MEKONG RIVER COMMISSION
For Sustainable Development

2015 LOWER MEKONG Regional Water Quality MONITORING REPORT

Prepared by:
The Mekong River Commission Secretariat
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Abbreviations

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

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 2015, the Mekong River Commission, with the assistance of the Member Countries, conducted a routine monitoring of water quality in 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 in the Mekong and Bassac River improved slightly compared to the monitoring results from 2014. When compared to the MRC Guidelines for the Protection and Human Health and Aquatic Life, water quality in the Mekong and Bassac Rivers was still of good quality in 2015, with only a small number of measurements of dissolved oxygen and chemical oxygen demand exceeding the guidelines, and a small number of measurements of nitrate-nitrite and total phosphorus exceeding threshold values used for calculating water quality indices for the protection of aquatic life and human health. In 2015, all pH values recorded were well within the MRC Guidelines for the Protection of Human Health and Aquatic Life.

Assessment results from the 2000-2015 data revealed that total phosphorus and chemical oxygen demand levels increased from 2000 to 2015, while nitrate-nitrite, ammonium and dissolved oxygen levels remained relatively constant. pH levels showed a slight decrease during the same period, but were still well within the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. A temporal analysis of data from 2000 to 2015 suggests that TSS levels in the Mekong River had decreased since 2000. The average TSS concentration of the Mekong River in 2000 was measured to be about 118.7 mg/L, whereas in 2015, the average monthly concentration for TSS was measured to be about 80.2 mg/L. However, when compared to the 2014 figure (76.5 mg/L), the average monthly TSS concentration increased slightly in 2015.

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

The assessment of the Water Quality Index for the Protection of Aquatic Life revealed that water quality in the Mekong and Bassac Rivers for the protection of aquatic life ranged from "moderate" quality to "high" quality in 2015. Of the 22 stations located in the Mekong and Bassac Rivers, 3 were rated as "high" quality while 18 were rated as "good" quality for the protection of aquatic life. Water quality for the protection of aquatic life degraded slightly in 2015 when compared with 2014, with three stations receiving lower rating scores in 2015.

Overall, it can be concluded that water quality in the Mekong and Bassac Rivers for the protection human health is still of good quality, with 11 stations rated as "excellent" and 11 stations rated as "good" quality. Compared to 2014, water quality for the protection of human health showed improvement at 3 stations, which resulted from the improvements observed for nitrate-nitrite and chemical oxygen demand levels.

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.

1. Introduction

1.1 BACKGROUND

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

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

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

1.2 WATER QUALITY MONITORING NETWORK

Recognising that sustainable development of water resources of the Lower Mekong River Basin will not be possible without effective management of water quality, the MRC Member Countries agreed to establish a Water Quality Monitoring Network (WQMN) to detect changes in 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. In 2006, the MRC, led by the Environment Programme, conducted a full assessment of water quality monitoring activities in the Mekong River under the WQMN. One of the outcomes of the assessment was the need to reduce the cost of monitoring while at the same time increase its suitability. An agreement was reached for the Network to include only primary stations, while the secondary stations would be monitored by individual Member Countries. Primary stations are those that are located in the mainstream and key tributaries of the Mekong River. In 2015, a total of 48 stations were included in the WQMN, of which 17 were located on the Mekong River, 5 on the Bassac River, and 26 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 Mekong water quality. A number of these stations were also strategically selected to detect transboundary water quality problems.

The WQMN is one of the MRC's core function activities which will be fully decentralised to the Member Countries by 2019.

1.3 OBJECTIVES

The decentralisation of the WQMN was completed for Thailand and Viet Nam in 2016. For Cambodia and Lao PDR, the decentralisation of the WQMN will be completed by 2019. Following decentralisation, Member Countries through their designated water quality laboratories, will be required to finance and undertake the monitoring, sampling and analysis of Mekong water quality. At national level, each Member Country has designated a water quality laboratory to undertake the monitoring, sampling, and analysis of 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 are to:

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

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

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 — annual water quality data and an annual water quality and data assessment report.

This report has been prepared in response to these required outputs. It provides the consolidated results from the water quality monitoring activities of the Member Countries, focusing on the compliance of water quality data with available water quality guidelines as defined in the MRC Procedures for Water Quality and its technical guidelines.

As such, the main objectives of this report are to:

- Provide the status of water quality in the Mekong River in 2015; assess water quality monitoring data provided by the WQMN laboratories in 2015 and compare them with the 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 issues observed in 2015
- Provide recommendations for future monitoring and continuous improvement of the water quality monitoring activities

2 Methodlogy for Monitoring and Data Assessment

2.1 MONITORING LOCATION AND FREQUENCY

Forty-eight stations were monitored by the WQMN in 2015. 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 2015, 11 stations are located in Lao PDR, 8 in Thailand, 19 in Cambodia and 10 in Viet Nam. Figure 2-1 illustrates their locations in the Lower Mekong Basin (17 on the Mekong River, 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 each month.

Table 2 1: A summary of 2015 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 lists the 22 mainstream stations monitored in 2015 in geographical order, from upstream to downstream, to facilitate the analysis of water quality trends along the Mekong River mainstream.

Table 2 2: Water quality monitoring stations in the Mekong and Bassac Rivers numbered in sequence from upstream to downstream and as monitored in 2015

Station No.	Name of station	Station ID	River	Countries	Latitude	Longitude
1	Houa Khong	H010500	Mekong River	Lao PDR	21.5471	101.1598
2	Chiang Saen	H010501	Mekong River	Thailand	20.2674	100.0908
3	Luang Prabang	H011200	Mekong River	Lao PDR	19.9000	102.0000
4	Vientiane	H011901	Mekong River	Lao PDR	17.9281	102.6200
5	Nakhon Phanom	H013101	Mekong River	Thailand	17.4250	104.7744
6	Savannakhet	H013401	Mekong River	Lao PDR	16.5583	104.7522
7	Khong Chiam	H013801	Mekong River	Thailand	15.3255	105.4937
8	Pakse	H013900	Mekong River	Lao PDR	15.1206	105.7837
9	Stung Treng	H014501	Mekong River	Cambodia	13.5450	106.0164
10	Kratie	H014901	Mekong River	Cambodia	12.4777	106.0150
11	Kampong Cham	H019802	Mekong River	Cambodia	11.9942	105.4667

12	Chrouy Changvar	H019801	Mekong River	Cambodia	11.5861	104.9407
13	Neak Loung	H019806	Mekong River	Cambodia	11.2580	105.2793
14	Kaorm Samnor	H019807	Mekong River	Cambodia	11.0679	105.2086
15	Tan Chau	H019803	Mekong River	Viet Nam	10.9079	105.1835
16	My Thuan	H019804	Mekong River	Viet Nam	10.2725	105.9100
17	My Tho	H019805	Mekong River	Viet Nam	10.3430	106.3505
18	Takhmao	H033401	Bassac River	Cambodia	11.4785	104.9530
19	Koh Khel	H033402	Bassac River	Cambodia	11.2676	105.0292
20	Koh Thom	H033403	Bassac River	Cambodia	11.1054	105.0678
21	Chau Doc	H039801	Bassac River	Viet Nam	10.9552	105.0867
22	Can Tho	H039803	Bassac River	Viet Nam	10.0580	105.7977

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

2.2 SAMPLING TECHNIQUES

In an effort to standardise sampling techniques, in 2015 the MRC continued to work with the designated laboratories of the Member Countries to identify appropriate sampling techniques for collecting water samples.

Through consultations, it was agreed that the water sampling, sample preservation, sample transportation and storage, would be carried out in accordance with methods outlined in the 20th edition of the Standard Methods for the examination of Water and Wastewater (Clesceri et al., 1998) or in accordance with national standards complying with the requirements of method validation of ISO/IEC 17025-2005. Specifically, the designated laboratories are required to:

- Collect water samples using the simple surface grab technique at the middle of the stream where free flowing water is observable
- Collect water samples at about 30 to 50 cm under the surface of the stream
- If in-situ measurement is not possible, immediately preserve samples collected with proper preservative agents (i.e. sulphuric acid for nutrients measurement) and store in a cooler to prevent further breakdown of chemicals and biological contents
- Analyse all water samples within the recommended holding time
- All designated laboratories of the MRC WQMN are required to adhere to the MRC QA/QC procedures which were developed in accordance with ISO/IEC 17025-2005 and personnel safety procedures when collecting water samples and measuring water quality parameters.

2.3 LABORATORY ANALYSES

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 2015, 18 water quality parameters were measured by the MRC WQMN (Table 2-3). Of the 18 parameters measured in 2015, 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.

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

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-NH_4/SM
Total Nitrite and Nitrate (NO_{2-3}-N)	4500-NO_{2-3}/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

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 in 2015. 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 TREND 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 a monotonic relationship). Therefore, a non-parametric method was used for trend analysis as this method minimises the importance of both extremes and missing values. Variations along the mainstream were assessed for data obtained in 2015. Trend analysis of water quality from 2000 to 2015 was also carried out for selected water quality parameters. Box-and-whisker plots were used to characterise water quality data for spatial and temporal analysis. A box-and-whisker plot is normally used to analyse variation and central tendency of data. It is a useful statistical tool which can be used to explore a dataset and show key statistics associated with it.

In particular, when using box-and-whisker plots, the following key statistical information can be drawn (Nord, 1995):

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

2.4.3 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; Kaorm Samnor versus Tan Chau; and Koh Thom versus Chau Doc. Comparisons were made for two stations at a time using key pollutant monitoring data during the period 2005–2014 and 2015 for the station closest upstream and downstream of the national border, respectively.

Box-and-whisker plots, using the statistical software package SPSS 23, were used to characterise water quality data. Any observed differences between the upstream and downstream stations were tested using an independent t-test, to determine whether the differences observed are statistically significant.

2.4.4 WATER QUALITY INDICES

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

These indices include:

- Water Quality Index for the Protection of Aquatic Life (WQIal)
- Water Quality Index for the Protection of Human Health 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

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 allows 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 parameter listed in Table 2-4 meets its respective target value in Table 2-6, one point is scored; otherwise the score is zero
- "n" is the number of samples from the station in the year
- "M" is the maximum possible score for the measured parameters in the year

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

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

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

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

2.4.4.2 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 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 the human health acceptability index. The list of the approved parameters to be included in the calculation of the rating score for the 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

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

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
NH3 (mg/L)	0.5
DO (mg/L)	4
NO2-3 – N (mg/L)	5
COD (mg/L)	5
BOD (mg/L)*2	4

* BOD has been approved by the MRC Member Countries as one of the parameters to be included in the calculation of the Water Quality Index for the Protection of Human Health – 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 Human Health – Human Health Acceptability Index

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

2.4.4.3 Water Quality Index for Agricultural Use

Another index adopted by the MRC Member Countries as a means for communicating water quality monitoring information to the public is the Water Quality Index for Agricultural Use, focusing on water quality for general irrigation and paddy rice.

The indices for general irrigation and paddy rice are calculated based on water quality guidelines for salinity (electrical conductivity). The electrical conductivity guidelines, together with the degree of consequence, for the indices for general irrigation and paddy rice are outlined in Table 2-8.

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

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

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

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 charts and reliability score testing using ion balance tests
- 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 Discussion

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. This data is also assessed against the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life[2] . As can be seen in the tables, exceedances of the 2015 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 2015 (Table 3-1), four parameters had some or all measured values not meeting the MRC water quality criteria. These included:

- **pH**

In 2015, the pH values recorded in the Mekong ranged from 6.5 to 8.4 with the minimum pH value recorded at Houa Khong Water Quality Monitoring Station in Lao PDR, in September 2015. The maximum pH value was recorded at Vientiane Water Quality Monitoring Station in March 2015. Based on the assessment of the 2015 water quality data, all pH values were recorded to be within the upper and lower limits of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life (pH levels between 6 and 9).

The average pH value of the Mekong River in 2015 was recorded at about 7.5, which was relatively similar to the average pH value recorded between 1985 to 2014 (pH of 7.5).

