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2011 Annual Water Quality Data Assessment Report

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Environment Programme

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Acronyms

COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
EC	Electrical Conductivity
EHM	Ecological Health Monitoring
EP	Environment Programme
ISO	International Organization for Standardization
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMCs	National Mekong Committees
PWQ	Procedures for Water Quality
QA/QC	Quality Assurance/Quality Control
TSS	Total Suspended Solids
WQCA	MRC Water Quality Criteria for the Protection of Aquatic Life
WQCH	MRC Water Quality Criteria 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
WQIhi	Water Quality Index for Human Impacts
WQMN	Water Quality Monitoring Network

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

Since its inception 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 2011, 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 5 were located in the Bassac River. In all, 18 water quality parameters were monitored on a monthly or bi-monthly basis at each station while additional 6 parameters were monitoring monthly or bi-monthly during the wet season at each station.

The results of the monitoring showed that water quality of the Mekong River is still of good quality with only a few numbers of dissolved oxygen and chemical oxygen demand samples 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 nutrients, total suspended solids and chemical oxygen demand levels exhibited opposite trends as the river flowed from upstream to downstream.

Compared to previous years, nutrient levels increased slightly in 2011 with total phosphorus and ammonium levels showing increasing trends from 1985 to 2011 while nitrate-nitrite levels remain relatively constant. While dissolved oxygen levels remained relatively constant from 1985 to 2011, chemical oxygen demand levels increased slightly during the same time frame. Total suspended solids level showed a noticeable decrease between 1985 and 2011, from an average value of about 300 mg/L to about 80 mg/L.

With the maximum recorded electrical conductivity of 35 mS/m, no restriction on the use of the Mekong and Bassac Rivers water for agricultural purposes was recorded in 2011.

The analysis of the 2011 water quality data using the MRC Water Quality Index for "Human Impacts" reveals that the degree of human impact (pressure exerted by human activities) on water quality of the Mekong and Bassac Rivers ranged from "not impacted" to "severely impacted", with six stations being classified as "severely impacted"

by human activities. Despite six stations being classified as “severely impacted” by human activities, all monitoring stations in the Mekong and Bassac Rivers were rated as “good” or “excellent” for the protection of aquatic life. The results of the ecological health monitoring also confirmed that the biodiversity and ecological capability of the Mekong and Bassac Rivers to support fish and other aquatic functions was still mostly excellent with many ecological health monitoring stations being classified as either “excellent” or “good”.

Overall, it can be concluded that the Mekong and Bassac Rivers are still fairly unpolluted. The water quality in the Delta tends to be more impacted by human activities than in other sections of the Lower Mekong Basin, partly because of more intensive agriculture and higher population densities and cumulative effects of pollutants flowing from upstream to downstream.

1. INTRODUCTION

1. INTRODUCTION

1.1 BACKGROUND

The Mekong River, originating in the Tibetan Plateau, is the longest river in Southeast Asia and the 12th longest river in the world at 4,880 km. It is also the 8th largest river in the world in terms of mean annual discharge (flow) at the mouth, which is about 14,500 m3/s (MRC, 2011). From the Tibetan Plateau, the river flows in a south-easterly direction, running through China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam before discharging into the South China Sea.

At its confluence with the South China Sea, the Mekong River has a total catchment area of about 795,000 km2 (MRC, 2011). The Mekong River is functionally subdivided into seven broad physiographic regions described by topography, drainage patterns and the geomorphology of river channels. The upper three regions (Tibetan Plateau, Three Rivers, and Lancang Basin) make up the Upper Mekong Basin while the lower 4 regions (Northern Highlands, Khorat Plateau, Tonle Sap Basin and the Delta) make up the Lower Mekong Basin (MRC, 2010). 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, 2010).

According to the Mekong River Commission State of the Basin Report (2010), the Lower Mekong River is home to about 60 million people of which about 75% live in rural areas and depend on the Mekong River for livelihoods and food security. The Mekong River is also biodiversity rich with over 850 fish species identified. As such, water quality monitoring is an integral part for 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

To assist the Member Countries detect changes in the environment and take preventive and remedial action if water quality deteriorated, the Interim Mekong Committee (forerunner to the Mekong River Commission) established a Water Quality Monitoring Network (WQMN) in 1985 with the initial involvement of the Lao PDR, Thailand and Viet Nam. Cambodia later joined the WQMN in 1993. Since its inception, the network has provided a continuous record of water quality in the Mekong River and its tributaries by measuring a number of different water quality parameters. In 2011, a total of 48 stations were monitored by the WQNM. Of the 48 stations, 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. As of 2005, all 48 stations were classified as “primary stations,” designed to detect

changes and capture pressures and threats to the Mekong water quality. While only 48 stations were monitored in 2011, at its peak (2009), up to 87 stations were monitored by the WQMN (55 primary stations and 32 secondary stations). A reduction in the number of monitoring stations was made after an analysis found that water quality of the Mekong River is still good and could be reasonably represented by the 48 stations.

WQMN is one of the MRC core function activities that require to be decentralised to the Member Countries. At regional level, the overall management of the WQMN is under the MRC Environment Programme (EP). Since the inception of the WQMN, the EP has provided both technical and financial supports 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 contact details of the designated laboratories can be found in Appendix A. The designated laboratories are responsible for undertaking a 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 a 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 for the MRCS for validation and storage in the MRC data portal; and
- Produce annual water quality data assessment report, outlining the results of water quality monitoring, analysis and assessment.

