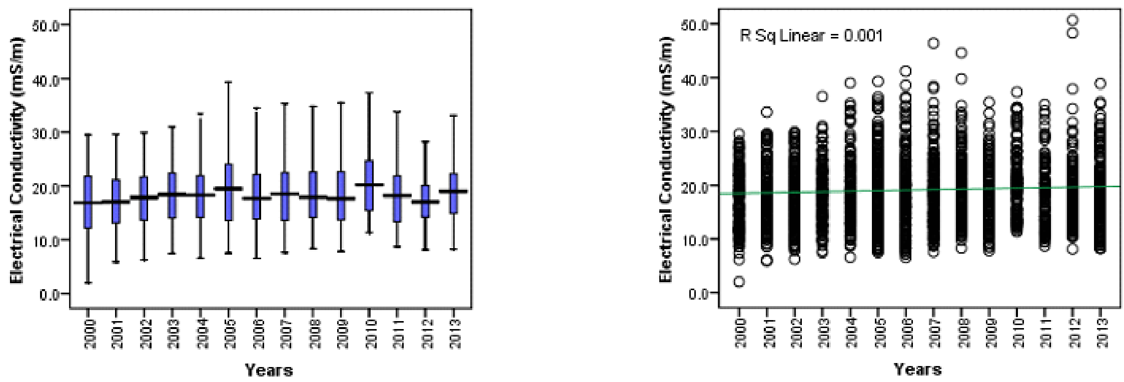


Figure 3.4. Temporal variation in Electrical Conductivity levels in the Mekong River as observed from 2000 to 2013



for both rivers continued to be relatively low, with values ranging from 8.2 to 72.0 mS/m for the Mekong River (Table 3.1) and from 7.4 to 24.4 mS/m for the Bassac River (Table 3-2).

Spatially, conductivity levels in the Mekong River in 2013 were higher in stations located in the upper part of the Lower Mekong River, while more variable in the station located in the Delta and closest to the East Sea. For example, Houa Khong Station (1), the uppermost station of the MRC WQMN, reported electrical conductivity values ranging from 26.0 to 35.1 mS/m with an average value of 28.4 mS/m while My Tho Station (17) – the last station of the Mekong River before the river enters the East Sea - reported values ranging from 13.9 to 72.0 mS/m with an average value of 25.0 mS/m. It should be noted, however, that water quality monitoring in the Mekong Delta was

[5] 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.

done during low tide to minimise sea water intrusion. During high tide, the stations in the Mekong Delta would have elevated electrical conductivity values due to sea water intrusion.

Compared to the MRC Water Quality Guidelines for the Protection of Human Health, other than the maximum value (72.0 mS/m) recorded at My Tho (17), electrical conductivity values observed in 2013 fell outside the recommended range of 70 to 150 mS/m. This, however, should not be seen as an issue since historically the electrical conductivity values of the Mekong River are naturally low, as can be seen in Figure 3.4 where electrical conductivity values rarely exceeded 50 mS/m.

3.1.2.3 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 column , but currently provides an indication of long-term trends in sediment content in the Mekong River.

In 2013, the TSS concentrations observed along the Mekong River were highly variable, ranging from 2.4 to 802.0 mg/L. The average TSS concentration was about 95.9 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 6.0 to 230.0 mg/L, with an average value of 58.3 mg/L (Table 3-2).

For both rivers, the lowest TSS concentrations were observed during the dry season (November to April). Along the Mekong River, the average dry season TSS concentration was recorded to be about 48.4 mg/L. The highest dry season concentration for TSS was recorded to be 616.0 mg/L at Vientiane Water Quality Monitoring Station (4) on 25 December 2012 while the lowest concentration was recorded to be 2.4 mg/L at Chiang Sean Water Quality Monitoring Station (6) in March 2013.

Along the Bassac River, dry season TSS concentrations ranged from 6.0 to 94.0 mg/L, with the highest dry season concentration recorded at Chau Doc (21) in February 2013 and the lowest concentration recorded at Koh Khel (19) in April and November 2013. The average dry season TSS concentration for the Bassac River was recorded to be about 38.0 mg/L.

During the wet season, the average concentration for the Mekong River was recorded at about 143.3 mg/L, with values ranging from 6.0 to 802.0 mg/L. The lowest wet

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

season TSS concentration was recorded in Neak Loung (12) in May 2013, while the highest concentration was recorded at Vientiane (4) in July 2013. With values ranging from 10.0 to 230.0 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 Koh Thom (20) in September, while the lowest concentration was recorded at Koh Khel (19) in May 2013.

Spatial variation in TSS along the Mekong and Bassac Rivers in 2013 is shown in Figure 3.5. As can be seen in the figure, TSS concentrations were highly variable in the Mekong River section between Houa Khong (1) and Krom Samnor (14). Of these 14 stations, Vientiane Water Quality Monitoring Station recorded the most variable concentrations for TSS, ranging from 34.0 to 802.0 mg/L.

The temporal analysis of data from 2000 to 2013 suggests that TSS levels in the Mekong River remain relatively unchanged since 2000 (Figure 3.6). However, when compared to historical records dating back from 1985 (Figure 3.7), TSS concentration shows a decreasing trend, with the

Figure 3.5. Spatial variation in TSS concentrations along the Mekong River (1-17) and Bassac River (18-22) as observed in 2013

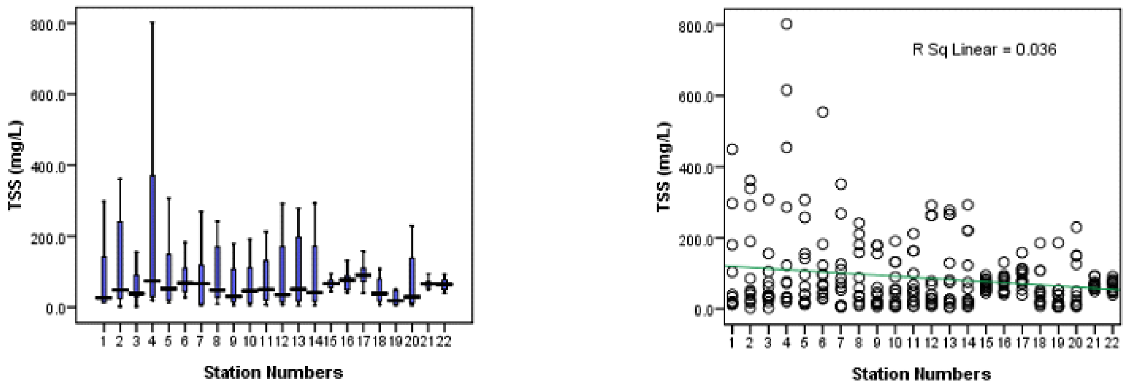


Figure 3.6. Temporal variation in TSS concentrations along the Mekong River as observed from 2000 to 2013

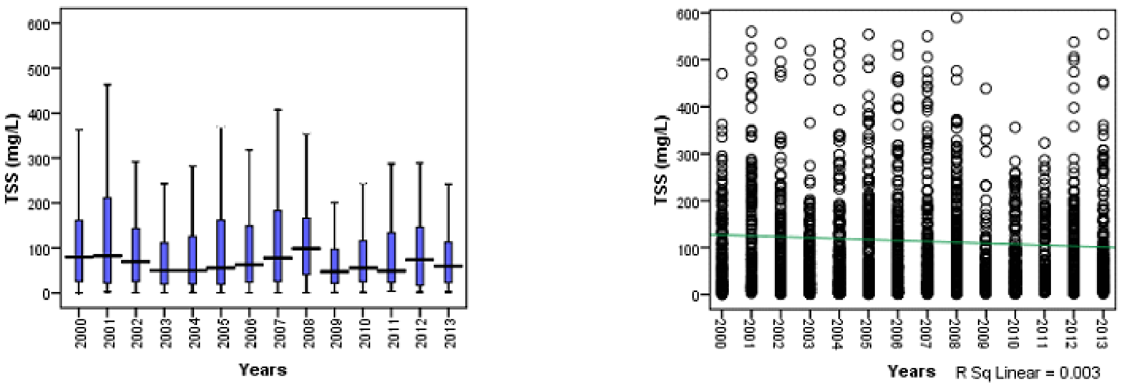


Figure 3.7. Temporal variation in TSS concentrations along the Mekong River as observed from 1985 to 2013