- **Electrical Conductivity**

With the maximum Electrical Conductivity (EC) value of 53.8 mS/m, all 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 had been observed in the Delta (Vietnam's stations) during high tide due to the intrusion of sea water, and had been recorded with a maximum value of 841.0 mS/m.

[2] 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.

This maximum value was recorded at My Tho Water Quality Monitoring Station in April 1998. In 2015, 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.

Dissolved Oxygen (DO)

In 2015, 59 of the 204 sampling occasions (or approximately 30% of sampling occasions) recorded dissolved oxygen values of less than the recommended MRC values for the protection of human health (6 mg/L). In addition, 7 sampling occasions recorded dissolved oxygen values of less than the recommended values for the protection of aquatic life (5 mg/L). Majorities of the non-compliance were recorded during the dry season months. Of the 17 stations located in the Mekong River, 12 stations reported DO values of less than 6 mg/L on at least one occasion. These stations include Houa Khong, Luang Prabang, Vientiane, Savannakhet, and Pakse in Lao PDR; Nakhon Phanom in Thailand; Kratie, Neak Loung and Kaorm Samnor in Cambodia; and Tan Chau, My Thuan, and My Tho in Viet Nam. Of the listed stations, Pakse, Tan Chau, My Thuan and My Tho recorded at 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 – 2014) from the same stations, the mean dissolved oxygen concentration in the Mekong River in 2015 (6.9 mg/L) was slightly lower than the mean level recorded from 1985 – 2014 (7.3 mg/L).

Chemical Oxygen Demand (COD)

In 2015, the maximum COD concentration was recorded at 13.7 mg/L, which is considerably higher than the recommended MRC Water Quality Guidelines for the Protection of Human Health (5 mg/L). The mean COD concentration, however, was recorded at 2.5 mg/L, which was slightly higher than the historical mean COD concentration of 2.2 mg/L from 1985 to 2014.

The maximum COD concentration was recorded at Khong Chiam Water Quality Station in August 2015. Of the 17 water quality monitoring stations along the Mekong River, 9 stations recorded COD values greater than the recommended MRC Water Quality Guidelines for the Protection of Human Health (5 mg/L) on at least one sampling occasion in 2015. These stations were Chiang Saen, Nakhon Phanom, and Khong Chiam in Thailand; Luang Prabang, Vientiane, Savannakhet, and Pakse in Lao PDR; and Neak Loung and Kaorm Samnor in Cambodia.

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

- All EC values recorded in 2015 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 average electrical conductivity rarely exceeding 30 mS/m during low tide. In 2015, the maximum EC value was recorded at 25.1 mS/m. Historically, high electrical conductivity values have been recorded in the Delta during high tide due to the intrusion of sea water. The highest recorded electrical conductivity value in the Bassac River was measured at Dai Ngai Water Quality Monitoring Station in April 2005 at 1050 mS/m. However, it should be noted that following the review of the WQMN, water quality monitoring at Dai Ngai Water Quality Monitoring Station was discontinued in 2009. In 2015, 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 6.9 mg/L. The mean DO concentration increased slightly when compared to the value recorded in 2014 (6.1 mg/L). When compared to the historical mean from 1985 to 2014 (6.4 mg/L), the 2015 mean DO concentration also increased slightly. Based on the results of the 2015 water quality monitoring, all five stations located in the Bassac River recorded DO concentrations of less than the recommended guidelines for the protection of aquatic life (5 mg/L) on one occasion or more.

- Despite all five stations recording noncompliance of DO concentration at least once during the monitoring period in 2015, COD levels above the guidelines were recorded at only one station (Koh Khel). The mean COD concentration in the Bassac River in 2015 was 2.6 mg/L, which was slightly lower than the mean COD value recorded in 2014 (3.0 mg/L). This value is also lower than the historical mean value of 3.4 mg/L from 1985 to 2014. The maximum COD concentration of 5.9 mg/L was recorded at Koh Khel, Cambodia in March 2015.

Table 3-1: Comparison of water quality data in the Mekong River between 1985-2014 and 2015 (yellow shading marks non-compliance with WQGH or WQGA)

Parameters	Unit	Water Quality Guidelines		1985-2014				2015			
		Protection of Human Health (WQGH)	Protection of Aquatic Life (WQGA)	Max	Mean	Min	Stdev	Max	Mean	Min	Stdev
Temp	-	Natural	Natural	38.0	27.0	13.0	3.07	32.5	28.0	20.0	2.9
pH	-	6 – 9	6 – 9	9.9	7.5	3.8	0.51	8.4	7.5	6.5	0.4
TSS	mg/L	-	-	5716	155.3	0.1	270.34	637.0	80.2	5.00	93.2
EC	mS/m	70 - 150	-	841.0	20.7	1.2	28.2	53.8	19.2	3.6	7.6
NO32	mg/L	5	5	1.42	0.24	0.00	0.16	1.12	0.28	0.01	0.19
NH4N	mg/L	-	-	2.99	0.05	0.00	0.11	0.49	0.04	0.00	0.06
TOTN	mg/L	-	-	4.89	0.58	0.00	0.39	1.34	0.47	0.09	0.23
TOTP	mg/L	-	-	2.2	0.09	0.00	0.12	2.00	0.15	0.00	0.21
DO	mg/L	≥ 6	> 5	13.9	7.3	2.3	1.1	10.8	6.9	3.6	1.3
COD	mg/L	5	-	65.0	2.2	0.0	2.0	13.7	2.5	0.3	1.9

Table 3-2: Comparison of water quality data in the Bassac River between 1985-2014 and 2015 (yellow shading marks non-compliance with WQGH or WQGA)

Parameters	Unit	Water Quality Guidelines		1985-2014				2015			
		Protection of Human Health (WQGH)	Protection of Aquatic Life (WQGA)	Max	Mean	Min	Stdev	Max	Mean	Min	Stdev
Temp		Natural	Natural	34.0	28.9	23.5	1.9	31.9	29.5	27.1	1.2
pH	-	6 -- 9	6 – 9	9.4	7.2	3.8	0.4	7.7	7.1	6.4	0.3
TSS	mg/L	-	-	939.0	78.1	0.1	86.2	197.6	53.5	6.0	50.6
EC	mS/m	70 - 150	-	1050.0	20.2	1.3	58.8	25.1	14.6	8.0	4.9
NO32	mg/L	5	5	3.02	0.26	0.00	0.22	1.02	0.37	0.04	0.20
NH4N	mg/L	-	-	3.04	0.07	0.00	0.15	0.63	0.10	0.00	0.12
TOTN	mg/L	-	-	4.03	0.76	0.03	0.46	2.34	0.73	0.17	0.36
TOTP	mg/L	-	-	1.78	0.14	0.00	0.14	0.69	0.18	0.01	0.12
DO	mg/L	≥ 6	> 5	12.3	6.4	1.8	1.0	9.2	6.3	4.4	1.1
COD	mg/L	5	-	13.1	3.3	0.0	1.8	5.9	2.6	0.6	1.1

3.1.2 INDIVIDUAL TRENDS ANALYSIS

3.1.2.1 pH

In aquatic ecosystems, pH can affect many chemical and biological processes. This is because pH affects the solubility and availability of nutrients and heavy metals in water (USGS, 2016). At extremely low pH, some toxic compounds and elements from sediments may be released into the water where they can be taken up by aquatic animals or plants, and ultimately by humans through direct contact and/or human consumption of aquatic animals or plants (USEPA, 2012). Additionally, changes in pH can also influence the availability of trace elements, iron and nutrients, such as phosphate and ammonia in water. As such, pH is one of the key water quality parameters monitored by the MRC Water Quality Monitoring Network. In 2015, 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 recommended guidelines, the results of 2015 monitoring revealed that all pH values measured along the Mekong and Bassac River were well within the guidelines (pH values of 6 to 9 for both the protection of human health and aquatic life).

The spatial trend for pH in the Mekong and Bassac Rivers is shown in Figure 3.1. In general, pH values were slightly higher in the upper part (stations located in Lao PDR and Thailand) when compared with the lower part of the river (stations located in Cambodia and Viet Nam). For example, Houa Khong Station (1), the uppermost station of the MRC WQMN, reported pH values ranging from 6.5 to 8.0 with an average value of 7.6, while My Tho Station (17) – the last station on the Mekong River before the river enters the East Sea - reported values ranging from 6.7 to 7.4 with an average value of 7.1.
Results of the temporal analysis of pH data from 2000 to 2015 are shown in Figure 3.2. Based on a visual inspection of Figure 3.2, it can be seen that the overall pH levels remained relatively constant from year to year since 2000. In 2000, the average pH value was recorded at 7.6, while in 2015 the average pH value was recorded at 7.5.

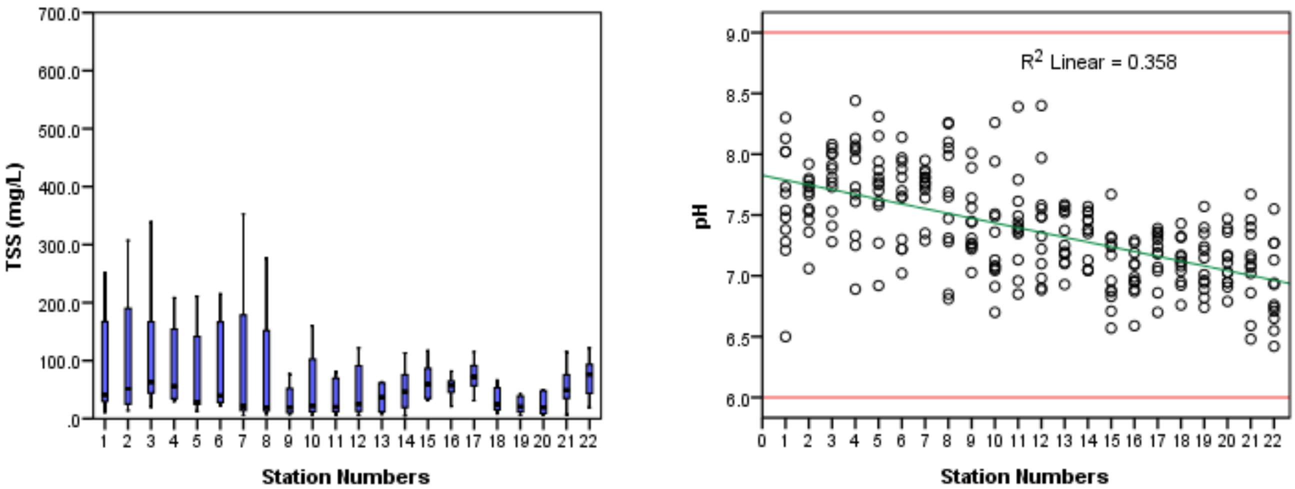

Figure 3.1: Spatial variation in pH levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2015 (the horizontal lines at 6.0 and 9.0 represent lower and upper pH limits of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life)

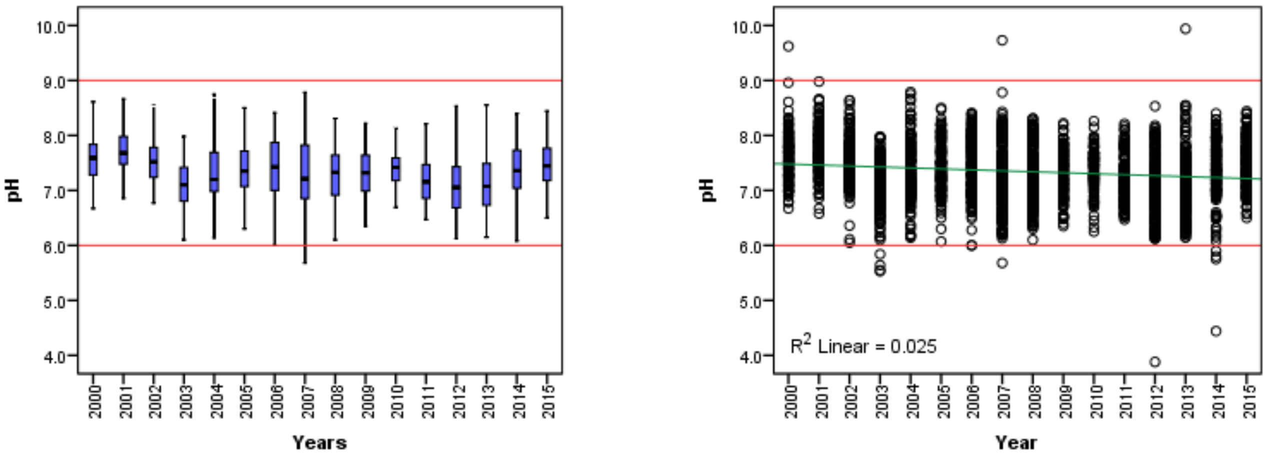

Figure 3.2: Temporal variation in pH levels in the Mekong River from 2000 - 2015 (the horizontal lines at 6.0 and 9.0 represent lower and upper pH limits of the MRC Water Quality Guidelines for the Protection of Human Health and the Protection of Aquatic Life)

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 in the Mekong River. Under normal circumstance and in areas that are not affected by saline intrusion, the Mekong and Bassac Rivers, similar to other waterbodies, have constant ranges of conductivity, and therefore any sudden and significant change in electrical conductivity can be an indicator of water pollution. Wetzel (2001) states that pollution from agricultural runoff or sewage leaks can increase electrical conductivity levels, while Murphy (2007) reports that a spill of an organic compound, such as oil, can reduce electrical conductivity levels.