1.3 OBJECTIVES OF THE REPORT

This report is a compilation of the designated WQMN laboratories' 2011 water quality data and Annual Water Quality Data Assessment Reports. It has been prepared to provide the consolidated results of the water quality monitoring activities, focusing on the implementation of the Procedures for Water Quality and compliance with their associated technical guidelines. However, in addition to the compliance with the technical guidelines the report also addresses indicators for impacts from human activities. As such, the main objectives of this report are to:

- Provide the status of the 2011 water quality of the Mekong River, assessing and summarising water quality monitoring data monitored by the WQMN laboratories in 2011;
- Identify any changes observed in the Mekong River water quality compared to the results of the water quality monitoring of past years;
- With the MRC Water Quality Indices, assess human impacts on the Mekong River water quality and assess the adequacy of the water quality for aquatic life protection and agricultural uses; and

- Provide recommendations for future monitoring and continuous improvement of the water quality monitoring activities.

In addition to this report, periodical report cards are issued with condensed overview information on the environmental conditions of the Mekong River. Report cards cover the compliance with the technical guidelines of the Procedures for Water Quality (human health and ecological health) as well as impacts from human activities.

2. WATER QUALITY MONITORING METHODOLOGY

2. WATER QUALITY MONITORING METHODOLOGY

2.1 FIELD SAMPLING PLAN

2.1.1 Sampling Locations and Frequency

Forty-eight stations were monitored by the WQMN in 2011. 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 2011, 11 stations are located in the Lao PDR, 8 are located in Thailand, 19 are located in Cambodia and 10 are located 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.

In 2011, the monitoring frequencies varied between Member Countries. In the Lao PDR, Thailand and Cambodia, the monitoring of water quality was carried out on a bi-monthly basis while the monitoring in Viet Nam was carried out in a monthly basis. The variation in frequency of the water quality monitoring was first introduced in 2009 and has been implemented by the Member Countries ever since. Prior to 2009, the monitoring of water quality of the Mekong River and its tributaries was carried out uniformly on a monthly basis. However, prior to the start of the 2009 monitoring year, a review was conducted to assess the trend of the Mekong River water quality, and subsequently, the methodology employed by the MRC WQMN to conduct water quality of the Mekong River. During the review, temporal variations of all water quality parameters were assessed and the results indicated that water quality of the Mekong River and its tributaries stayed relatively unchanged from 1985 to 2008. Consequently, a joint decision was made by the Mekong River Commission Secretariat and the Member Countries to reduce the monitoring frequency in the Lao PDR, Thailand and Cambodia where the Mekong River and its tributaries are characterised as free flowing and well

Table 2-1. A summary of 2011 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	Bi-monthly
Thailand	8	3	0	5	Bi-monthly
Cambodia	19	6	3	10	Bi-monthly
Viet Nam	10	3	2	5	Monthly
Total	48	19	5	26	Bi-monthly or Monthly

Table 2-2. Water quality monitoring stations in the Mekong and Bassac Rivers numbered in sequential from upstream to downstream and as monitored in 2011

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 Chaim	H013801	Mekong River	Thailand	15.3183	105.5000
8	Pakse	H013900	Mekong River	Lao PDR	15.1206	105.7837
9	Stung Trieng	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	Khos 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

mixed. The reduction of the monitoring frequency also helped reduce cost for operating the MRC WQMN in each Member Countries.

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 2011. 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.

2.1.2 Sampling Techniques

In an effort to standardise the sampling techniques, the Environment Programme has continued to work with the designated laboratories of the Member Countries to identify appropriate sampling techniques for collecting water samples. Through

Figure 2.1. An illustration of water quality monitoring stations of the MRC WQMN in the Lower Mekong Basin

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;
- 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 was developed in accordance with ISO/IEC 17025-2005 and personnel safety procedures when collecting water samples and measuring water quality parameters.

2.2 LABORATORIES ANALYSIS

2.2.1 Water Quality Parameters 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 2011, 18 water quality parameters were measured by the MRC WQMN (Table 2-3). Of the 18 parameters measured in 2011, 12 are routine water quality parameters that are required to be measured for each sample month. The other 6, major anions and major cations, are required to be analysed for each sample taken between April and October (the wet season).

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 20th 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 ($NO_{2\text{-}3}$-N)	4500-$NO_{2\text{-}3}$/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

* Only measured during the wet season in Lao PDR, Thailand and Cambodia on a bi-monthly basis and Viet Nam on a monthly basis.

2.3 DATA ASSESSMENT AND REPORTING

2.3.1 Water Quality Objectives and Guidelines

Recognising the rapid development within the Lower Mekong Basin and also the importance of Mekong riverine environment on economic and social well-being, the Governments of the Lao PDR, Thailand, Cambodia and Viet Nam signed an Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin in 1995 (also known as the 1995 Mekong Agreement). The Procedures for Water Quality, approved in 2011, define water quality objectives of the 1995 Mekong Agreement – "to maintain acceptable/good water quality."

To assist the Member Countries fulfil their obligations and implement the Procedures for Water Quality, Technical Guidelines for Implementation of Procedures for Water Quality were developed, comprising water quality guidelines for the protection of human health and aquatic life (Appendix A and Appendix B). These guidelines were developed specifically for the Mekong region and based on the national guidelines of the Member Countries. While they have not been officially approved by the MRC Joint Committee, the guidelines have been finalised by the Technical Body on Water Quality, a regional working group established to develop the guidelines, and have been used by the Member Countries to assess the Mekong River water quality.