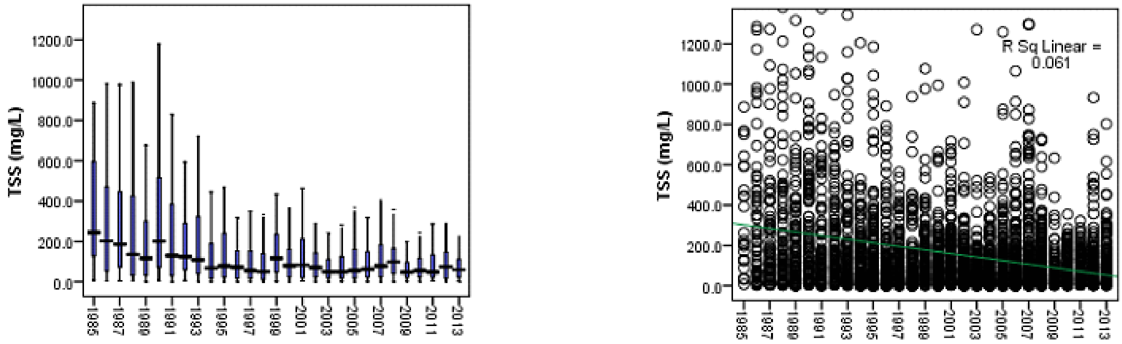
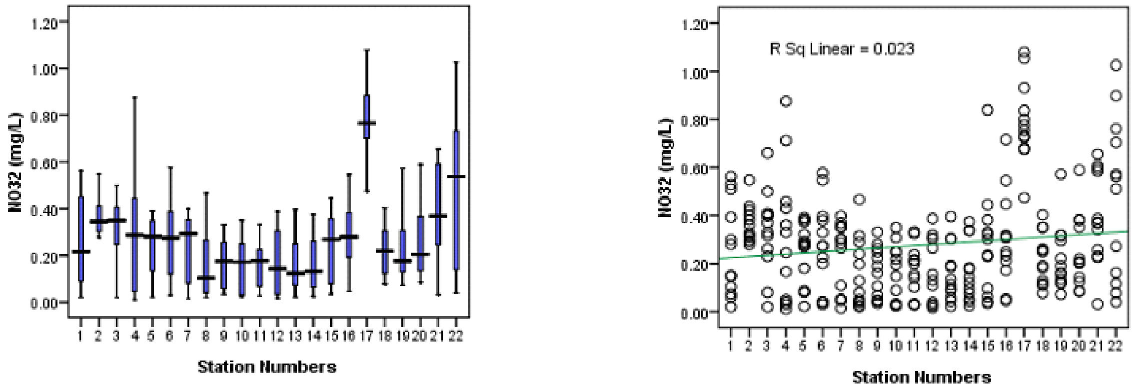


Figure 3.8. Spatial variation in nitrate-nitrite concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2013



greatest reduction observed between 1985 and 1991. The average TSS concentration for 2013 was 95.9 mg/L, compared to the average value of 162.7 mg/L from 1985-2012 (Table 3-1).

3.1.2.4 Nutrients

The MRC WQMN designated laboratories continued to monitor concentrations of nitrite-nitrate, ammonium and total phosphorus as part of nutrient monitoring in 2013. 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 2013 nitrate-nitrite data show a similar pattern to that of the 2012 data, as a spatial analysis of water quality data revealed that nitrate-nitrite concentrations were highly variable in a number of stations located in the upper-most part of the Mekong River (Houa Khong (1), Luang Prabang (3), and Vientiane (4)) and a number of stations located in the Mekong Delta (My Tho (17), Chau Doc (21), and Can Tho (22)). At these stations, the highest concentrations of nitrate-nitrite were observed during the onset of the monsoon season (May and June). Slight elevation of nitrate-nitrite concentrations was recorded at My Tho (17) in the Mekong River and Can Tho (22) in the Bassac River. However, the measured val-

Figure 3.9. Temporal variation in nitrate-nitrite concentrations in the Mekong River as observed from 2000 to 2013

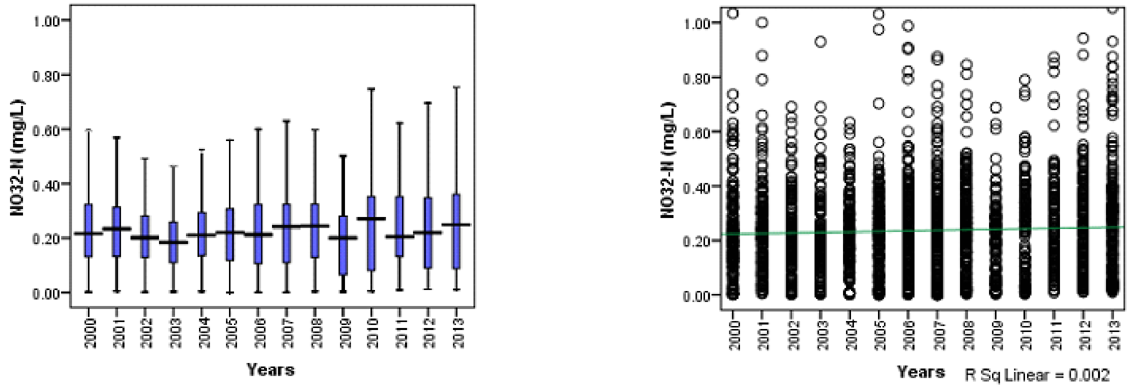
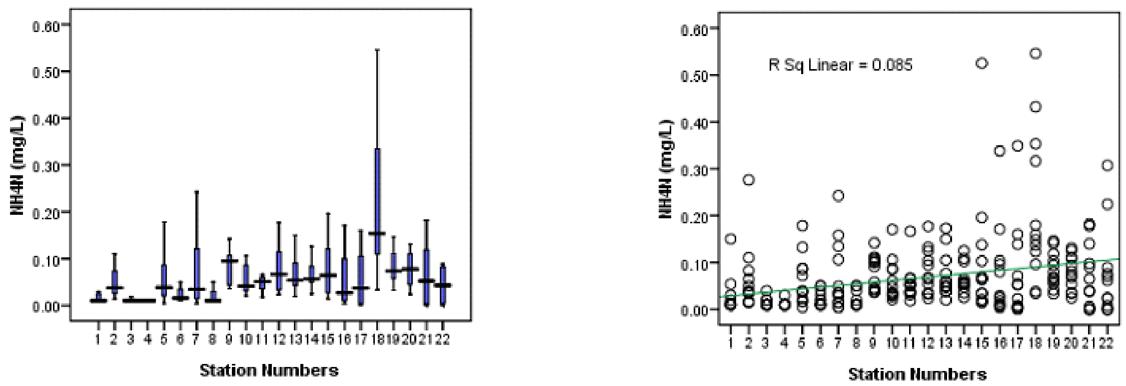


Figure 3.10. Figure 3.10: Spatial variation in ammonium concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2013



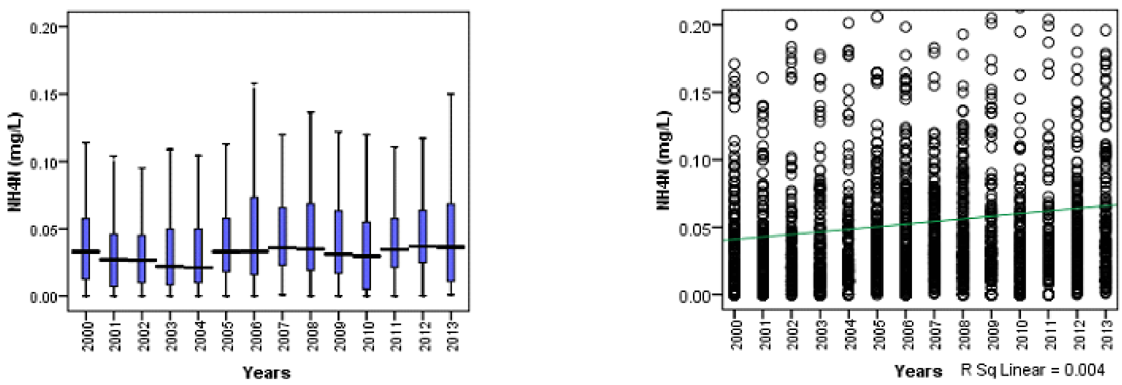
ues were well below the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (5 mg/L).

Temporal analysis of nitrate-nitrite concentration from 2000 to 2013 reveals that nitrate-nitrite concentrations in the Mekong River remained relatively constant (Figure 3.9). 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 2013 was recorded to be about 0.27 mg/L.

Other than the elevated level observed at Takhmao Monitoring Station (18), ammonium concentrations remained relatively low in 2013 (Figure 3.10). The highest concentrations were measured at Takhmao (18) which is located on the Cambodian side of the Bassac River. At Takhmao, ammonium levels were highly variable with values (measured as N) ranging from 0.03 to 0.55 mg/L. It is unclear what caused elevated ammonium levels at Takhmao, but the elevation does not seem to be seasonally based as all but two measured values exceeded the threshold value used for calculating Water Quality Index for Human Impact (0.05 mg/L) (Table 2-4).

Temporal analysis of data from 2000 to 2013 for the Mekong River reveals that ammonium concentrations remain relatively

Figure 3.11. Temporal variation in ammonium concentrations in the Mekong River as observed from 2000 to 2013



constant (Figure 3.11), whereas the average ammonium concentration in the Mekong River slightly increased from about 0.04 mg/L in 2000 to about 0.06 mg/L in 2013.