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 20.7 and 20.2 mS/m, respectively (Tables 3-1 and 3-2).[3]

In 2015, electrical conductivities for both rivers continued to be relatively low, with values ranging from 3.6 to 53.8 mS/m for the Mekong River (Table 3-1) and from 8.0 to 25.1 mS/m for the Bassac River (Table 3-2).

Spatially, conductivity levels in the Mekong River in 2015 exhibited a bow shape characteristic as shown in Figure 3.3, where the conductivity levels were highest in the upper part and lower part of the Lower Mekong River, but lowest in the middle part of the river. For example, Houa Khong Station (1), the uppermost station of the MRC WQMN, reported electrical conductivity values ranging from 20.0 to 32.8 mS/m with an average value of 27.1 mS/m, and My Tho Station (17) – the last station in the Mekong River before the river enters the East Sea - reported values ranging from 13.9 to 42.5 mS/m with an average value of 24.7 mS/m, while Chrouy Changvar (12) – the station located in the middle part of the Lower Mekong River – reported values ranging from 3.6 to 19.9 mS/m with an average value of 13.2 mS/m. When compared to 2014, the electrical conductivity levels recorded at My Tho Water Quality Monitoring Station (17) were highly variable and slightly elevated. In 2014, electrical conductivity levels at this station were reported to range from 11.9 to 25.2 mS/m with an average value of 17.1 mS/m. It should be noted, however, that My Tho Water Quality Station is the lowest station monitored as part of the WQMN, and may have been affected by sea water intrusion.

[3] 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.

Compared to the MRC Water Quality Guidelines for the Protection of Human Health, all electrical conductivity values observed in 2015 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.

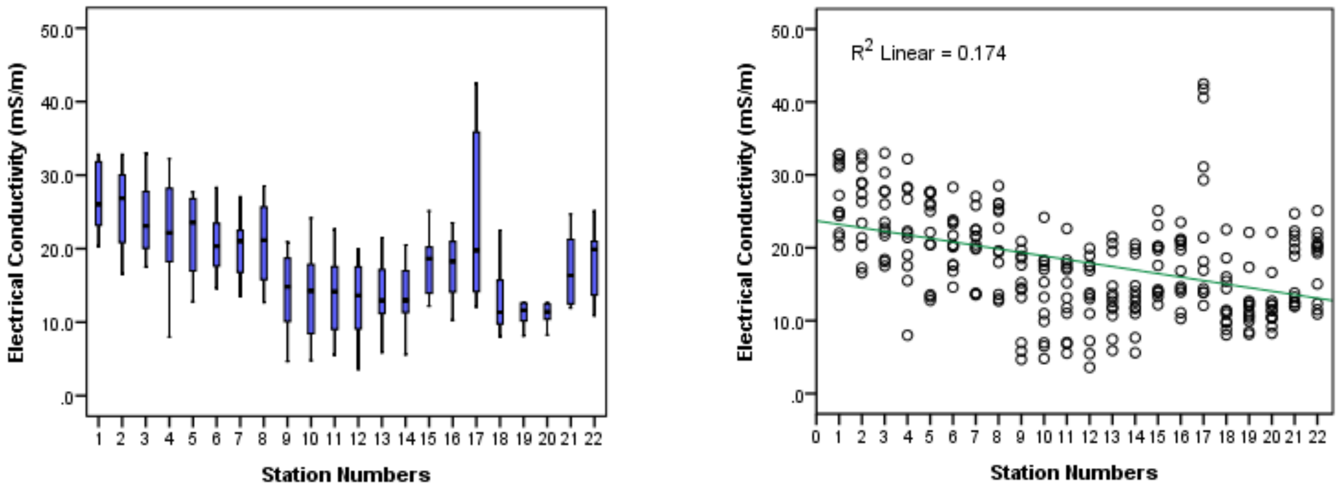

Figure 3.3: Spatial variation in Electrical Conductivity levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2015

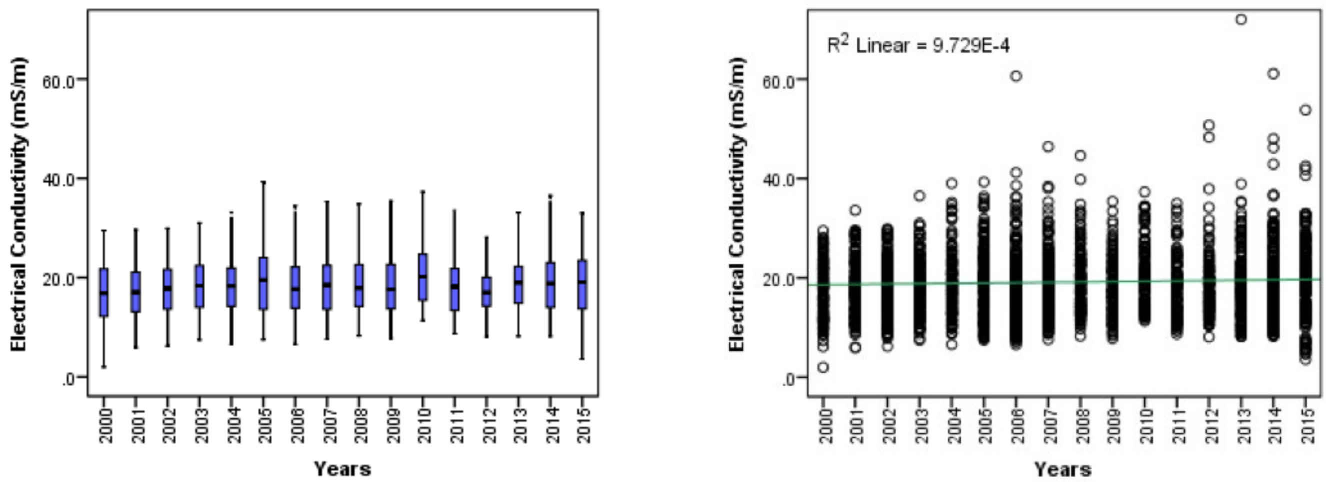

Figure 3.4: Temporal variation in Electrical Conductivity levels in the Mekong River as observed from 2000 to 2015

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 2015, the TSS concentrations observed along the Mekong River continued to be highly variable, with values ranging from 5 to 637 mg/L. The average TSS concentration was about 80.2 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 197.6 mg/L, with an average value of 53.5 mg/L (Table 3-2).

Spatially, the highest TSS levels were observed in the upper part of the Lower Mekong River. TSS levels at stations located in this part of the river were also highly variable, as can be seen in Figure 3.5. The maximum TSS concentration of 637.0 mg/L recorded in 2015 was observed at Chiang Saen Station (2) in August 2015.

For both rivers, the lowest TSS concentrations were observed during the dry season (November to April). In general, the Lower Mekong River receives very little to no rainfall during the dry season, which

causes the dry season TSS concentrations to be lower than those generally observed during the wet season. Along the Mekong River, the average dry season TSS concentration was recorded to be about 32.1 mg/L. The highest dry season concentration for TSS was recorded at 148.0 mg/L at Luang Prabang Water Quality Monitoring Station (3) in January 2015, while the lowest concentration was recorded at 3.5 mg/L at Kaorm Samnor Water Quality Monitoring Station (14) in April 2015.

Along the Bassac River, dry season TSS concentrations ranged from 6.0 to 115.0 mg/L, with the highest dry season concentration recorded at Chau Doc (21) in November 2015 and the lowest concentration recorded at Koh Thom (20) in April 2015. The average dry season TSS concentration for the Bassac River was recorded at about 32.3 mg/L.

During the wet season, the average concentration for the Mekong River was recorded at about 127.8 mg/L, with values ranging from 10.0 to 637.0 mg/L. The lowest wet season TSS concentration was recorded in Stung Treng (9) in June 2015, while the highest concentration was recorded at Chiang Saen (2) in August 2015. With values ranging from 6.0 to 197.6 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 Khel (19) in August 2015, while the lowest concentration was recorded at Koh Thom (19) in May 2015.

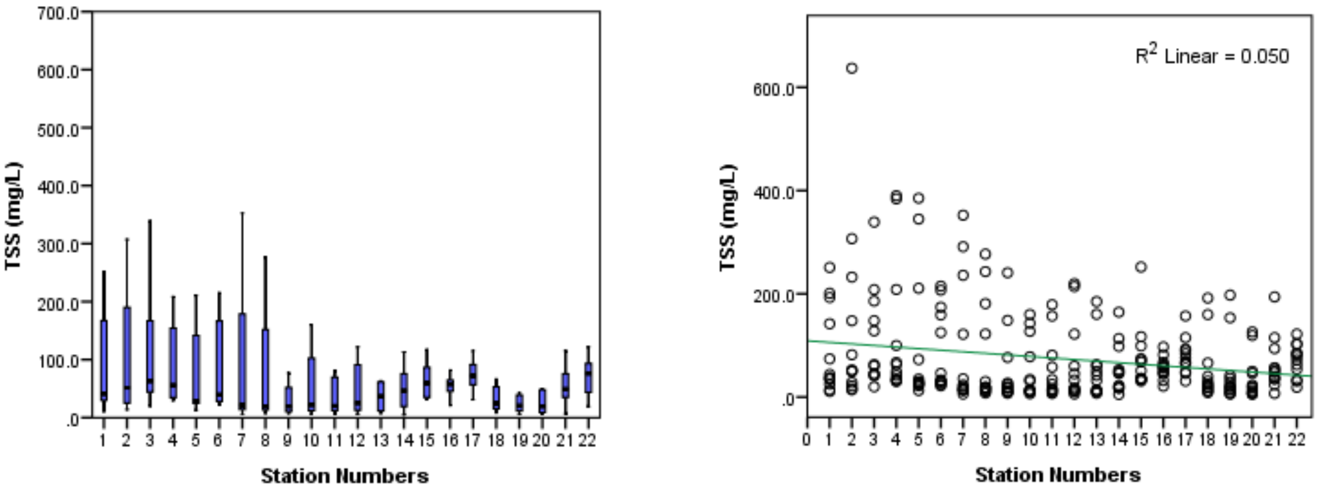

Figure 3.5: Spatial variation in TSS concentrations along the Mekong River (1-17) and Bassac River (18-22) as observed in 2015

The temporal analysis of data from 2000 to 2015 suggests that TSS levels in the Mekong River had decreased since 2000 (Figure 3.6). The average TSS concentration in the Mekong River in 2000 was measured at about 118.7 mg/L, whereas in 2015, the average monthly concentration for TSS was measured at about 80.2 mg/L.
This figure is, however, slightly elevated compared to the figure recorded in 2014. In 2014, the average TSS concentration for the Mekong River was recorded at 76.5 mg/L.