2.3.2 Data assessment

The maximum, average and minimum values of each water quality parameter were analysed for each monitoring station for 2011. 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 exceedances that need special attention.

Additionally, variations of key water quality parameters were assessed spatially and temporally. Variations along the mainstream were assessed for data obtained in 2011. Trend analysis of water quality from 1985 to 2011 was also carried out for selected water quality parameters. Box-and-whisker plots were used to characterise water quality data spatial and temporal analysis. Box-and-whisker plot is a useful statistical tool which can be used to explore a dataset and show key statistics associated with that dataset. In particular, when using box-and-whisker plot 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.

Another way to assess the water quality of the Mekong River is through the use of the MRC Water Quality Indices which combine

Equation 2.1

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

Where,

"Pi" is the points score of sample day **i**. If each of the parameters listed in Table 2-4 meeting its respective target value in Table 2-6, it respective weighting are 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. Weight for each parameter used for calculating indices for human impact on water quality and for the protection of aquatic life

Parameters	Target Values[1]	Weighting Factors[2]
Human Impact on Water Quality		
DO (mg/L)	≥ 6	1
NH_4 – N (mg/L)	< 0.05	1
COD (mg/L)	< 5	1
T-P (mg/L)	<0.08	1
Protection of Aquatic Life		
pH	6 – 9	2
EC (mS/m)	< 70	2
NH_3 (mg/L)	< 0.2	2
DO (mg/L)	> 5	2
NO_{2-3} – N (mg/L)	< 0.7	1
T-P (mg/L)	< 0.13	1

[1] Water Quality Guidelines found in Chapters 1 and 2 of the Technical Guidelines for the Implementation of the Procedures for Water Quality (TGWQ) are used for this 2011 Annual Water Quality Data Assessment Report, where available. It should be noted, however, that while Chapters 1 and 2 of the TGWQ are finalised by the Technical Body for Water quality, it has not been officially endorsed by the MRC Joint Committee. The missing target values were supplemented with previous established values for the MRC Water Quality Indices. The use of water quality guidelines of the Technical Guidelines for the Implementation of the Procedures for Water Quality may caused the results of the assessment found in this report to be differ from assessment found in other MRC's reports and publications.

[2] Point score (p) for meeting water quality target values.

Table 2-5. Rating systems for the MRC Water Quality Indices

Rating Score	Class
Human Impact on Water Quality	
10 ≥ WQI ≥ 9.5	A: Not Impacted
9.5 > WQI ≥ 8.5	B: Slightly Impacted
8.5 > WQI ≥ 7	C: Impacted
WQI < 7	D: Severely Impacted
Protection of Aquatic Life	
10 ≥ WQI ≥ 9	A: High Quality
9 > WQI ≥ 8	B: Good Quality
8 > WQI ≥ 7	C: Moderate Quality
WQI < 7	D: Poor Quality

Agricultural Use			
	Degree of Restriction Based on Conductivity		
	A: None	**B: Some**	**C: Severe**
General Irrigation (EC_mS/m)	< 70	70 - 300	> 300
Paddy Rice Irrigation (EC_mS/m)	< 200	200 - 480	> 480
Livestock and Poultry (EC_mS/m)	< 500	500 - 800	> 800

the results for several parameters into one overall value describing the water quality. The indices were developed based on reviews of scientific literature and statistical characteristics of available water quality data obtained through the MRC WQMN. They can be used to express overall water quality of the Mekong River and its tributaries at specific location and time based on several water quality parameters. They can also be used to turn complex water quality data into information that can be understood by the public.

To assist the Member Countries interpret the results of the MRC WQMN data, three water quality indices were developed and adopted in July 2006 (Wilanders, 2007). These include:

- 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 3 categories: (i) general irrigation, (ii) irrigation of paddy rice, (iii) livestock and poultry.

While one formula (Equation 2.1) is used to determine the value for each water quality indicator, the type and number of water quality parameters used are varied depending on the objective of the assessment (i.e. assessing the suitability of water quality for the protection of aquatic life, etc.). The

numbers and types of water quality parameters used for each index are outlined in Table 2-5, together with their target values and weighting for meeting the target values. The table also provides a classification of the water quality based on the calculation of the rating score.

2.4 QUALITY ASSURANCE AND QUALITY CONTROL

Recognising the needs 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 designated laboratory in Viet Nam has received ISO/IEC 17025-2005 certification. The certification was gained in 2007 and 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 ensuring sampling teams are equipped with appropriate sampling and safety equipments and preservative chemical reagents;
- Apply quality control during sampling which consist 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 equipments;
- 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 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

Tables 3-1 and 3-2 provide comparison of the maximum, mean and minimum values of key water quality parameters of the 22 stations located in the Mekong and Bassac Rivers between 2011 and 1985-2010. These data are also assessed against the proposed MRC water quality criteria for the protection of human health and for the protection of aquatic life. As can be seen in the table, exceedances are only observed when comparing the 2011 water quality data with the MRC water quality criteria for human health. No single water quality value was observed to exceed the MRC water quality criteria for the protection of aquatic life.