To examine whether the ammonium data observed at Takhmao (18) in 2013 was abnormal, a temporal analysis of ammonium data from 1995 (the beginning of monitoring at this location) to 2013 was carried out. The results of this analysis are shown in Figure 3.12. As can be seen in the figure, ammonium concentrations recorded at Takhmao Monitoring Station have increased steadily since the start of the monitoring, where the average ammonium concentration was reported to be about 0.04 mg/L. In 2013, the average ammonium concentration recorded at Takhmao Monitoring Station was about 0.21 mg/L. Based on the available data at Takhmao, the maximum annual average concentration was recorded in 2012 at about 0.53 mg/L, with the maximum recorded value reaching 1.13 mg/L in November 2012 (Figure 3.12). One-way ANOVA analysis was carried out to compare the means of annual data, and the result of this analysis suggests that the difference observed in the means is statistically significant with a P value of less than 0.001. Takhmao Monitoring Station is located directly downstream of Phnom Penh on the Bassac River and likely has been subjected to significantly increased discharges over time from industrial and domestic sources that could explain the observed increase in ammonium concentrations.

Spatial variation of total phosphorus in 2013 was high, especially for stations located in Cambodia and Viet Nam (Figure 3.13). In the Mekong River (1-17), the total phosphorus concentrations also show a slightly increasing trend from upstream to downstream, with generally higher levels recorded in My Tho (17). In 2013, the lowest concentrations of total phosphorus were generally found in upstream stations, particularly on the Lao side of the river, where the concentrations were less than 0.01 mg/L.

On the Bassac side of the river, concentrations of total phosphorus were less variable, with values ranging from 0.02 to 0.47

Figure 3.12. Temporal variation of ammonium concentration at Takhmao Monitoring Station

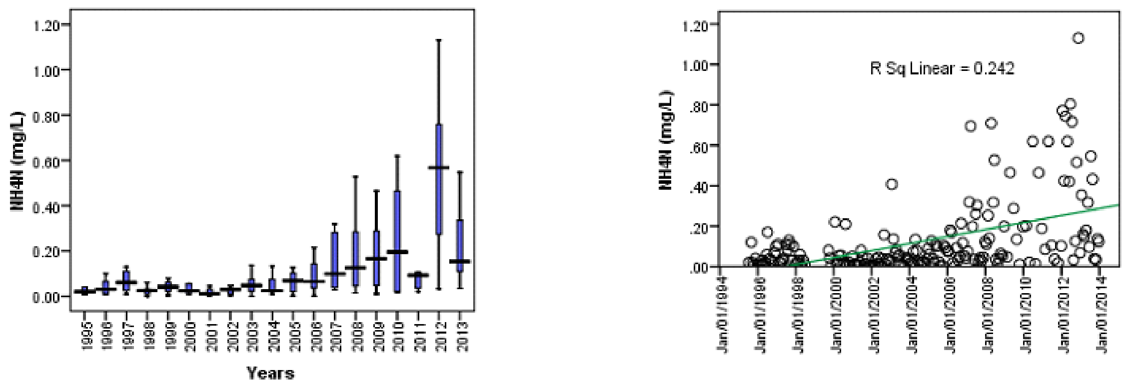
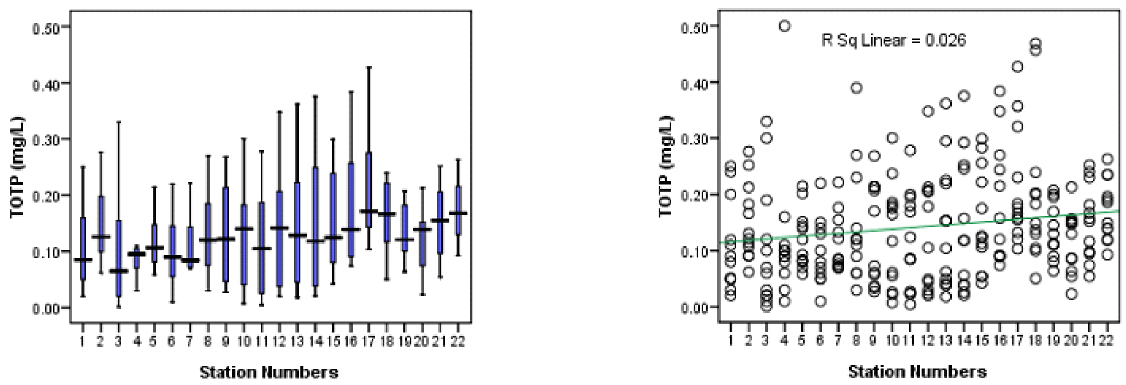


Figure 3.13. Spatial variation in total phosphorus concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2012



mg/L. The maximum concentration was recorded in Takhmao (18) in August 2013 while the minimum concentration was recorded in Koh Thom (20) in March 2013.

Between 2000 and 2013, total phosphorus concentrations in the Mekong River increased slightly, from mean concentration of about 0.058 mg/L in 2000 to about 0.14 mg/L in 2013 (Figure 3.14). One-way ANOVA analysis of means reveals that the increase is statistically significant with a P value of less than 0.001. A result of increased human activities, such as agricultural runoff and municipal wastewater discharge in the downstream part of the basin, was likely the reason for the increasing trend.

3.1.2.5 Dissolved oxygen and chemical oxygen demand

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. 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).

Figure 3.14. Temporal variation in total phosphorus concentrations in the Mekong River as observed from 2000 to 2013

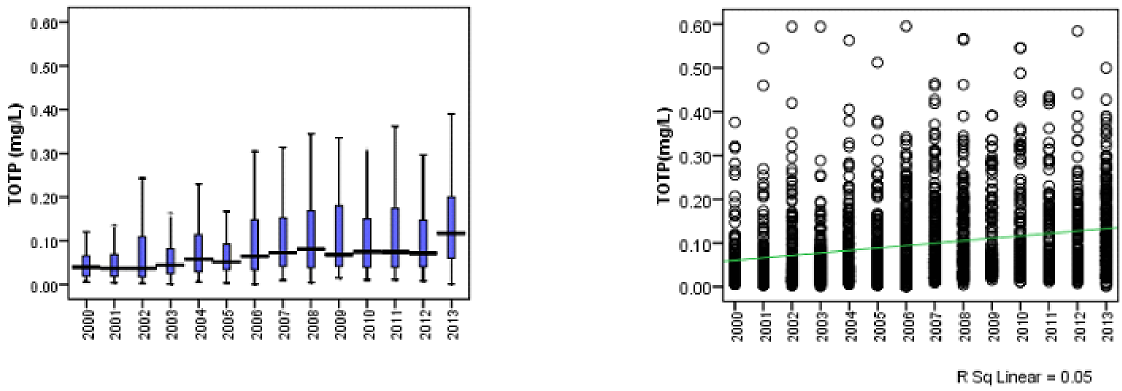
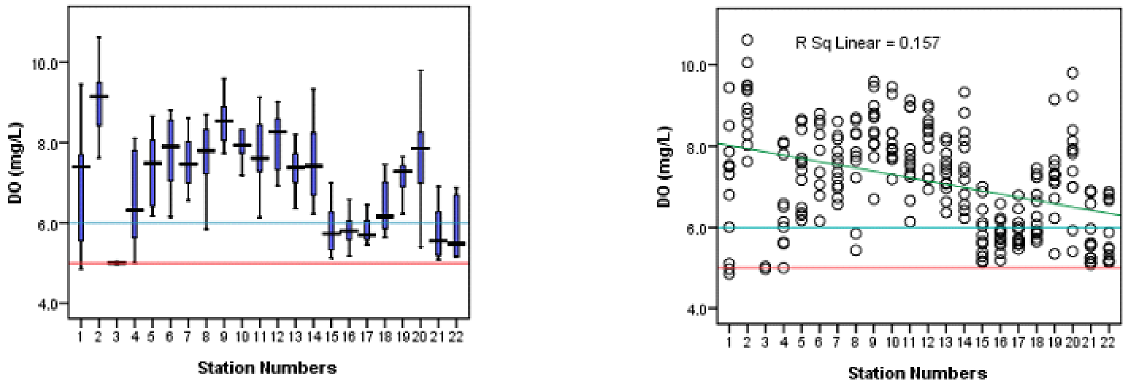


Figure 3.15. Spatial variation in dissolved oxygen (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2013 (horizontal lines at 5 mg/L and 6 mg/L represent values for the MRC Water Quality Guidelines for the Protection of Aquatic Life and the Protection of Human Health, respectively)



The 2013 dissolved oxygen data was compared with the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. In 2013, 13 water quality monitoring stations in the Mekong and Bassac Rivers recorded dissolved oxygen levels below the MRC Water Quality Guidelines for the Protection of Human Health (WQGH) (≥ 6mg/L). Of these 13 stations, 5 stations are located in Lao PDR while the other stations are located in the Delta (15-22). In comparison, no station in Lao PDR recorded a dissolved oxygen value of less than 6 mg/L in 2012.