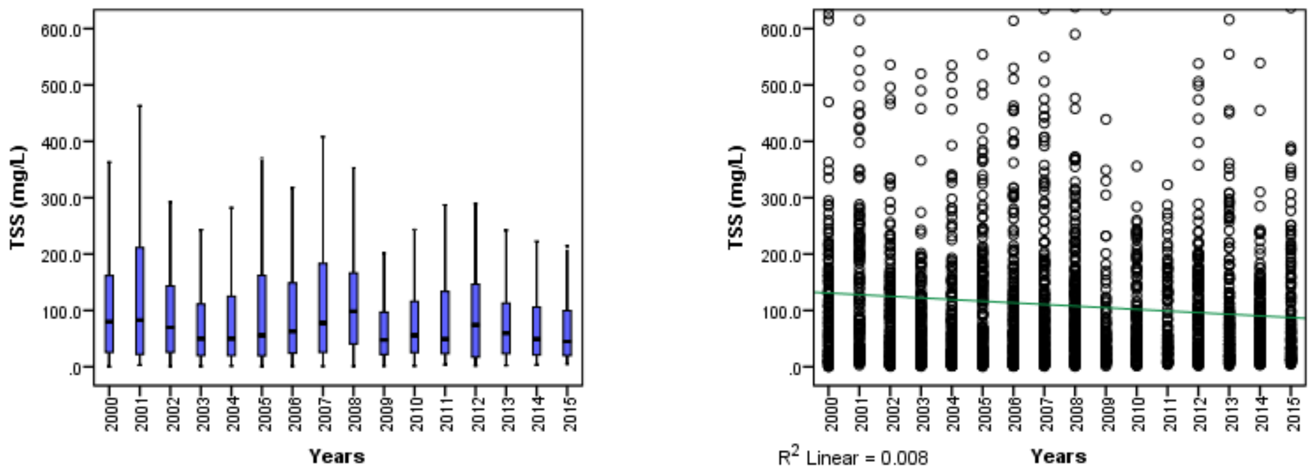

Figure 3.6: Temporal variation in TSS concentrations along the Mekong River as observed from 2000 to 2015

3.1.2.4 Nutrients

■ **Nitrogen**

The MRC WQMN designated laboratories continued to monitor concentrations of nitrite-nitrate, ammonium and total phosphorus as part of nutrient monitoring in 2015. 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 2015 nitrate-nitrite data shows a similar pattern to that of the 2014 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 Lower Mekong River (Houa Khong (1) and Luang Prabang (3)) 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). A slight elevation of nitrate-nitrite concentrations was recorded at My Tho (17) in the Mekong River and Chau Doc (21) and Can Tho (22) in the Bassac River. However, the measured values 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 concentrations from 2000 to 2015 reveals that nitrate-nitrite concentrations in the Mekong River remained relatively constant (Figure 3.8). For the Mekong River, the average nitrate-nitrite concentration (measured as N) in 2000 was recorded at about 0.23 mg/L while the average concentration for nitrate-nitrite in 2015 was recorded at about 0.28 mg/L.

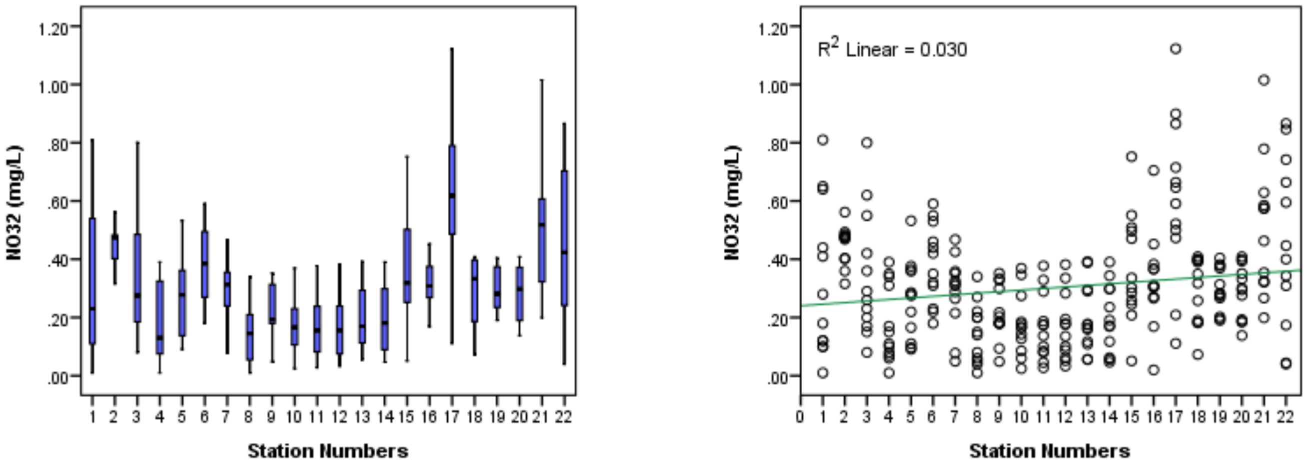

Figure 3.7: Spatial variation in nitrate-nitrite concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2015

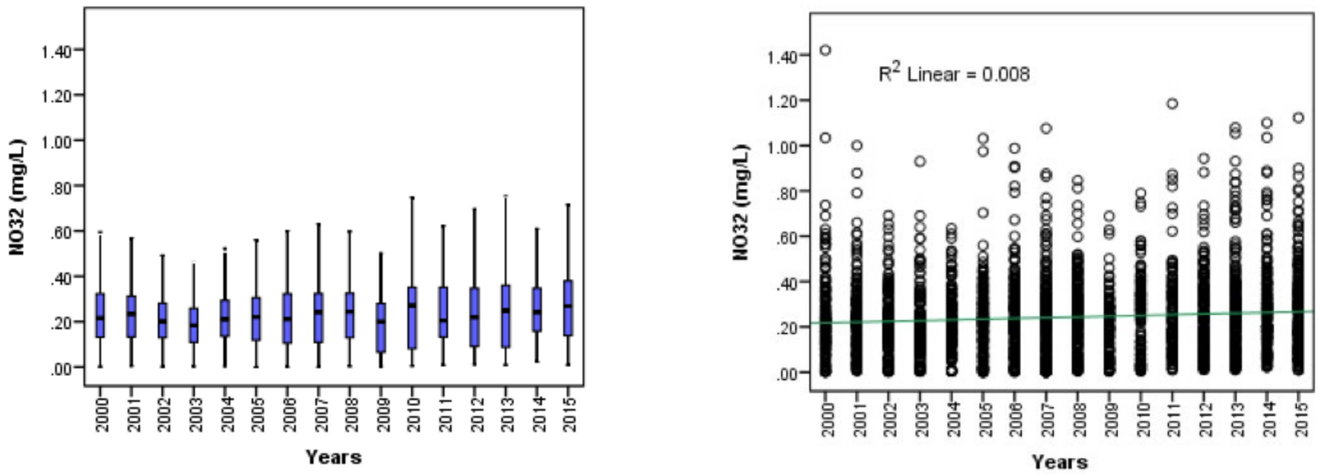

Figure 3.8: Temporal variation in nitrate-nitrite concentrations in the Mekong River as observed from 2000 to 2015

Other than the elevated levels observed at Takhmao Monitoring Station (18), concentrations of ammonium remained relatively low in 2015 (Figure 3.9). The highest concentrations were measured at Takhmao (18), which is located on the Cambodian side of the Bassac River. At this station, ammonium levels were highly variable with values (measured as N) ranging from 0.02 to 0.63 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 three measured values exceeded the threshold value used for calculating Water Quality Index for Human Impact (0.05 mg/L) (Table 2-4). Spatially, ammonium levels recorded at stations located in the upper parts of the Lower Mekong River were low and less variable when compared to those recorded at the stations located in the Mekong Delta.

Temporal analysis of data from 2000 to 2015 for the Mekong River reveals that ammonium concentrations remain relatively constant (Figure 3.10). The average monthly ammonium concentrations in the Mekong River were recorded at 0.05 mg/L in 2000 and at about 0.04 mg/L in 2015.

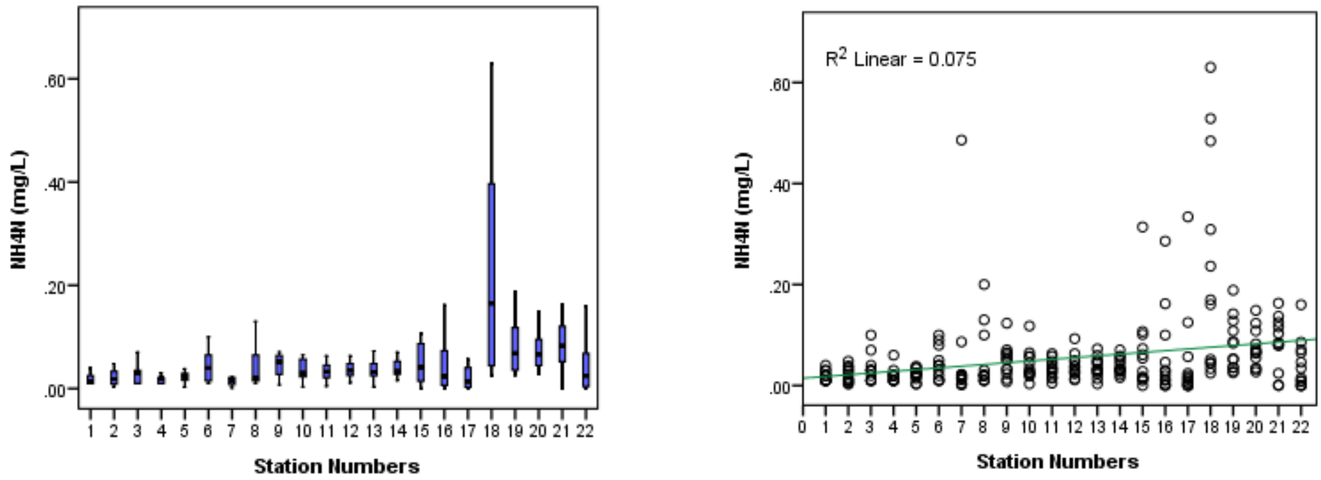

Figure 3.9: Spatial variation in ammonium concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2015

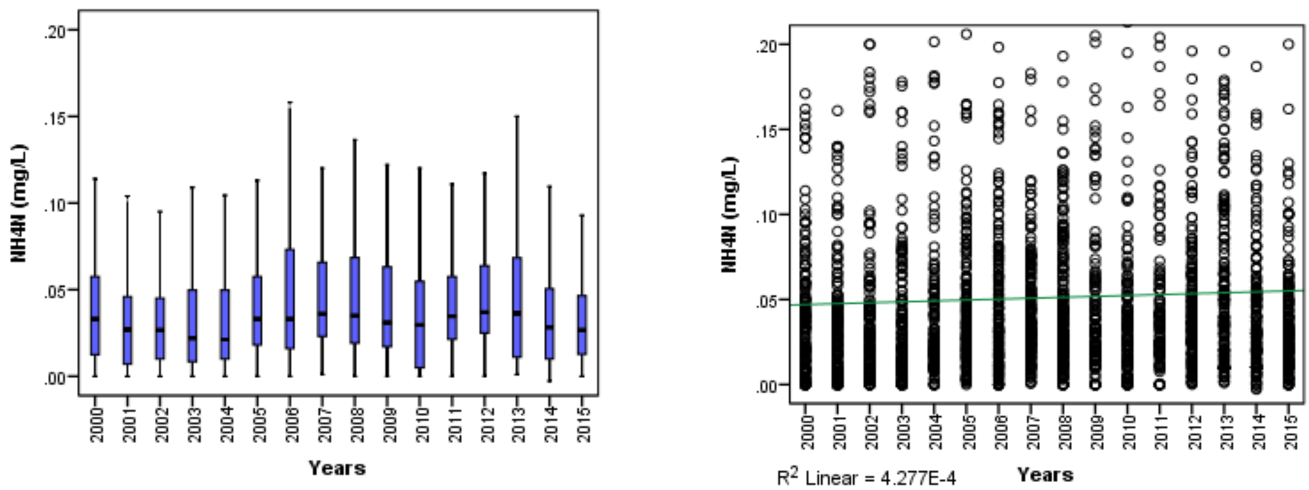

Figure 3.10: Temporal variation in ammonium concentrations in the Mekong River as observed from 2000 to 2015

Phosphorus

In 2015, total phosphorus concentrations measured at Houa Khong Water Quality Monitoring Station (1) were highly variable compared to other stations. The highest concentration at this station was recorded during the wet season in August 2015 at 1.9 mg/L. Spatially, there was no significant difference in the levels of total phosphorus between the upper and lower stations, as can be seen in Figure 3.11.
Compared to the threshold value used for calculating Water Quality Index for the Protection of Aquatic Life (0.13 mg/L) (Table 2-4), elevated concentrations of total phosphorus were observed at all monitoring stations on at least one monitoring occasion.