Of the key water quality parameters measured in 2011 (Tables 3-1 and 3-2), only three parameters had some or all measured values not complying with the MRC water quality criteria for the protection of human health. These included:

- Electrical Conductivity (EC) with all values 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 generally 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. In 2011, all samplings in the Delta, for both the Mekong River and the Bassac River, were carried out during low tide which explains the low levels of electrical conductivity recorded in 2011.
- Dissolved oxygen (DO) concentrations at some stations were observed to be lower than the suggested MRC water quality criteria for the protection of human health. The value of 5.5 mg/L was recorded as the minimum value for both the Mekong River and the Bassac River. This value is slightly below the water quality criteria for the protection of human health. This value, however, is higher than the suggested criteria for the protection of aquatic life.
- Chemical oxygen demand (COD) concentration for some stations in the Mekong River and the Bassac River slightly exceeded the water quality criteria for the protection of human health (5 mg/L). The maximum value observed along the Mekong River in 2011 was 6.1 mg/L while the maximum value observed along the Bassac River was 6.4 mg/L. However, the average COD values were estimated to be about 2.2 mg/L and 3.3 mg/L, respectively for the Mekong River and the Bassac River.

Compared to historical data (1985-2010), the average pH, TSS, EC, and DO values decreased slightly in 2011. On the other hand, the average nutrient values (NH4, NO3-2, TOT-P) increased slightly in 2011 compared to the 1985-2010 data. Water quality trend for each water quality parameter will be discussed in more detailed in the following sections.

Table 3-1. A comparison of water quality data of the Mekong River between 1985-2010 and 2011

Parameters	Unit	Water Quality Guidelines		1985-2010 Water Quality Data[3]				2011 Water Quality Data			
		Protection of Human Health (WQCH)	Protection of Aquatic Life (WQCA)	Max	Mean	Min	St Dev	Max	Mean	Min	St Dev
Temperature		Natural	Natural	38.0	26.8	13.0	3.1	31.5	27.2	18.0	2.5
pH	-	6 – 9	6 – 9	9.7	7.6	3.8	0.5	8.2	7.2	6.5	0.4
TSS	mg/L	-	-	5716	173	0.1	296.8	323	82	4	74.2
EC	mS/m	70 – 150	-	841	21	1	31.4	35	18	9	6.0
NO_{3-2}	mg/L	5	5	1.42	0.24	0.01	0.16	1.19	0.26	0.01	0.19
NH_4N	mg/L	-	-	2.99	0.05	0.01	0.12	1.11	0.06	0.00	0.11
TOT-N	mg/L	-	-	4.89	0.61	0.01	0.40	2.38	0.49	0.04	0.33
TOT-P	mg/L	-	-	2.11	0.09	0.01	0.11	0.43	0.12	0.01	0.11
DO	mg/L	≥ 6	> 5	13.9	7.3	1.0	1.1	9.0	7.1	5.5	0.7
CODMN	mg/L	5	-	16.4	2.2	0.0	1.7	6.1	2.2	0.4	1.3

Table 3-2. A comparison of water quality data of the Bassac River between 1985-2010 and 2011

Parameters	Unit	Water Quality Guidelines		1985-2010 Water Quality Data[3]				2011 Water Quality Data			
		Protection of Human Health (WQCH)	Protection of Aquatic Life (WQCA)	Max	Mean	Min	St Dev	Max	Mean	Min	St Dev
Temperature		Natural	Natural	34.0	29.1	23.8	1.8	33.5	28.2	24.5	1.9
pH	-	6 – 9	6 – 9	9.4	7.2	6.1	0.4	7.5	7.0	6.5	0.2
TSS	mg/L	-	-	636	71	0	82	276	84	10	63
EC	mS/m	70 – 150	-	64	13	1	5	22	13	8	4
NO_{3-2}	mg/L	5	5	1.99	0.24	0.00	0.19	1.20	0.33	0.03	0.27
NH_4N	mg/L	-	-	3.04	0.05	0.00	0.12	0.62	0.08	0.00	0.11
TOT-N	mg/L	-	-	4.03	0.74	0.03	0.43	1.56	0.67	0.17	0.35
TOT-P	mg/L	-	-	1.78	0.12	0.00	0.12	0.45	0.16	0.04	0.10
DO	mg/L	≥ 6	> 5	12.3	6.4	1.9	1.1	9.9	6.5	5.5	0.9
CODMN	mg/L	5	-	13.1	3.2	0.0	1.8	6.4	3.3	1.1	1.4

[3] Water quality data from 1985-2010 included those collected during high tide.

3.1 ANALYSIS OF WATER QUALITY TRENDS

3.1.1 pH

pH is one of the key water quality parameters monitored by the MRC Water Quality Monitoring Network. This is because pH can affect the dynamic 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.

Recognising the importance of pH on the Mekong Riverine environment, the Member Countries have agreed to establish water quality criteria 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 criteria (Table 3-1), the results of the 2011 monitoring revealed that the pH values along Mekong River were within the water quality criteria for pH (pH values of 6 to 9 for both the protection of human health and the protection of aquatic life). In 2011, the highest pH level was observed at Vientiane monitoring station (pH of 8.2) while the lowest pH level was observed at Stung Trieng monitoring station (pH of 6.5). Both, however, are well within the water quality criteria for pH.