In addition to violating the MRC WQGH, three of Lao PDR's five mainstream stations (Houa Khong (1), Luang Prabang (3), and Vientiane (4),) 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. Other than the five stations in Lao PDR, no other station recorded dissolved oxygen level lower than 5 mg/L in 2013.

In Houa Khong (1), the dissolved oxygen levels were highly variable in 2013 with values ranging from 4.9 to 9.4 mg/L. Of the

Figure 3.16. Temporal variation in dissolved oxygen (mg/L) in the Mekong River as recorded from 2000 to 2013 (horizontal lines at 5 mg/L and 6 mg/L represent values for the MRC Water Quality Guidelines for the Protection of Aquatic Life and the Protection of Human Health, respectively)

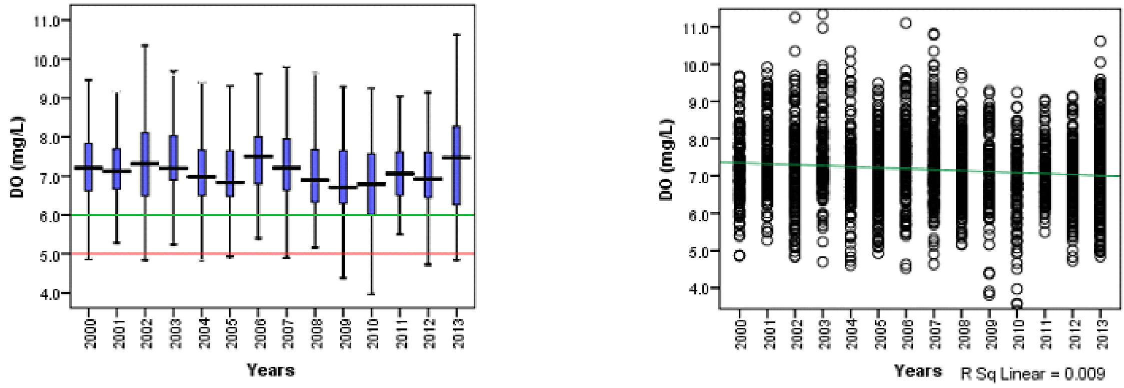
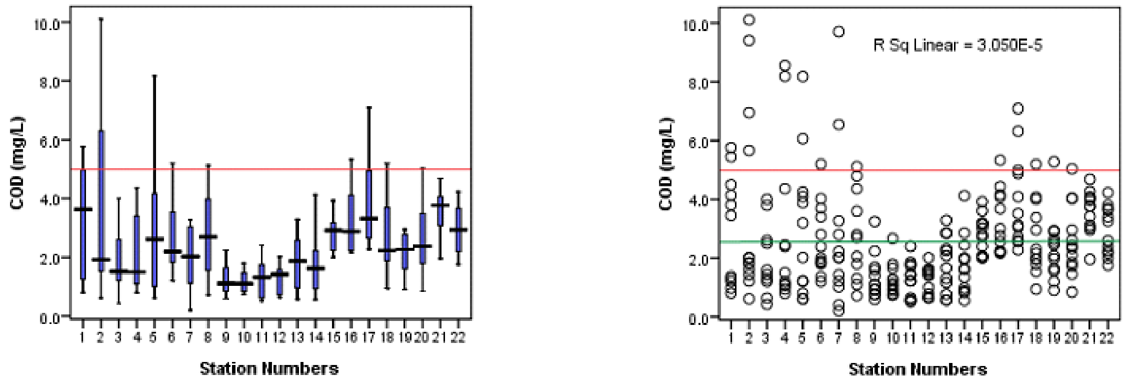


Figure 3.17. Spatial variation in COD (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2013 (horizontal line at 5 mg/L represents threshold values for the MRC Water Quality Guidelines for the Protection of Human Health)

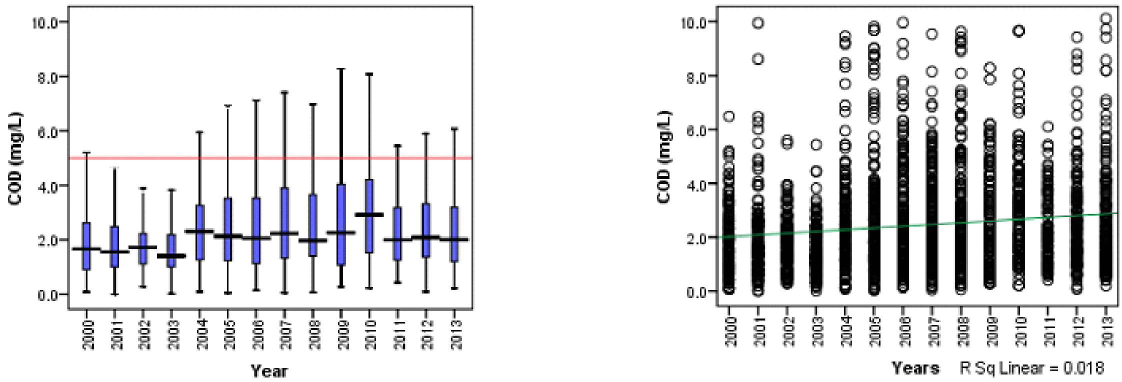


total data collected at Houa Khong, 25% fell below the MRC WQGH of 6 mg/L while 17% fell below the MRC WQGA of 5 mg/L.

In Luang Prabang (3), all dissolved oxygen values were recorded to be lower than the MRC WQGH of 6 mg/L which may be a reflection of faulty equipment or systematic error in the way dissolved oxygen was measured. In comparison, all dissolved oxygen values measured in 2012 at Luang Prabang were well above the MRC WQGH, and with a minimum value of 7.3 mg/L. Further investigation will need to be carried out to identify potential causes of the non-compliance.

The analysis of the spatial variation of 2013 dissolved oxygen data along the mainstream reveals that on average dissolved oxygen concentrations tended to be higher in the middle section of the Mekong River (Figure 3.15). In 2013, the highest dissolved oxygen recording was observed at Chiang Sean monitoring station (10.6 mg/L) while the lowest was observed at Luang Prabang monitoring station (4.9 mg/L).

Figure 3.18. Temporal variation in COD (mg/L) in the Mekong River as recorded from 2000 to 2013 (the horizontal line at 5 mg/L represents the threshold values for the MRC Water Quality Guidelines for the Protection of Human Health)



A temporal analysis of dissolved oxygen in the Mekong River from 2000 to 2013 reveals that dissolved oxygen concentrations in the mainstream did not change significantly during the time period. Based on the visual inspection of Figure 3.16, no difference in the median and mean values of dissolved oxygen between 2000 and 2013 was observed.

Dissolved oxygen levels in water are influenced by many factors. Among the most important is organic matter accompanying industrial and municipal waste water effluents. The direct discharge of these contaminated effluents into natural water bodies can cause depletion of dissolved oxygen, leading to the increased mortality of aquatic organisms. The amount of oxygen needed to oxidise the organic and inorganic material is called Chemical Oxygen Demand (COD). Under the MRC Water Quality Monitoring Network, COD is monitored in parallel with dissolved oxygen.

Figure 3.17 shows spatial variations in COD along the Mekong and Bassac Rivers in 2013. The spatial variations observed for COD were high for certain stations, including Chiang Sean (2) and Nakhon Phanom (5). At Chiang Sean monitoring station, COD concentrations varied from 0.6 to 10.1 mg/L, with the mean concentration of about 3.7 mg/L. Similarly, at Nakhon Phanom, COD concentrations varied from 0.6 to 8.2 mg/L, with the mean concentration of about 3.0 mg/L.

As can be seen in Figure 3.17, 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). COD data for 2013 also reveal that 12 water quality monitoring stations in the Mekong and Bassac Rivers recorded COD levels above the MRC Water Quality Guidelines for the Protection of Human Health (WQGH) (5 mg/L). In comparison, the analysis of 2012 COD data reveals that only eight water quality monitoring stations reported COD values higher than the threshold value of the MRC WQGH (5 mg/L). No COD threshold value has been set for the MRC Water Quality Guidelines for the Protection of Aquatic Life (WQGA).

Figure 3.18 reveals that COD concentrations in the Mekong River remained relatively constant from 2000 to 2013. 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 2013.

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. 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.