In the Bassac River, the highest total phosphorus concentration was measured at Takhmao (18) in 2015. At this station, total phosphorus levels ranged from 0.08 to 0.69 mg/L. Of the twelve measurements recorded in Takhmao, eight were reported to exceed the threshold value used for calculating Water Quality Index for the Protection of Aquatic Life (0.13 mg/L). The exceedances were recorded mainly during the wet season between May and October 2015.

Between 2000 and 2015, total phosphorus concentrations in the Mekong River increased slightly, from a mean concentration of about 0.058 mg/L in 2000, to about 0.15 mg/L in 2015 (Figure 3.12). 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 the likely reason for the trend. Despite the increase, with a maximum total phosphorus concentration of 1.9 mg/L, no eutrophication was observed in the Mekong River.

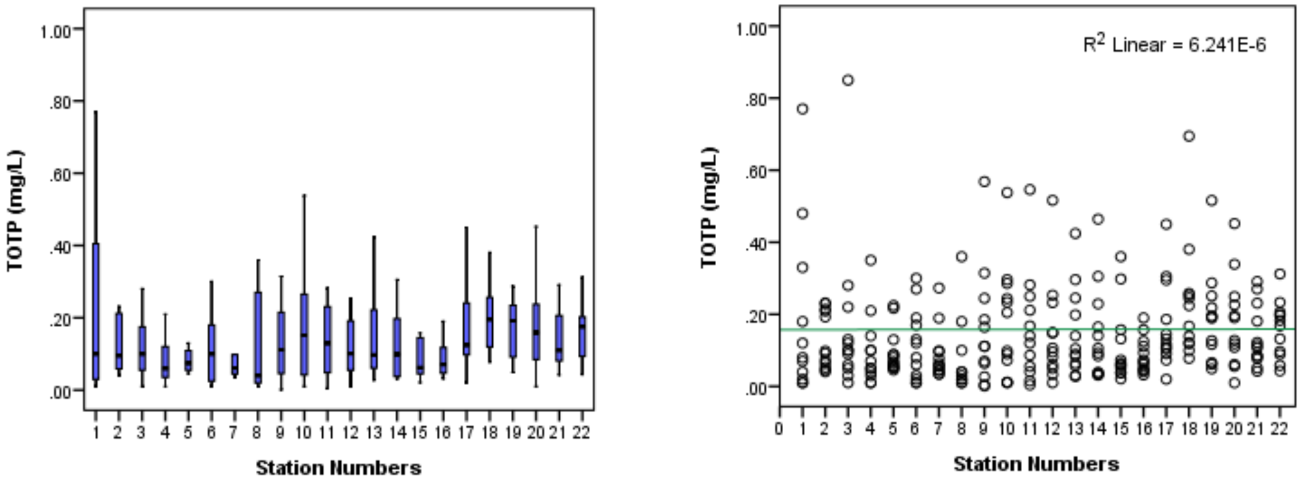

Figure 3.11: Spatial variation in total phosphorus concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2015

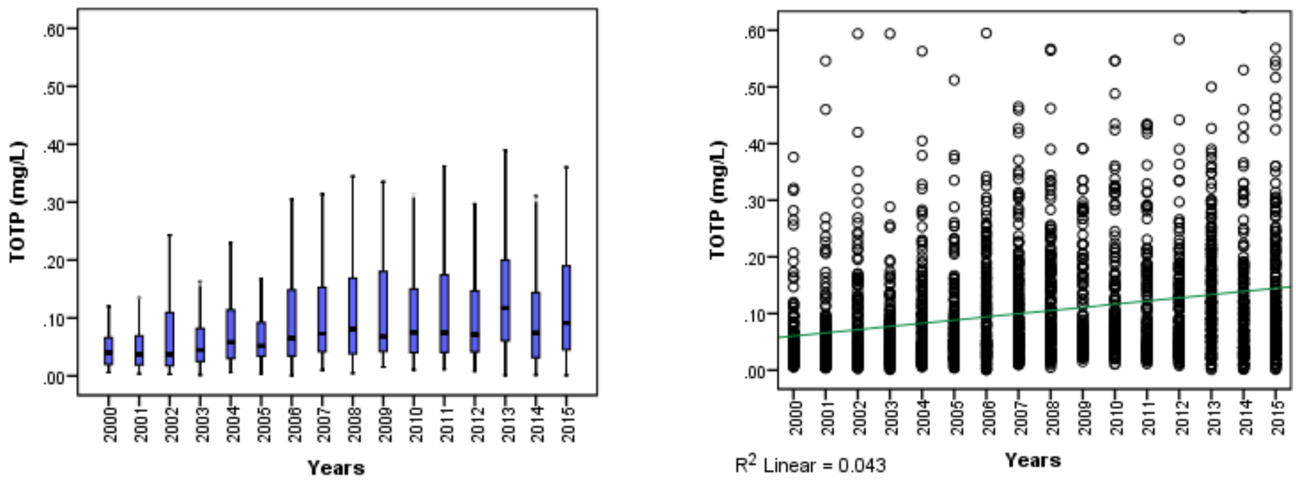

Figure 3.12: Temporal variation in total phosphorus concentrations in the Mekong River as observed from 2000 to 2015

3.1.2.5 Dissolved oxygen and chemical oxygen demand

- **Dissolved oxygen (DO)**

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

The 2015 dissolved oxygen data was compared with the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. Of the 22 water quality monitoring stations located in the Mekong and Bassac Rivers, 17 stations recorded dissolved oxygen levels below the MRC Water Quality Guidelines for the Protection of Human Health (≥ 6 mg/L). In comparison, 16 water quality monitoring stations recorded dissolved oxygen levels below the MRC Water Quality Guidelines for the Protection of Human Health in 2014 (Ly & Larsen, 2014).

Of the 17 stations that recorded dissolved oxygen levels below the MRC Water Quality Guidelines for the Protection of Human Health in 2015, 5 stations are located in Lao PDR while the other stations are located in the Delta (15-22). In comparison, the same 5 stations in Lao PDR also recorded a dissolved oxygen value of less than 6 mg/L in 2014 (Ly & Larsen, 2014).

In addition to violating the MRC WQGH, of the four Lao PDR mainstream stations, one (Pakse (8)) 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. In addition to Pakse Water Quality Monitoring Station, all stations in the Mekong Delta (15-22) recorded dissolved oxygen levels lower than 5 mg/L in 2015.

At Pakse Water Quality Monitoring Station (8), 42% of 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, only 17% of dissolved oxygen values measured in 2014 at Pakse were lower than the MRC WQGH, with an average value of 7.2 mg/L. Further investigations will need to be carried out to identify potential causes of the non-compliance.

The analysis of the spatial variation of 2015 dissolved oxygen data along the mainstream reveals that, on average, dissolved oxygen concentrations tended to be higher in the upper and middle sections of the Mekong River (Figure 3.13). In 2015, the highest dissolved oxygen value in the Mekong River was observed at Kampong Cham (11) monitoring station (10.8 mg/L) in December 2015, while the lowest was observed at Pakse monitoring station (3.6 mg/L) in January 2015.

Along the Bassac River, the highest dissolved oxygen concentration was recorded in Takhmao (18) at 9.2 mg/L in June, while the lowest dissolved oxygen values were recorded at Koh Thom monitoring station (20) at 4.4 mg/L in October 2015.

A temporal analysis of dissolved oxygen in the Mekong River from 2000 to 2015 reveals that dissolved oxygen concentrations in the mainstream did not change significantly during the time period. Based on the visual inspection of Figure 3.14, no significant differences in the median and mean values of dissolved oxygen between 2000 and 2015 were observed.

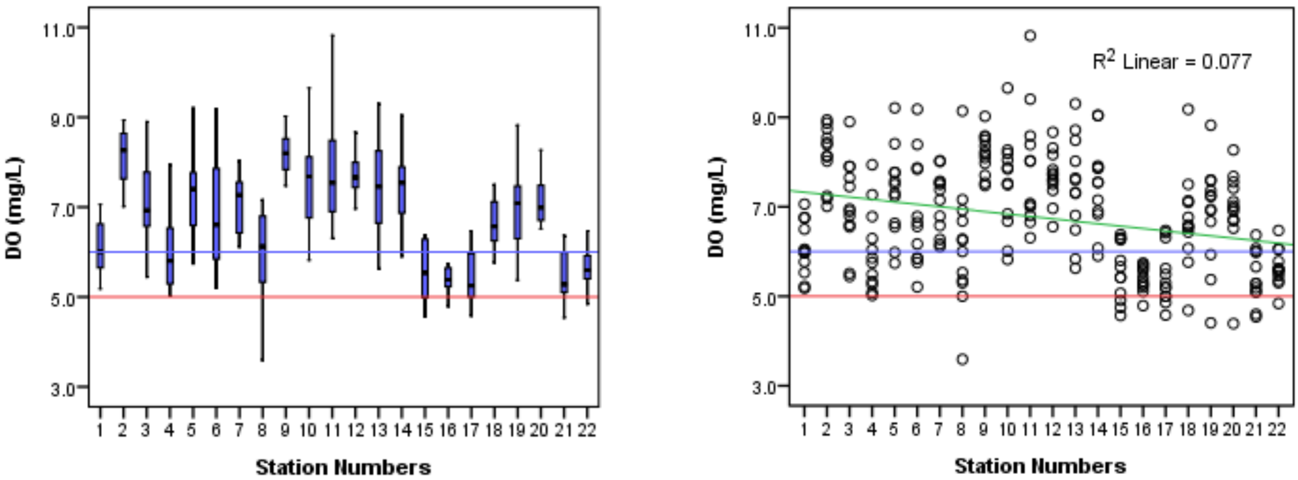

Figure 3.13: Spatial variation in dissolved oxygen (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2015 (horizontal lines at 5 mg/L and 6 mg/L represent values for the MRC Water Quality Guidelines for the Protection of Aquatic Life and the Protection of Human Health, respectively)