The spatial trend for pH in the Mekong River and in the Bassac River is shown in Figure 3-1. As can be seen in the figure, pH values tend to be higher in upstream stations

Figure 3.1. Variation in pH levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2011

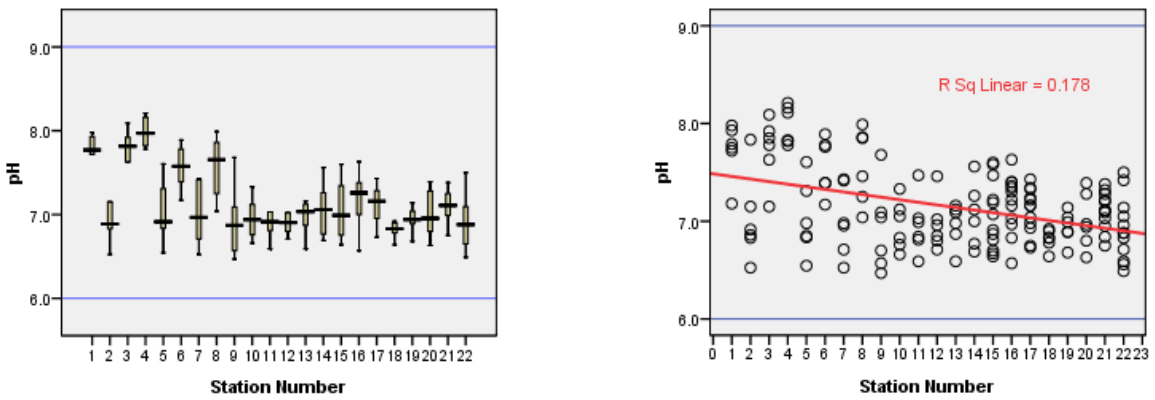


Figure 3.2. Annual variation of pH levels in the Mekong River from 1985 to 2011

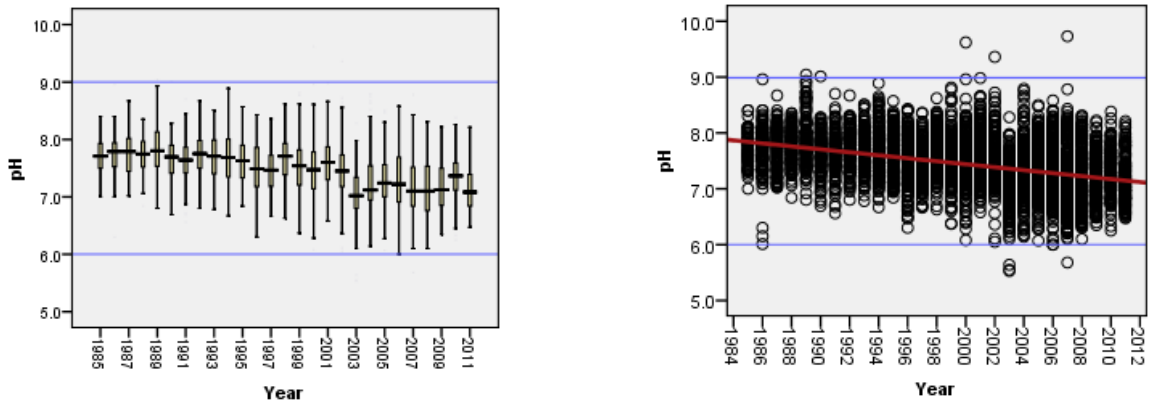
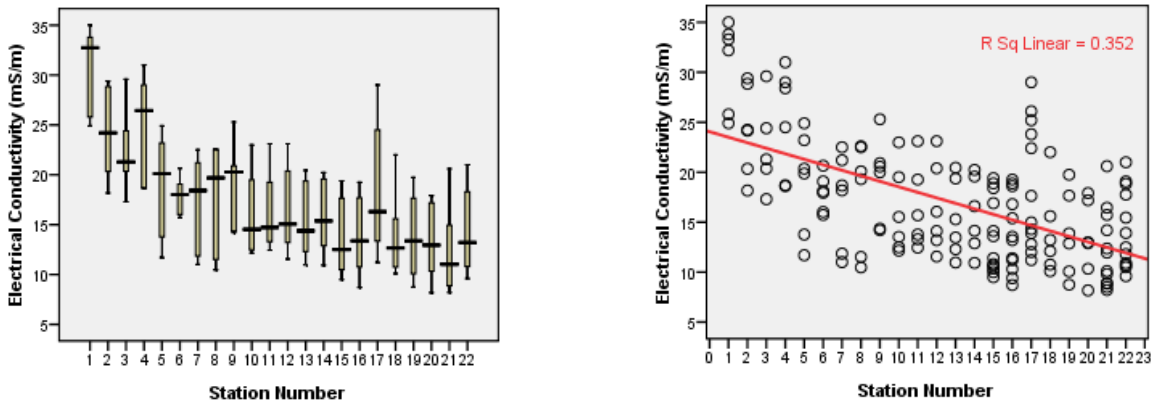


Figure 3.3. Variation in Electrical Conductivity levels along the Mekong River (1-17) and Bassac River (18-22) as observed in 2011



with all mainstream stations monitored in Lao PDR (Stations 1, 3, 4, 6 and 8) having pH levels higher than the neutral level (pH of 7). On the other hand, the lowest pH levels were observed at the stations in the Mekong Delta.

3.1.2 Electrical Conductivity (EC)

Electrical conductivity is another useful water quality indicator monitored by the MRC WQMN. It provides a valuable baseline that has been used to identify any emerging effects of development on water quality of the Mekong River.