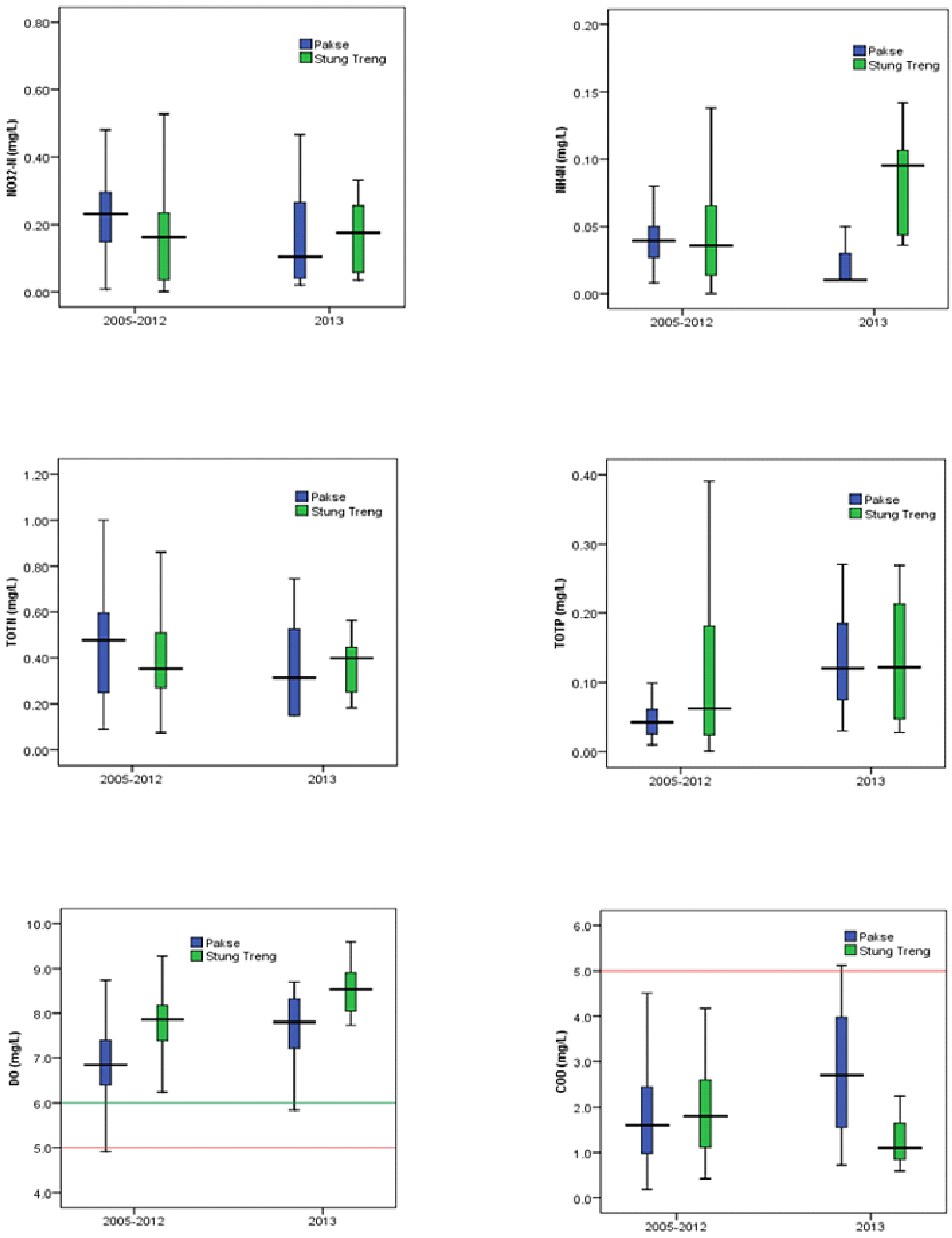
5. Cambodia/Viet Nam – Both the Mekong and the Bassac Rivers have stations that can be used to capture transboundary effects on water quality. On the Mekong side, Krom Samnor station in Cambodia and Tan Chau in Viet Nam are located not too far from the Cambodian/Vietnamese border. Similarly, Koh Thom 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 was carried out to examine potential transboundary water quality issues of 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 3.19 provides a summary of the comparison of 2013 water quality between the two stations. As can been seen in the figure, generally higher concentrations

Figure 3.19. Comparisons of water quality data at Pakse and Stung Treng (the horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life)



of nitrate-nitrite, ammonium, and total nitrogen were observed in Stung Treng than at Pakse. These conditions indicate that transboundary water quality issues associated with these parameters might be of potential concern. In comparison, the 2012 water quality data revealed a completely opposite condition where generally higher concentration of nitrate-nitrite, ammonium and total nitrogen were observed in Pakse than at Stung Treng.

Independent t-tests were carried out to determine whether the differences observed between the two stations for nitrate-nitrite, ammonium, and total nitrogen were statistically significant. Based on the results of the analysis, it can be concluded that, while the concentrations of nitrate-nitrite and total nitrogen tends to be higher in Stung Treng than in Pakse, independent t-tests failed to reveal any statistically significant difference between the mean concentrations of the two stations for both parameters, with P values of 0.87 and 0.98, respectively, for nitrate-nitrite and total nitrogen.

On the other hand, an independent t-test reveals that the difference between mean concentrations of ammonium at Pakse (M = 0.02 mg/L, Std. = 0.005) and Stung Treng (M = 0.08 mg/L, Std. = 0.01) was statistically significant with a P value of less than 0.001. It should be noted, however, that despite an indication of potential transboundary water quality issues associated with ammonium, the ammonium levels recorded in 2013 at both stations were still too low to impair water quality of the Mekong River.

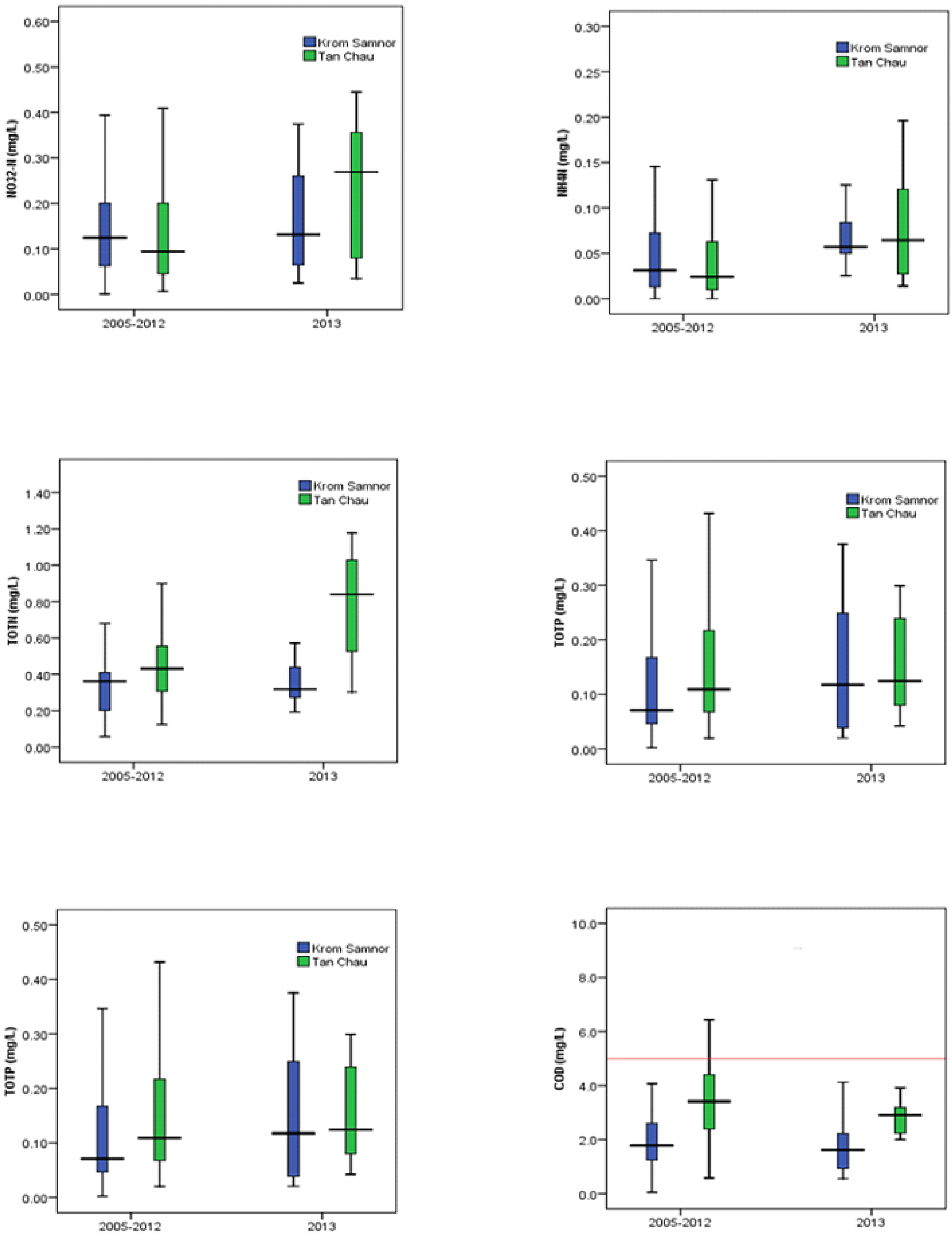
Unlike conditions observed for nitrate-nitrite, ammonium and total nitrogen, concentrations of chemical oxygen demand were slightly higher at Pakse than at Stung Treng, in 2013, which could indicate that that there is no need to be concerned about transboundary water quality associated with COD. The average concentration of COD at Stung Treng was recorded to be about 1.4 mg/L compared to 2.7 mg/L recorded at Pakse. An independent t-test reveals a statistically significant difference between the mean concentrations of total phosphorus at Pakse (M = 2.7 mg/L, Std = 0.46) and Stung Treng (M = 1.4 mg/L, Std = 0.22), with a P value of 0.011.