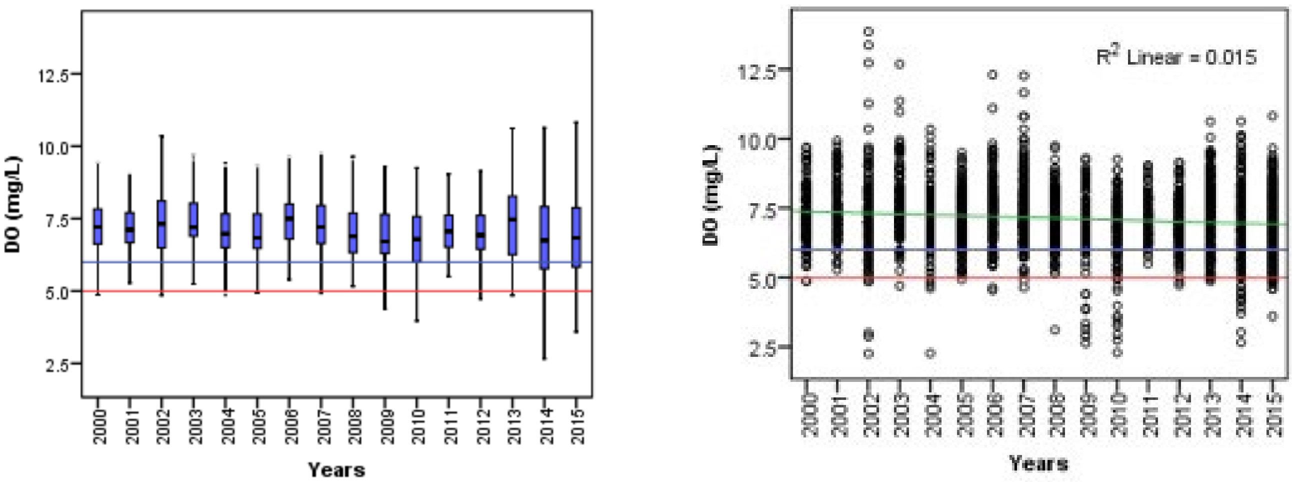

Figure 3.14: Temporal variation in dissolved oxygen (mg/L) in the Mekong River as recorded from 2000 to 2015 (horizontal lines at 5 mg/L and 6 mg/L represent values for the MRC Water Quality Guidelines for the Protection of Aquatic Life and the Protection of Human Health, respectively)

Chemical oxygen demand (COD)

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

Figure 3.15 shows spatial variations in COD along the Mekong and Bassac Rivers in 2015. As can be seen in Figure 3.15, COD concentrations fluctuate as the river runs from upstream to downstream, with the lowest and less variable concentrations recorded in the middle section of the river (where, accordingly, dissolved oxygen was found to be highest). Individually, a number of stations recorded COD values exceeding the MRC Water Quality Guidelines for the Protection of Human Health of 5 mg/L.

These stations include Chiang Saen (2), Vientiane (4), Nakhon Phanom (5), Savannakhet (6), Khong Chiam (7), Pakse (8), Neak Loung (13), Kaorm Samnor (14), and Koh Khel (19). In comparison, the analysis of 2014 COD data reveals that 9 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).

The highest COD concentration was recorded in Khong Chiam at 13.7 mg/L. At this station, COD concentrations were highly variable in 2015, ranging from 0.4 to 13.7 mg/L, with the mean concentration of about 3.0 mg/L.
Figure 3.16 reveals that COD concentrations in the Mekong River increased slightly from 2000 to 2015. For comparison, the mean COD concentration for the 17 Mekong Stations was about 1.9 mg/L in 2000, while the mean COD concentration for the same stations was about 2.5 mg/L in 2015. Compared to 2014, however, the COD centration levels for the same station decreased slightly. In 2014, the mean COD concentration was about 2.7 mg/L.

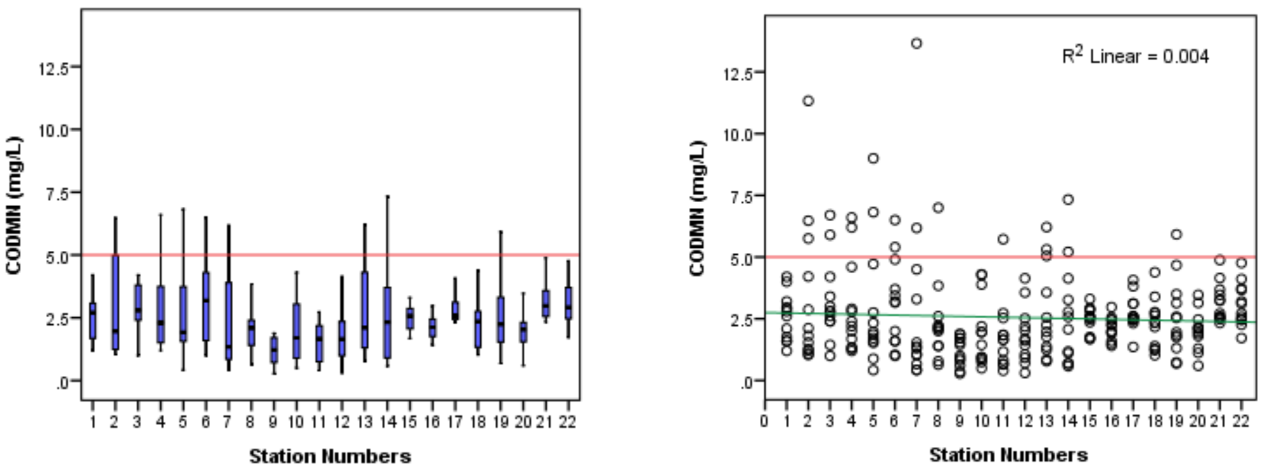

Figure 3.15: Spatial variation in COD (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2015 (horizontal line at 5 mg/L represents threshold values for the MRC Water Quality Guidelines for the Protection of Human Health)

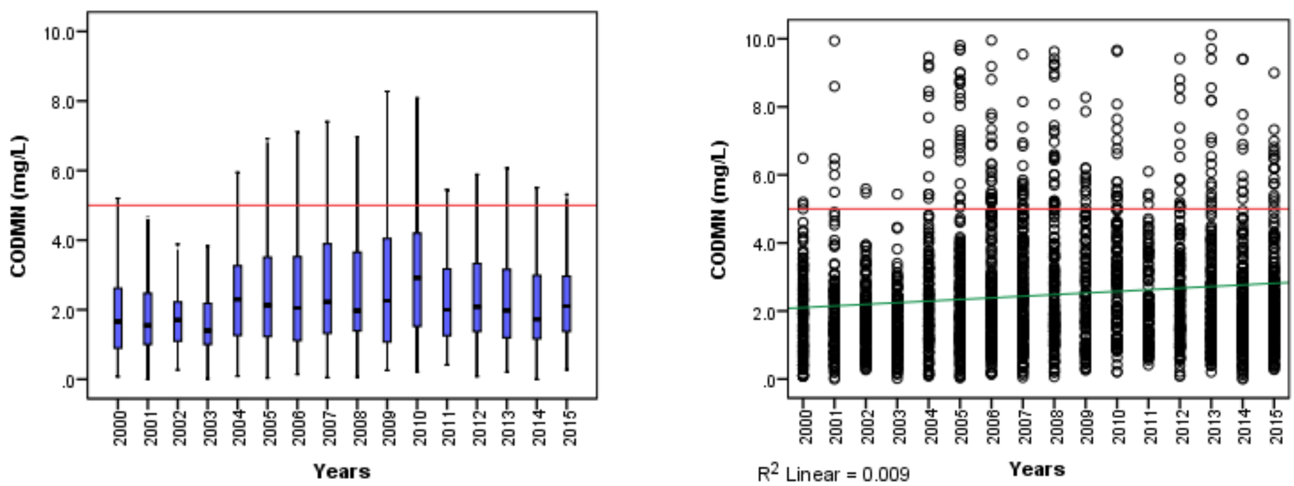

Figure 3.16: Temporal variation in COD (mg/L) in the Mekong River as recorded from 2000 to 2015 (the horizontal line at 5 mg/L represents the threshold values for the MRC Water Quality Guidelines for the Protection of Human Health)

3.2 TRANSBOUNDARY WATER QUALITY

The Mekong River Commission (2008), in its Technical Paper No. 19, identified five main transboundary areas along the Mekong River. These are:

1. People's Republic of China/Lao PDR — a water quality monitoring station was established in Houa Khong in 2004 to monitor the boundary between the Upper and Lower Mekong Basin.

2. Lao PDR/Myanmar — no water quality station exists in this part of the river since it is remote and sparsely populated.

3. Thailand/Lao PDR — a number of monitoring stations exist along this stretch of the Mekong River, including those located in the vicinity of urban areas such as Vientiane, Nakhon Phanom and Savannakhet. However, none of the stations can be referred to as transboundary stations since they receive run-off from both countries and water is normally sampled in the middle of the river.

4. Lao PDR/Cambodia — while not located directly at the border of the two countries, Pakse and Stung Treng monitoring stations have, in the past, been considered as transboundary stations. Data from these stations have been used to assess transboundary effects on water quality.

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

3.2.1 PAKSE VS. STUNG TRENG

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

Figure 3.17 provides a summary of the comparison of 2015 water quality between the two stations. As can been seen in the figure, generally higher concentrations of nitrate-nitrite 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.

An independent t-test was carried out to determine whether the difference observed in mean concentrations of nitrate-nitrite between the two stations was statistically significant. The results of an independent t-test revealed that the difference between mean concentrations of nitrate-nitrite at Pakse (M = 0.15 mg/L, Std. = 0.102) and Stung Treng (M = 0.22 mg/L, Std. = 0.095) was not statistically significant with a P value of 0.098.

Similarly, the results of an independent t-test carried out for total nitrogen at the two stations revealed that the difference observed in mean concentrations at Pakse (M = 0.26 mg/L, Std. = 0.167) and Stung Treng (M = 0.39 mg/L, Std. = 0.18) was not statistically significant, with a P value of 0.085.

Unlike conditions observed for nitrate-nitrite and total nitrogen, concentration levels of ammonium and total phosphorus were fairly similar. With the P value close to 1, the results of an independent t-test carried out for ammonium further confirm that there was no significant difference in the observed means at Pakse (M = 0.05, Std. = 0.061) and Stung Treng (M = 0.05, Std. = 0.031).

Similarly, the P value for total phosphorus was 0.36, which further confirms that the difference in means observed for total phosphorus levels at Pakse (M = 0.33, Std. = 0.611) and Stung Treng (M = 0.16, Std. = 0.161) was not significant.

The average concentration of COD at Stung Treng was recorded at about 1.2 mg/L (Std. = 0.59) compared to 2.4 mg/L (Std. = 1.69) recorded at Pakse, which further indicated that there was likely no transboundary water quality issue between the two stations in 2015. An independent t-test reveals that the difference observed between the two mean values is statistically significant, with a P value of 0.03.

Dissolved oxygen levels observed at the two stations further confirms non-transboundary water quality issues, with higher concentrations generally observed at Stung Treng than Pakse. An independent t-test reveals a statistically significant difference between the mean DO concentrations at Pakse (M = 6.1 mg/L, Std. = 1.36) and Stung Treng (M = 8.2 mg/L, Std. = 0.46), with a P value of 0.00.