Based on the results of the monitoring, the Mekong River can be characterised as a river with relatively low conductivity with values ranged from 8 mS/m to 35 mS/m (Table 3-1). Compared to the MRC water quality criteria for the protection of human health, the electrical conductivity values observed in 2011 fell outside the recommended range of 70 to 150 mS/m. This, however, should not be seen as non-compliance since historically the electrical conductivity values of the Mekong River are generally low with the average EC value of 19 mS/m from 1985 to 2010.

Figure 3.4. Variation in TSS concentrations along the Mekong River (1-17) and Bassac River (18-22) as observed in 2011

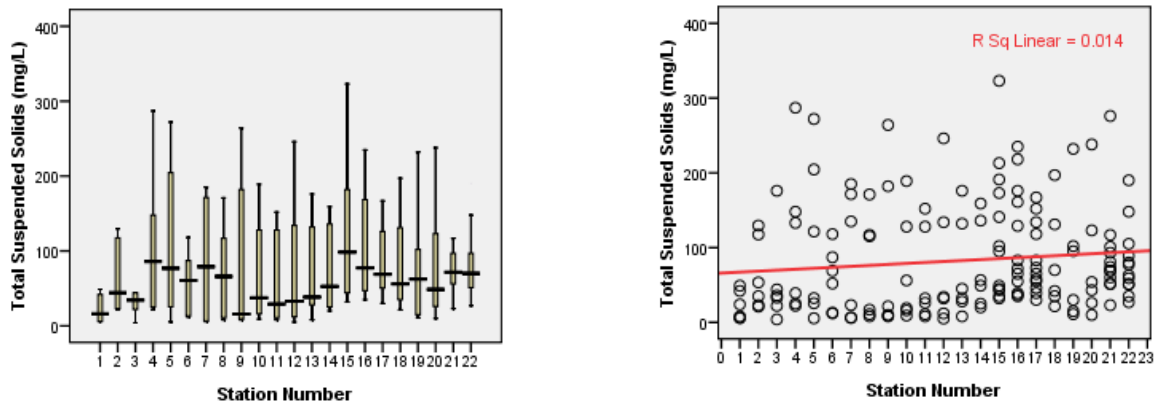
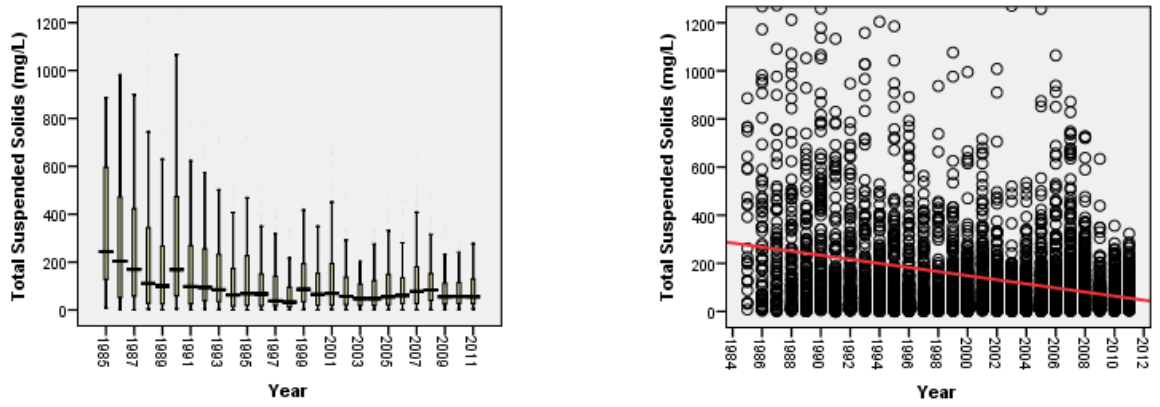


Figure 3.5. Temporal variation in TSS in the Mekong River from 1985 to 2011



The spatial trend of electrical conductivity along the Mekong River, as shown in Figure 3-3, reveals that electrical conductivity values were highest in upstream stations and lowest in downstream stations. It should be noted however that water quality samplings in the Mekong Delta were taken during the 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.

3.1.3 Total Suspended Solids

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[4], but currently provides an indication of long term trend in sediment content in the Mekong River.

[4] Analytical methods used by the designated laboratories may vary. However, all methods must meet international standard ISO/IEC 17025-2005.

Figure 3.6. Spatial variation in nitrate-nitrite concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2011