Dissolved oxygen levels observed at the two stations show a completely different picture to that observed for COD, with higher concentration generally observed at Stung Treng than Pakse. This further indicates that transboundary water quality associated with COD was of no concern in 2013. An independent t-test reveals a statistically significant difference between the mean DO concentrations at Pakse (M = 7.6 mg/L, Std. = 0.35) and Stung Treng (M = 8.5 mg/L, Std. = 0.23), with a P value of 0.042

3.2.2 Krom Samnor VS. Tan Chau

Krom Samnor and Tan Chau monitoring stations are located on the Mekong River, with Krom Samnor being on the Cambodian side of the Mekong River and Tan Chau being on the Vietnamese side. To assess potential transboundary water quality issues at these two stations, a comparison was made on a number of key water quality

Figure 3.20. Comparisons of water quality data at Krom Samnor and Tan Chau (horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life)



parameters, including nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen and chemical oxygen demand. The outcomes of these analyses are illustrated in Figure 3.20.

With the exception of total phosphorus levels, water quality of the Mekong River is more degraded in Tan Chau than in Krom Samnor, which may be a reflection of transboundary water quality issues in relation to these parameters (nitrate-nitrite, ammonium, total nitrogen, and COD). For instance, in 2013, generally higher levels of nitrate-nitrite, ammonium, total nitrogen and chemical oxygen demand concentrations were observed at Tan Chau than at Krom Samnor. Statistically, however, independent t-tests reveal the only significant difference to be total nitrogen concentrations and chemical oxygen demand concentrations at the two stations. For total nitrogen, an independent t-test reveals that the difference in the mean concentrations for Krom Samnor (M = 0.35 mg/L, Std. = 0.12) and Tan Chau (M = 0.79 mg/L, Std. = 0.31) was statistically significant with a P value of less than 0.001.

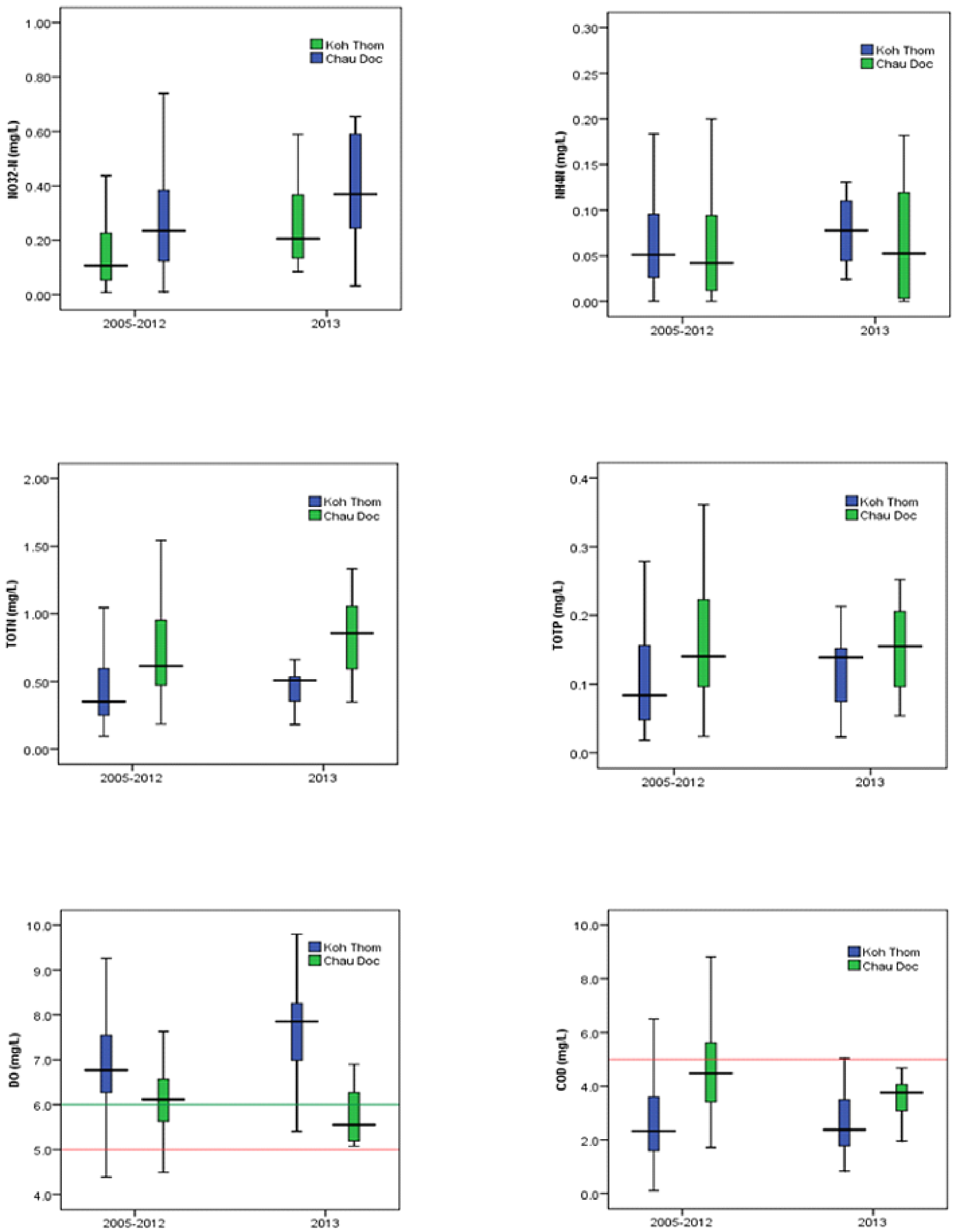
Similarly, an independent t-test reveals that the difference in the mean concentrations of COD at Krom Samnor (M = 1.8 mg/L, Std = 0.11) and Tan Chau (M = 2.8 mg/L, Std = 0.62) was statistically significant, with a P value of 0.003.

With a P value of 0.14, independent t-tests failed to reveal a statistically significant difference between the mean concentrations of nitrate-nitrite at Krom Samnor (M = 0.16 mg/L, Std = 0.12) and Tan Chau (M = 0.28 mg/L, Std = 0.23). Independent t-tests also failed to show any significant difference between the mean concentrations of ammonium at Krom Samnor (M = 0.07 mg/L, Std = 0.03) and Tan Chau (M = 0.11 mg/L, Std = 0.14) with a P value of 0.34. While concentrations of these parameters were higher in the downstream station compared to the upstream one, it is important to note that only total nitrogen and COD significantly differed between the two stations. However, when comparing the mean COD concentrations of the two stations (1.8 mg/L for Krom Samnor and 2.8 mg/L for Tan Chau) to the MRC WQGH (5 mg/L), it can be seen that the mean concentrations were still lower than the guideline, which is an indicator of no transboundary issue.

Elevated chemical oxygen demand, total nitrogen and total phosphorus levels in surface water can deplete dissolved oxygen which is vital for aquatic life. However, the levels of total nitrogen, total phosphorus and chemical oxygen demand, recorded in 2013, at both Krom Samnor and Tan Chau monitoring stations are still low and have not caused serious impairment to water quality at either station, as evident by the relatively high dissolved oxygen recorded at both stations.

Dissolved oxygen levels at Tan Chau were slightly lower than those observed at Krom Samnor. This trend is to the complete reverse of the trends observed for chemical oxygen demand, nitrate-nitrite, ammonium and total nitrogen at the same stations,

Figure 3.21. Comparisons of water quality data at Koh Thom and Chau Doc (the horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life)



which is expected. The difference in mean concentration of dissolved oxygen is also statistically significant based on the results of an independent t-test, with a P value of less than 0.001 (Krom Samnor (M = 7.6 mg/L, Std. = 0.99) and Tan Chau (M = 5.9 mg/L, Std. = 0.63).

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 3-20 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 2012, and from the period of 2005-2011.

In terms of pollutant levels, Figure 3-20 shows that concentrations of nitrate-nitrite, total nitrogen, total phosphous and chemical oxygen demand were generally higher in the downstream stations (Chau Doc) than the upstream stations (Koh Thom) in both 2012 and from the period of 2005 to 2011. This can potentially reflect pollution discharges between the two stations.

The analysis of individual pollutants, in 2012, for both stations revealed that the observed difference in the mean concentrations of nitrate-nitrite were statistically significant with a P value of 0.05. Mean nitrate-nitrite concentrations for Koh Thom and Chau Doc were estimated to be 0.141 mg/L (Std = 0.10) and 0.258 mg/L (Std = 0.17), respectively. Statistically, the observed difference in the mean concentrations of chemical oxygen demand, between Koh Thom (M = 4.12 mg/L, Std = 1.16) and Chau Doc (M = 4.12 mg/L, Std = 0.84), was also significant, with a P value of 0.01.