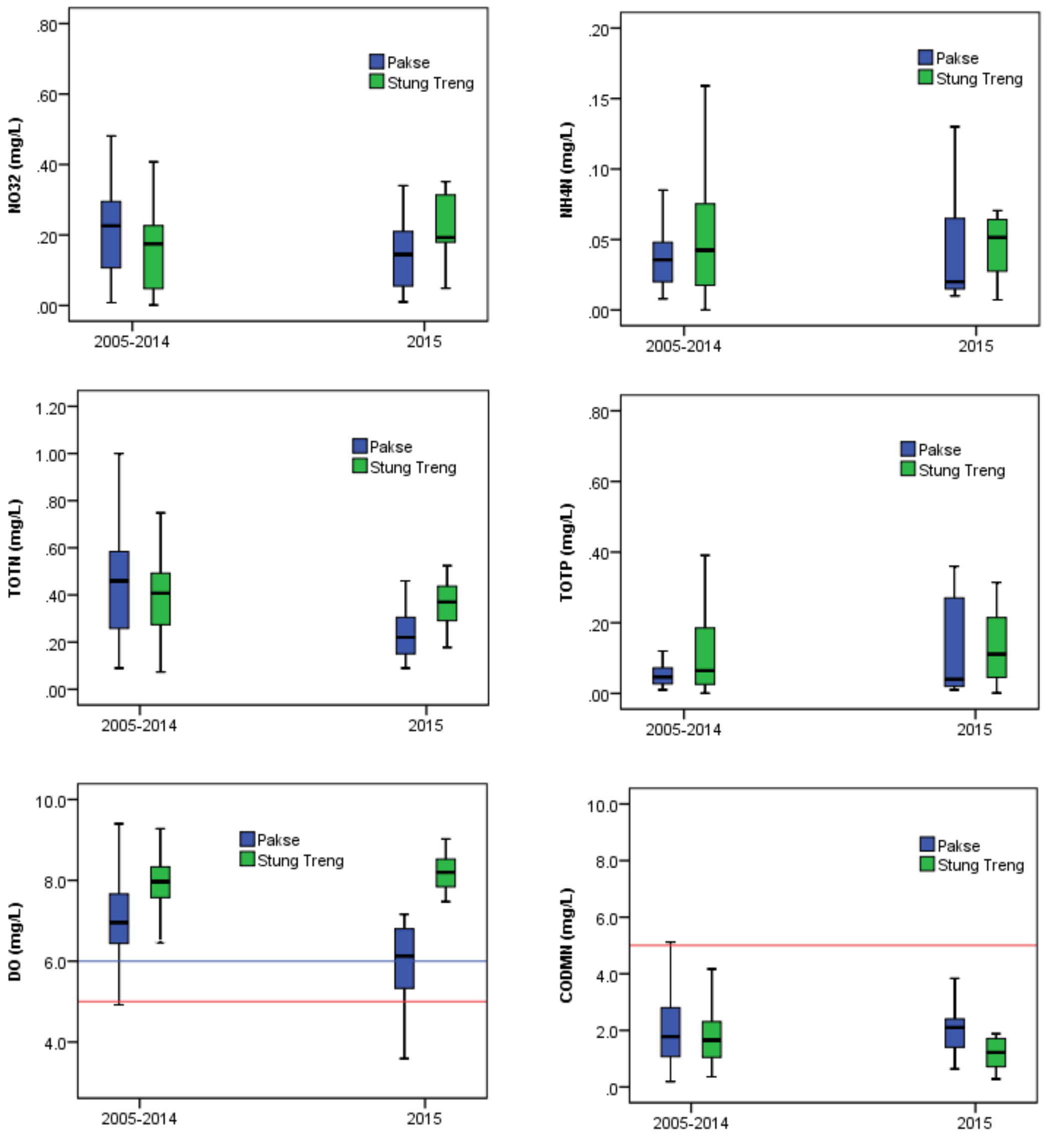

Figure 3.17: Comparisons of water quality data at Pakse and Stung Treng (the horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life)

3.2.2 KAORM SAMNOR VS. TAN CHAU

Kaorm Samnor and Tan Chau monitoring stations are located on the Mekong River, with Kaorm Samnor being on the Cambodian side 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 parameters, including nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen and chemical oxygen demand. The outcomes of these analyses are illustrated in Figure 3.18.

With the exception of total phosphorus levels, water quality in the Mekong River in 2015 was more degraded in Tan Chau than in Kaorm 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 2015, generally higher levels of nitrate-nitrite, ammonium, total nitrogen and chemical oxygen demand concentrations were observed at Tan Chau than at Kaorm Samnor. Statistically, however, independent t-tests reveal the only significant difference to be total nitrogen concentrations and nitrate-nitrite concentrations at the two stations. For total nitrogen, an independent t-test reveals that the difference in the mean concentrations for Kaorm Samnor (M = 0.37 mg/L, Std. = 0.14) and Tan Chau (M = 0.63 mg/L, Std. = 0.23) was statistically significant with a P value of 0.03.

With a P value less than 0.014, an independent t-test reveals that the difference between the mean concentrations of nitrate-nitrite at Kaorm Samnor (M = 0.20 mg/L, Std = 0.12) and Tan Chau (M = 0.37 mg/L, Std = 0.19) was statistically significant.
On the other hand, an independent t-test also failed to show any significant difference between the mean concentrations of ammonium at Kaorm Samnor (M = 0.04 mg/L, Std = 0.016) and Tan Chau (M = 0.07 mg/L, Std = 0.086) with a P value of 0.3. Similarly, an independent t-test reveals that the difference in the mean concentrations of COD at Kaorm Samnor (M = 2.6 mg/L, Std = 2.1) and Tan Chau (M = 2.5 mg/L, Std = 0.52) was not statistically significant, with a P value of less than 0.8.

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 nitrate-nitrite significantly differed between the two stations. However, maximum nitrate-nitrite levels of the two stations (0.39 mg/L for Kaorm Samnor and 0.75 mg/L for Tan Chau) were low when compared to the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (5 mg/L).

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 2015 at both Kaorm Samnor and Tan Chau monitoring stations are still low and have not caused serious impairment to water quality at either station, as evidenced by the relatively high dissolved oxygen recorded at both stations.

Dissolved oxygen levels at Tan Chau were slightly lower than those observed at Kaorm Samnor. This trend is the complete reverse of the trends observed for chemical oxygen demand, nitrate-nitrite, ammonium and total nitrogen at the same stations, which is expected. The difference in mean concentrations of dissolved oxygen is also statistically significant based on the results of an independent t-test, with a P value of 0.00 (Kaorm Samnor (M = 7.5 mg/L, Std. = 0.99) and Tan Chau (M = 5.6 mg/L, Std. = 0.65).

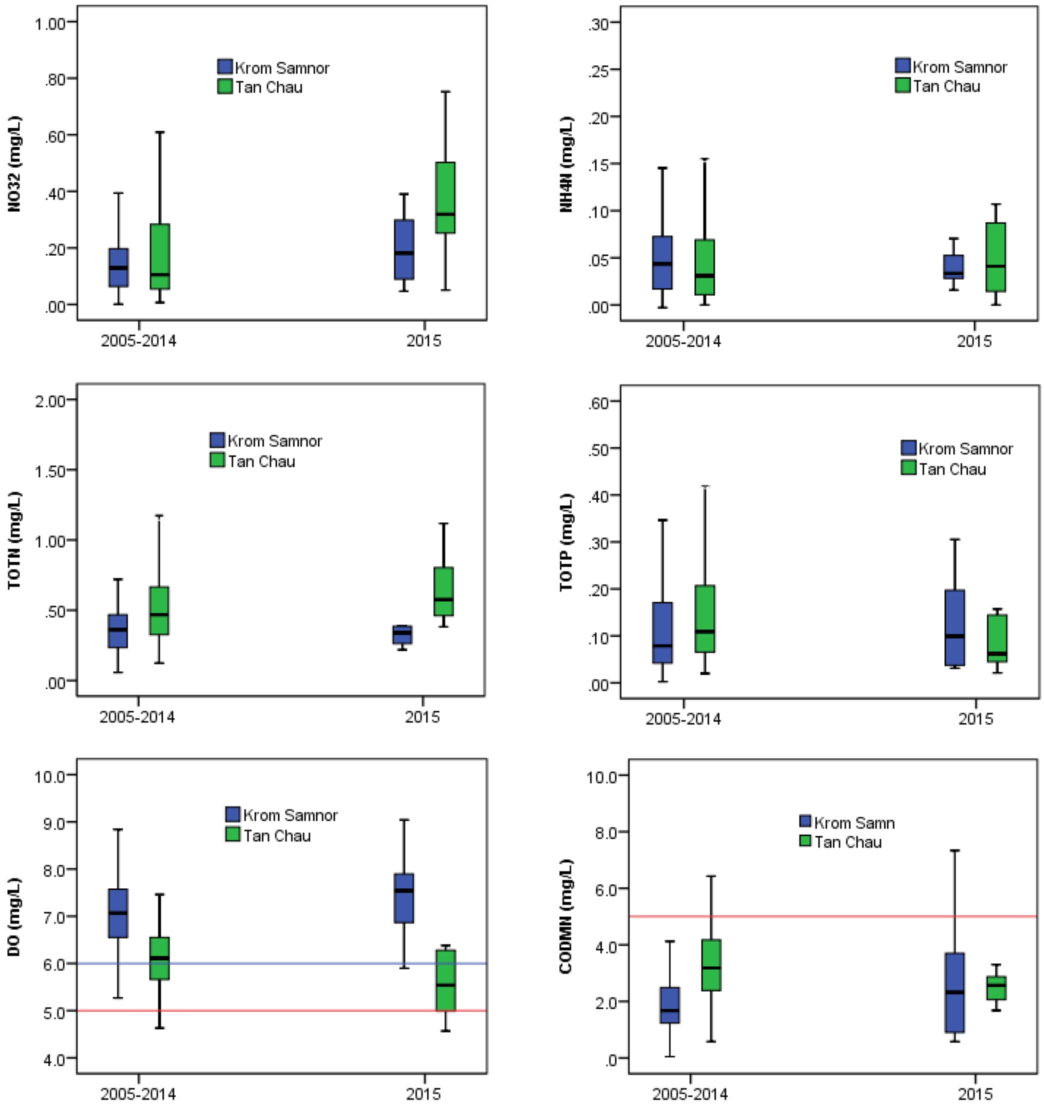

Figure 3.18: Comparisons of water quality data at Kaorm Samnor and Tan Chau (horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life)

3.2.3 KOH THOM VS. CHAU DOC

Similar analysis was carried out for Koh Thom (on the Cambodian side of the river) and Chau Doc (on the Vietnamese side of the river) water quality monitoring stations on the Bassac River to assess potential transboundary water quality issues. Figure 3.19 illustrates comparisons of the concentrations of nitrate-nitrite, ammonium, total nitrogen, total phosphorus, dissolved oxygen and chemical oxygen demand recorded at Koh Thom and Chau Doc monitoring stations in 2015, and from the period of 2005-2014.

In terms of pollutant levels, Figure 3.19 shows that concentrations of nitrate-nitrite, total nitrogen, and chemical oxygen demand were generally higher in the downstream station (Chau Doc) than the upstream station (Koh Thom) in both 2015 and from the period 2005 to 2014. This potentially reflects pollution discharges between the two stations.

The analysis of individual pollutants in 2015 for both stations revealed that the observed difference in the mean concentrations of nitrate-nitrite was statistically significant, with a P value of 0.007. Mean nitrate-nitrite concentrations for Koh Thom and Chau Doc were estimated to be 0.29 mg/L (Std = 0.09) and 0.51 mg/L (Std = 0.24), respectively. However, with the maximum concentrations recorded at 0.40 and 1.02 mg/L for Koh Thom and Chau Doc, respectively, nitrate-nitrite levels at these two stations were still well below the recommended MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (5 mg/L).

It should be noted that these figures were slightly higher than the figures recorded in 2014, when the mean nitrate-nitrite concentrations for Koh Thom and Chau Doc were estimated to be 0.17 mg/L (Std = 0.08) and 0.049 mg/L (Std = 0.18), respectively.

The observed difference in the mean concentrations of chemical oxygen demand between Koh Thom (M = 2.0 mg/L, Std = 0.79) and Chau Doc (M = 3.2 mg/L, Std = 0.78), was statistically significant, with a P value of 0.002. However, the maximum COD concentrations at the two stations (3.5 mg/L for Koh Thom and 4.9 mg/L for Chau Doc) were still below the MRC WQGH (5 mg/L), indicating that there is no transboundary issue.

In the case of total nitrogen, the result of an independent t-test for both stations revealed that the observed difference in the mean concentrations of total nitrogen was not statistically significant, with a P value of 0.07. Mean total nitrogen concentrations for Koh Thom and Chau Doc were estimated to be 0.63 mg/L (Std = 0.32) and 0.85 mg/L (Std = 0.21), respectively.