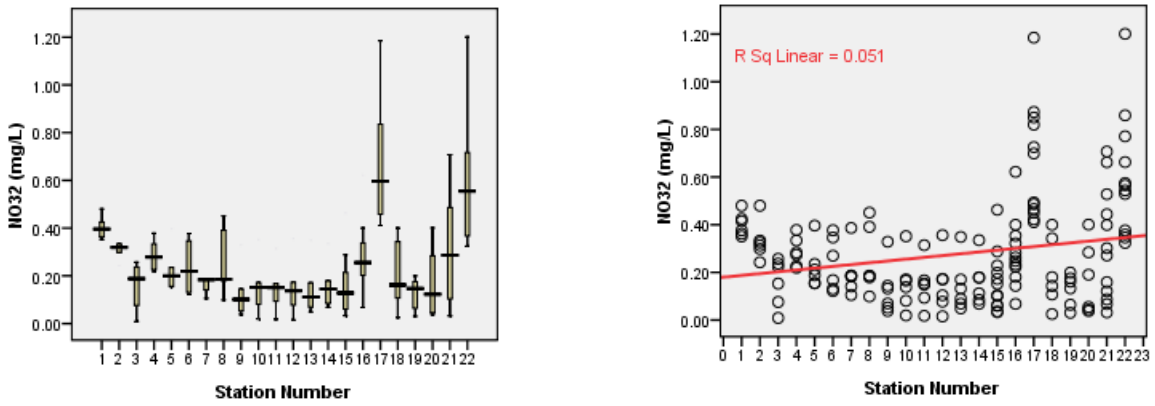
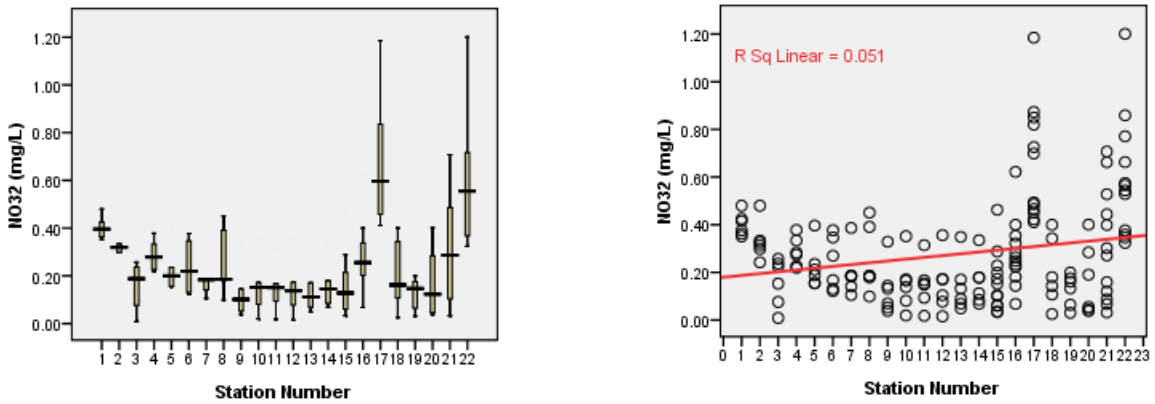


Figure 3.7. Temporal variation in nitrate-nitrite concentration in the Mekong River from 1985 to 2011



In 2011, the TSS concentrations observed along the Mekong and Bassac Rivers were highly variable, ranging from 4 mg/L to 323 mg/L. The average TSS concentration was observed to be about 82 mg/L (Table 3-1). The lowest TSS concentration was observed during the dry season at Luang Prabang Station in the Lao PDR while the highest TSS concentration was observed during the wet season at Tan Chau Station in Viet Nam.

Figure 3-4 shows the variation in TSS along the Mekong and Bassac Rivers in 2011. The spatial analysis of the 2011 data reveals that TSS concentrations increased slightly as the Mekong River flows from upstream stations to the Delta with the different in magnitude of about 15 mg/L. The temporal analysis of data from 1985 to 2011 suggests a TSS decreasing trends with greatest reduction observed between 1985 and 1991. However, since 1991 the median values of Total Suspended Solids have remained relatively constant (Figure 3.5).

3.1.4 Nutrients

In 2011, the MRC WQMN designated laboratories monitored concentrations of nitrite-nitrate, ammonium and total phosphorus as part of nutrients monitoring. Based on the 2011 monitoring results, the concentrations of nutrients at all main-

Figure 3.8. Spatial variation in ammonium concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2011

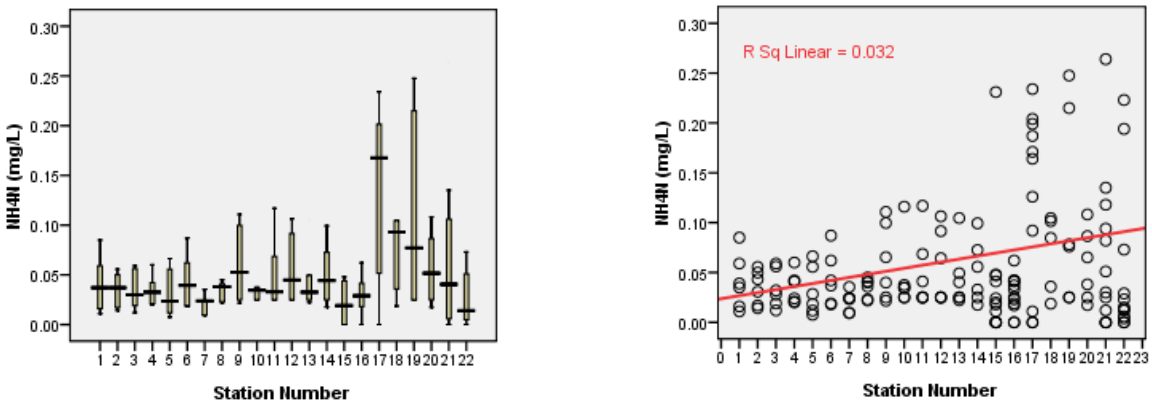
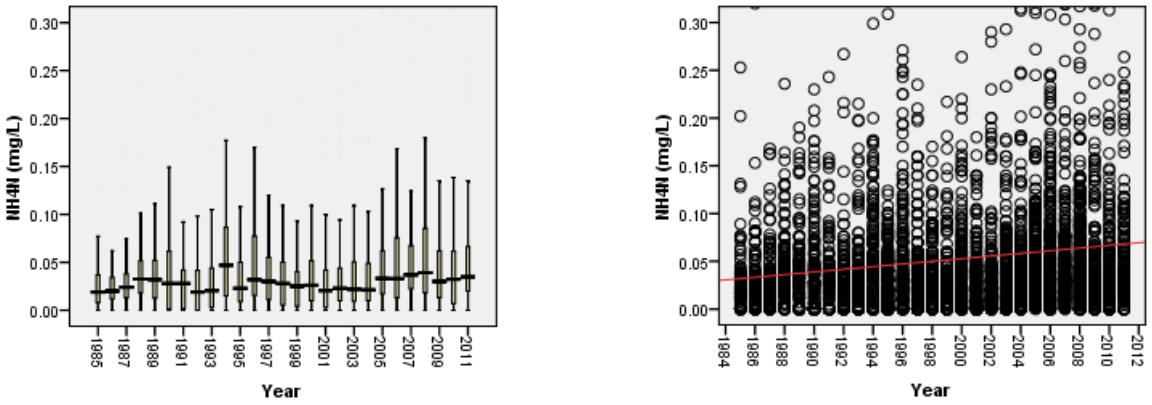