On the other hand, independent t-test failed to reveal any statistically significant difference for total nitrogen and total phosphorus at the two monitoring stations, with P values of 0.13 and 0.096, respectively for total nitrogen and total phosphorus.

Dissolved oxygen concentrations at Chau Doc were recorded to be generally lower than those recorded at Koh Thom. A comparison of mean dissolved oxygen concentrations between the two stations revealed that the difference is statistically significant, with the P value of 0.01. Mean dissolved oxygen concentrations for Koh Thom and Chau Doc was estimated to be 6.7 mg/L (Std = 0.84) and 5.9 mg/L (Std = 0.41), respectively.

Table 3-3. Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of aquatic life 2008-2013

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

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

3.3 WATER QUALITY INDICES

3.3.1 Water Quality Index for Protection of Aquaitc Life

In 2013, water quality at all but two monitoring stations in the Mekong and Bassac Rivers (My Tho and Can Tho Stations) was rated as "good" quality for the protection of aquatic life, following the newly revised water quality indices. My Tho and Can Tho are the furthest downstream monitoring stations on the Mekong and the Bassac Rivers, respectively. These two stations were the only two stations rated as "moderate" quality for the protection of aquatic life. The slight impairment at My Tho and Can Tho stations can be attributed to the elevated total phosphorus concentrations above the threshold value, which were recorded in 83% and 75% of sampling occasions, respectively. Elevated nitrate-nitrite levels were also observed at these two stations, with exceedance observed in 92% and 58% of sampling occasions, respectively for My Tho and Can Tho Monitoring Stations.

Between 2008 and 2013, the water quality of the Mekong and the Bassac Rivers remained relatively unchanged and is suitable for all aquatic life with only a minor degree of threat or impairment observed. Compared to 2012, the degrees of water quality impairment for the protection of aquatic life increased slightly with six stations (Luang Prabang, Vientiane, Savannakhet, Khong Chiam, Pakse and My Tho), recording higher degrees of impairment (lower water quality index scores) compared to the previous year. The main culprit for the increased degrees of impairment is the slightly elevated levels of total phosphorus. In 2013, 38% of the total phosphorus data at these six stations exceeded the guideline value for total phosphorus (0.13 mg/L). In comparison, only 18% of the total phosphorus data exceeded the guideline value in 2012.

3.3.2 Water Quality for the Protection of Human Health- Human Health Acceptability Index

The analysis of the 2013 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" quality. Of the 22 stations located on the Mekong and Bassac Rivers, 10 stations were rated as "excellent" in 2013 while 12 stations were rated as "good". Of the 10 stations rated as "excellent", 7 are located in Cambodia between Stung Trieng and Krom Samnor.

From 2008 to 2013, water quality for the protection of human health did not change significantly, with all stations recording either "good" or "excellent" quality. Compared to 2012, the degree of impairment for the protection of human health increased slightly (lower water quality index scores) at three stations (Pakse, My Thuan and Takhmao). Improvement of water quality in terms of human health was observed at three stations (Luang Prabang, Krom Samnor and Chau Doc) with water quality index for the protection of human health acceptability being classified as "excellent" in 2013, compared to "good" in 2012.

Table 3-4. Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of human health in term of human health acceptability 2008-2013

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

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

Table 3-5. Water quality class of the Mekong River (1-17) and Bassac River (18-22) for agricultural use for 2009-2013

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

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

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).

A spatial trend analysis carried out for electrical conductivity along the Mekong and Bassac Rivers (Section 3.1.2.2 and Figure 3.3) reveals that with the exception of a few exceedances observed at My Tho Station (17) all electrical conductivity values obtained from the water quality monitoring in 2013 were well below the threshold of the Water Quality Index for General Irrigation Use of 70 mS/m. In 2013, the maximum value for electrical conductivity was measured at My Tho Station (17), which was 72.0 mS/m.

With no recorded violation of the threshold values for Water Quality Indices for General Irrigation and Paddy Rice Irrigation, it can be concluded that there is no restriction on the use of water from the Mekong and Bassac Rivers for any type of agricultural use. The level of impairment of the Mekong and Bassac Rivers' water quality for agricultural use is summarised in Table 3-5.

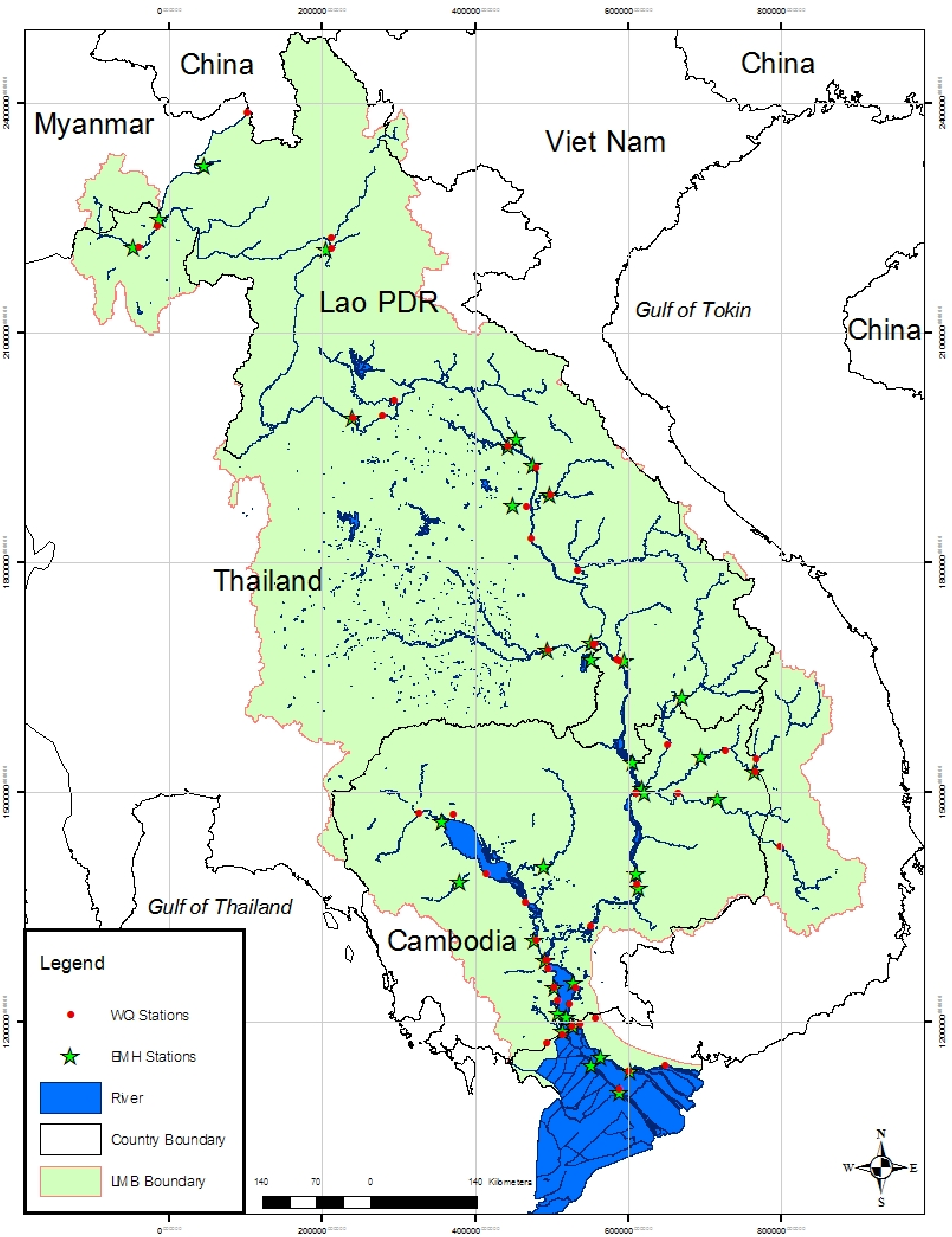


Figure 3.6. Locations of the EHM in relation to the location of the WQMN

3.4 ECOLOGICAL HEALTH INDEX

Another method used by the MRC to monitor the health of the Mekong River is Ecological Health Monitoring (EHM). The objective of the EHM is to determine whether changes in water quality have any effect on fish and other aquatic life in the Mekong River and its tributaries. The EHM is conducted by a group of national experts of the Member Countries, including biologists and ecologists. The EHM Programme was commenced by the MRC in 2004 and discontinued in 2008 due to a lack of funding. The Programme was resumed in 2011 at 41 stations (8 stations each in Lao PDR, Thailand, and Viet Nam, and 17 stations in Cambodia). Since then, the EHM programme has been conducted on a biennial basis. In 2013, a total of 41 stations were monitored, of which 22 stations were located at the same sites or close to the water quality monitoring stations of the MRC Water Quality Monitoring Network. Of these 22 stations, 11 are located in either the Mekong or Bassac Rivers. The locations of the EHM in relation to the locations of the Water Quality Monitoring Network are illustrated in Figure 3.22.