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 a P value of 0.00. Mean dissolved oxygen concentrations for Koh Thom and Chau Doc were estimated to be 6.9 mg/L (Std = 0.94) and 5.4 mg/L (Std = 0.59), respectively.

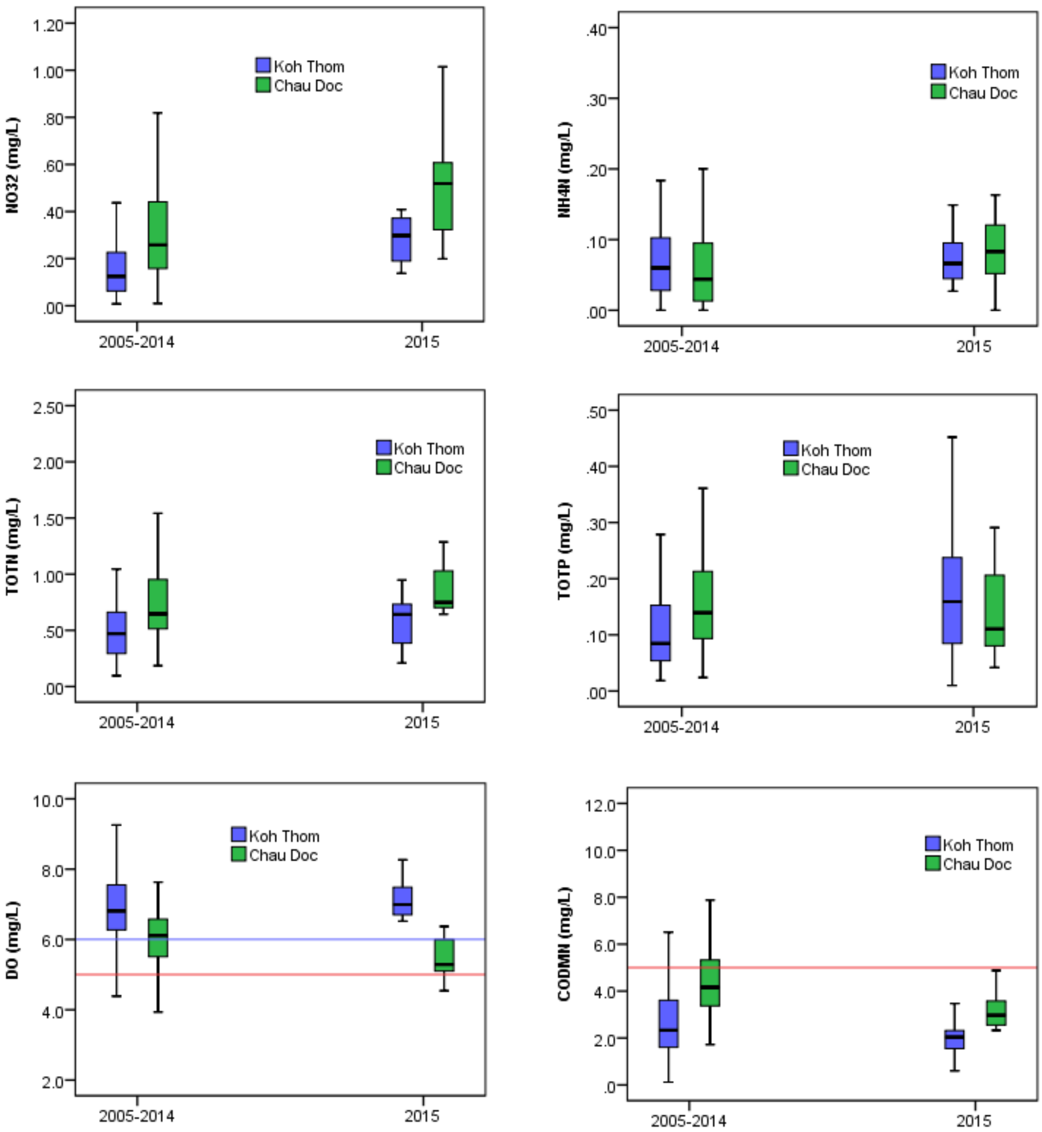

Figure 3.19: Comparisons of water quality data at Koh Thom and Chau Doc (the horizontal lines represent threshold values for the MRC Water Quality Guidelines for the Protection of Human Health and for the Protection of Aquatic Life)

3.3 WATER QUALITY INDICES

3.3.1 WATER QUALITY INDEX FOR THE PROTECTION OF AQUATIC LIFE

In 2015, the water quality of the Mekong and Bassac Rivers was classified from "moderate quality" to "high quality" for the protection of aquatic life (Table 3-3). Of the 17 monitoring stations located in the Mekong River, 3 (Vientiane, Nakhon Phanom, and Khong Chiam) were rated as "high quality" for the protection of aquatic life, while 13 were rated as "good quality" for the protection of aquatic life. My Tho was the only monitoring station to receive a rating of "moderate quality" for the protection of aquatic life. The slight impairment at My Tho Monitoring Station can be attributed to the elevated total phosphorus and nitrate-nitrite concentrations which were recorded in 50% and 67% of sampling occasions, respectively.

In the Bassac River, all stations monitored in 2015 were rated as "good quality" for the protection of aquatic life. Water quality data recorded at these monitoring stations reveal slightly elevated total phosphorus levels, with exceedance observed in 55% of total sampling occasions.

Between 2009 and 2015, water quality of the Mekong and the Bassac Rivers remains relatively unchanged and suitable for all aquatic life with only a minor degree of threat or impairment observed. Compared to 2014, the degrees of water quality impairment for the protection of aquatic life decreased slightly with 3 stations (Chiang Saen, Kampong Cham, and Koh Thom) 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 total phosphorus. In 2015, 47% of the total phosphorus data at these three stations was recorded as exceeding the guideline value for total phosphorus (0.13 mg/L). In comparison, only 17% of the total phosphorus data was recorded as exceeding the guideline value in 2014.

Table 3 3: Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of aquatic life 2009-2015

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

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

3.3.2 WATER QUALITY INDEX FOR THE PROTECTION OF HUMAN HEALTH

An analysis of the 2015 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 quality" or "excellent quality". Of the 22 stations located in the Mekong and Bassac Rivers, 11 stations were rated as "excellent quality" in 2015, while the remaining stations were rated as "good quality". Of the 11 stations rated as "excellent quality", 10 were located in Cambodia and Viet Nam.

From 2009 to 2015, water quality for the protection of human health did not change significantly, with ratings ranging from "moderate quality" to "excellent quality". Compared to 2014, the degree of impairment for the protection of human health increased slightly (lower water quality index scores) at 5 stations (Pakse, Kampong Cham, Neak Loung, Kaorm Samnor, and Koh Khel).

Improvement of water quality in terms of the protection of human health was observed at 4 stations (Houa Khong, Savannakhet, My Tho and Takhamao). Water quality at Houa Khong, My Tho and Takhamao Monitoring Stations were rated as "excellent quality" for the protection of human health in 2015. In comparison, ratings at these same stations were either "moderate quality" or "good quality" in 2014. The improvement can be attributed to the reduction in chemical oxygen demand levels, which only exceeded the guideline value of 5 mg/L in 4% of sampling occasions. For comparison, the exceedance observed at the same stations in 2014 was 19% of sampling occasions.

Table 3 4: Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of human health in terms of human health acceptability 2009-2015

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

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

3.3.3 WATER QUALITY INDEX FOR AGRICULTURAL USE

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

An analysis of electrical conductivity data from 2015 reveals that all electrical conductivity values fell within the guideline value for Water Quality Index for General Irrigation Use of 70 mS/m. The maximum value for electrical conductivity in 2015 was recorded at 53.8 mS/m. With no recorded violation of the guideline values for Water Quality Indices for General Irrigation and Paddy Rice Irrigation, it can be concluded that there was no restriction for all types of agricultural use of Mekong and Bassac River water. The level of impairment of the Mekong and Bassac Rivers' water quality for agricultural use is summarised in Table 3-5.

Table 3 5: Water quality class of the Mekong River (1-17) and Bassac River (18-22) for agricultural use for 2009-2015

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

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

4. Conclusions and Recommendations

4.1 CONCLUSIONS

Based on the results of the 2015 water quality monitoring survey, it can be concluded that the water quality of the Mekong and Bassac Rivers is still of good quality with only a small number of measurements of dissolved oxygen and chemical oxygen demand exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (Tables 3-1 and 3-2), and a small number of measurements of nitrate-nitrite and total phosphorus exceeding threshold values used for calculating water quality indices for the Protection of Aquatic Life (Table 2-4) and Human Health (Table 2-6). The majority of exceedances 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 (70-150 mS/m). However, it should be noted that the Mekong River is generally characterised as a low saline river with average electrical conductivity rarely exceeding 40 mS/m. When compared to 2014 data, water quality of the Mekong and Bassac River improved slightly in 2015.

The temporal analysis of data from 2000 to 2015 suggests that total phosphorus and chemical oxygen demand levels showed an increasing trend, while nitrate-nitrite, ammonium and dissolved oxygen levels remained relatively constant. pH levels showed a slight decrease during the period, but were still well within the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life (6-9). TSS levels in the Mekong River had decreased since 2000. The average TSS concentration of the Mekong River in 2000 was measured at about 118.7 mg/L, whereas in 2015, the average monthly concentration for TSS was measured at about 80.2 mg/L.

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. Maximum 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 water quality of the Mekong and Bassac Rivers for the protection of aquatic life ranged from "moderate" quality to "high" quality in 2015. Of the 22 stations located in the Mekong and Bassac Rivers, 3 were rated as "high" quality, while 18 were rated as "good" quality for the protection of aquatic life. Only one station (My Tho) was rated as "moderate" quality for the protection of aquatic life. The degree of water quality for the protection of aquatic life degraded slightly in 2015 when compared to 2014, with three stations receiving lower rating scores in 2015. The elevated total phosphorus levels in 2015 was the main reason for the observed degradation, with 49% of the data recorded exceeding the threshold value of 0.13, compared to only 17% in 2014.

The analysis of the 2015 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 11 stations rated as "excellent" and 11 stations rated as "good" quality. Compared to 2014, water quality for the protection of human health showed improvement at 3 stations (Houa Khong, My Tho and Takhmao), which resulted from the improvements observed for nitrate-nitrite and chemical oxygen demand levels. Despite the improvement observed at these 3 stations, slight impairments were observed at 5 other stations (Pakse, Kampong Cham, Neak Loung, Kaorm Samnor, and Koh Khel) when compared to 2014 results. From 2009 to 2015, water quality for the protection of human health did not change significantly, with all stations receiving ratings ranging from "moderate" to "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.

Member Countries' efforts to maintain acceptable/good water quality in the Mekong River has led to the development of TGWQ, where a number of additional water quality indicators have been proposed for monitoring in the near future. These indicators have been added taking into account emerging threats to water quality, including population growth, intensive agriculture and aquaculture, navigation, hydropower and industrialisation, which can often lead to increased inputs of chemicals and ultimately affect aquatic ecosystems and human health.

To assist the MRC Member Countries to implement their commitments, especially chapter 1 and chapter 2 of the Technical Guidelines on Water Quality, the MRCS has continued to provide training, PT samples, and additional support to the Member Countries' relevant line agencies. Considering the potential changes in the future monitoring of water quality, the following are recommended for the sustainable implementation of routine water quality monitoring under the MRC WQMN:

4.2 RECOMMENDATIONS

- Improve the knowledge on the relationships between water quality conditions and land use within the Lower Mekong Basin
- Assess temporal and spatial patterns of water quality for the whole Lower Mekong Basin
- In addition to the already monitored conventional water quality parameters, include water quality indicators listed in the draft Chapters 1 and 2 of the TGWQ, which include heavy metals as well as persistent and non-persistent organic substances
- Improve water quality risk assessment and methods for communicating the results of water quality monitoring, including a review of the MRC Water Quality Indices to ensure their consistency with the MRC TGWQ, including the Protection of Human Health and the Protection of Aquatic Life

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