As part of the EHM, four biological groups, namely benthic diatoms, zooplankton, littoral macro-invertebrates and benthic macro-invertebrates were monitored. For each biological group, three biological metrics, namely abundance, average richness and the Average Tolerance Score per Taxon (ATSPT) were measured. Thus, a total of twelve biological indicators were used to evaluate each site. The quality of each site was classified into one of the four following groups:

- **Class A (Excellent):** 10-12 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity to support fish and other freshwater functions are similar to those at the reference sites defined in the 2004 – 2007 survey. These reference sites provide a 'baseline' against which other sites can be measured.
- **Class B (Good):** 7-9 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity are slightly less than at the reference sites. Human activities may have caused some disturbance.
- **Class C (Moderate):** 4-6 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity are markedly less than at the reference sites. Disturbance resulting from human activities is present.
- **Class D (Poor):** 0-3 of the 12 indicators meet the guidelines. The biodiversity and ecological capacity are significantly less than that at the reference sites. Various disturbances from human activities are likely to be present.

Table 3-6 below provides results of the ecological health monitoring in the Mekong and Bassac Rivers at stations where water quality monitoring was also carried out. In addition to providing the 2013 ecological health monitoring results, the table also provides a comparison to the 2013 analysis results of the water quality index for the protection of aquatic life. Key observations of the ecological health monitoring results at these stations are as follows:

- Of the 22 sites listed in Table 3-6, all but six are rated as either "good" or "excellent", meaning that the biodiversity and ecological capacity of these sites to support fish and other freshwater functions are still relatively unaffected by human impacts. Of the six stations rated as "moderate", three are located in the Mekong mainstream (Neak Loung, Tan Chau/Thuong Thoi, and My Thuan), and two are located in the Bassac River (Chau Doc/Da Phuoc and Can Tho).
- No significant deviation was observed when comparing the results of the 2013 EHM to the classifications provided by the 2013 Water Quality Index for the Protection of Aquatic Life, i.e. stations receive approximately similar ratings for water quality and ecological health. Of the stations located in the Mekong and Bassac Rivers, three stations (Chiang Sean, Kratie, and Koh Khel) were classified as "good" quality for both EHM and WQIal. The results of the ecological health monitoring reveal that water quality of the Mekong and Bassac River was either "good" or "excellent" for support of fish and other freshwater functions, with the exception of the five stations (Neak Loung, Tan Chau, My Thuan, Can Tho, and Chau Doc) where they were rated as "moderate" for support of fish and other freshwater functions. In comparison, all but one station were rated as "good" for the protection of aquatic life by WQIal, with the one exception being Can Tho Monitoring Station where it was rated as "moderate" for the protection of aquatic life.

Table 3-4. Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of human health in term of human health acceptability 2008-2013.

Station Names	Countries	Rivers	2013 EHM	2013 WQI_{al}
Chiang Sean	Thailand	Mekong	B	B
Luang Prabang	Laos	Mekong	*	B
Vientiane	Laos	Mekong	*	B
Nakhon Phanom	Thailand	Mekong	A	B
Kong Chiam	Thailand	Mekong	A	B
Kratie / Kampi Pool	Cambodia	Mekong	B	B
Neak Loung	Cambodia	Mekong	C	B
Tan Chau / Thuong Thoi	Viet Nam	Mekong	C	B
My Thuan	Viet Nam	Mekong	C	B
Koh Khel	Cambodia	Bassac	B	B
Can Tho	Viet Nam	Bassac	C	C
Chau Doc / Da Phuoc	Viet Nam	Bassac	C	B
Chiang Rai	Thailand	Mae Kok	B	
Ban Chai Buri	Thailand	Song Kham	B	
Se Bang Fai Bridge	Laos	Se Bang Fai	*	
Na Kae	Thailand	Nam Kam	A	
Se Bang Hieng Bridge	Laos	Se Bang Hieng	*	
Se Done Bridge /Ban Hae	Laos	Se Done	*	
Ubon	Thailand	Mun	A	
Phum Phi (Phi Village)	Cambodia	Se San	B	
Prek Kdam	Cambodia	Tonle Sap	B	
Phnom Penh Port	Cambodia	Tonle Sap	C	

*: No EHM monitoring was carried out in 2013

4. CONCLUSIONS AND RECOMMENDATIONS

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Based on the results of the 2013 water quality monitoring survey, it can be concluded that, while slightly degraded compared to the 2012 water quality results, the water quality of the Mekong and Bassac Rivers is still of good quality with only a small number of measurements of pH, dissolved oxygen and chemical oxygen demand exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. The majority of values of dissolved oxygen and chemical oxygen demand above the guidelines were recorded in the Delta. 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. However, it should be noted that the Mekong River is generally characterised as a low saline river with the average electrical conductivity rarely exceeding 40 mS/m.

Assessing the 2000-2013 data, total phosphorus levels show an increasing trend from 2000 to 2013 and nitrate-nitrite and ammonium levels remain relatively constant while total phosphorus levels increased slightly. Dissolved oxygen and chemical oxygen demand levels also did not change significantly during the period.

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

The assessment of the Water Quality Index for the Protection of Aquatic Life revealed that all stations were rated as either "good" or "moderate" for the protection of aquatic life. In fact, 20 of the 22 stations located in the Mekong and Bassac Rivers were rated as "good" for the protection of aquatic life while only the two most downstream stations (My Tho and Can Tho) were rated as "moderate" for the protection for water quality. The degree of water quality impairment increased slightly in 2013 with six stations receiving lower rating scores when compared to 2012. Elevated level of total phosphorus was the main cause for the observed impairment with target values of 0.13 mg/L exceeded on 46% of the sampling occasions.

The analysis of the 2013 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 good, with 10 stations rated as "excellent" and 12 stations rated as "good" quality in 2013. From 2008 to 2013, water quality for the protection of human health did not change significantly, with all stations showing either "good" or "excellent" quality.

With no recorded violation of threshold values for Water Quality Indices for General Irrigation and Paddy Rice Irrigation, it can be concluded that there are no restrictions on the use of water from the Mekong or Bassac Rivers for any type of agricultural use.

The ecological health monitoring carried out by the Mekong River Commission confirms that water quality of the Mekong and Bassac Rivers in 2013 is still of good quality, 18 out of 22 stations rated as either "good" or "excellent", meaning that the biodiversity and ecological capacity of these sites to support fish and other freshwater functions are still relatively unaffected. The other six stations were rated "moderate" and may have been subjected to disturbances from human activities.

4.2 RECOMMENDATIONS

TThe maintenance of good or acceptable water quality to promote the sustainable development of the Mekong River is of paramount concern basin wide. So much so that the MRC Member Countries have adopted various tools, guidelines and methodologies to enhance the monitoring of water quality and to report the results of the monitoring. Not only have these measures helped improve the quality of data collected under the WQMN, they have also improved communication methods which allow water quality information to be effectively communicated to the public and water resource managers of the Member Countries and, in turn, help shape water resources management strategies and policies of the Member Countries, concerning water resource management of the Lower Mekong Basin.

Despite the concerted efforts of the Member Countries to enhance water quality management of the Mekong River, a number of shortcomings still exist and need to be addressed, including the insufficient capacity of WQMN Laboratories to monitor and analyse emerging toxic contaminants (e.g. heavy metals and persistent organic pollutants). Capacity improvement in connection with the implementation of Quality Assurance/Quality Control (QA/QC) in all facets of water quality monitoring and reporting will need to be continuously updated to ensure the integrity of the collected water quality data and the integrity of the water quality report.

As discussed in the previous sections of this report, while water quality of the Mekong and Bassac Rivers is still of good quality for the protection of aquatic life and human health and is still of desirable quality for agricultural purposes, elevated levels of individual parameters monitored by the WQMN have been recorded in the past few years, including nitrate-nitrite, total phosphorus and chemical oxygen demand. The causes of these increasing trends need to be further examined and addressed to ensure the objectives of water quality management are met, over both the short and longer terms.

Considering the potential changes in water quality conditions of the Mekong River, the following aspects need to be considered for the sustainable implementation of the routine water quality monitoring under the MRC WQMN:

- Improve the capacity of the WQMN to monitor and analyse emerging toxic contaminants in not only ambient surface water, but also in sediment and aquatic biota;
- Improve the capacity of the WQMN to implement QA/QC Procedures in water quality monitoring and laboratory analysis through:
- Identify potential causes of elevated nutrients in the Mekong River through study of the relationships between water quality conditions and land use within the Lower Mekong Basin;
- Improve capacity on report writing and data analysis, taking into account the use of newly developed and adopted tools for communicating water quality information, including the newly adopted water quality indices and water quality guidelines.

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