Figure 3.9. Temporal variation in ammonium concentration in the Mekong River from 1985 to 2011



stream stations in the Mekong River and Bassac River remained well below the MRC water quality criteria for the protection of human health and for the protection of aquatic life (Table 3-1).

The spatial variations of nitrate-nitrite concentrations are shown in Figure 3-6 which show slightly elevated nitrate-nitrite concentrations at My Tho (17) and Can Tho (22) monitoring stations. Both are located in the Mekong Delta. However, the measured values are well below the MRC water quality criteria for the protection of human health and aquatic life (5 mg/L). In 2011, nitrate-nitrite concentrations exhibited a u-shape trend as the river flows from upstream to downstream with the highest concentrations observed in the Delta, indicating potential increase nitrate-nitrite contaminated effluents, possibly due to intensive agricultural activities and urbanisation (MRC, 2010).

Temporal analysis of nitrate-nitrite concentration from 1985 to 2011 reveals that nitrate-nitrite concentrations in the Mekong River did not change significantly (Figure 3-7).

Ammonium concentrations remained relatively low in 2011 (Figure 3-8). The highest concentrations were measured in stations located in the Mekong Delta, particularly at My Tho (17) and the Cambodian side of the

Bassac River (Khos Khel - 19). Ammonium concentrations at these stations also varied greatly month to month. For example, at Khos Khel , the minimum concentration for ammonium was measured to be 0.025 mg/L while the maximum concentration was reported to be 0.248 mg/L.

Temporal analysis of data from 1985 to 2011 for the Mekong River reveals that ammonium concentration increased slightly (Figure 3-9), a potential reflection of increased human activities in the Mekong Basin and increased in untreated agricultural waste and human effluent.

Total phosphorus trends follow those of nitrate-nitrite and ammonium, increasing as the Mekong River flows downstream (Figure 3-10). In 2011, the lowest concentrations of total phosphorus were generally found in upstream stations where the concentrations were less than 0.2 mg/L. Total phosphorus concentrations of some downstream stations were slightly elevated, including Kampong Cham, Tan Chau, My Thauan and My Tho in the Mekong River and Can Tho in the Bassac River, where it reached as high as 0.448 mg/L. A result of increase human activities (agricultural run-off and municipal wastewater discharge)

Figure 3.10. Spatial variation in total phosphorus concentrations in the Mekong River (1-17) and Bassac River (18-22) in 2011

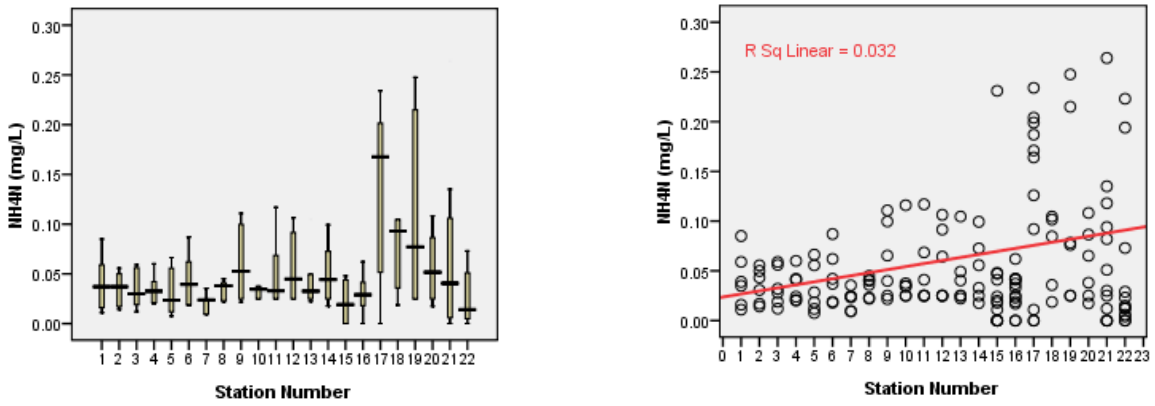


Figure 3.11. Temporal variation in total phosphorus concentration in the Mekong River from 1985 to 2011

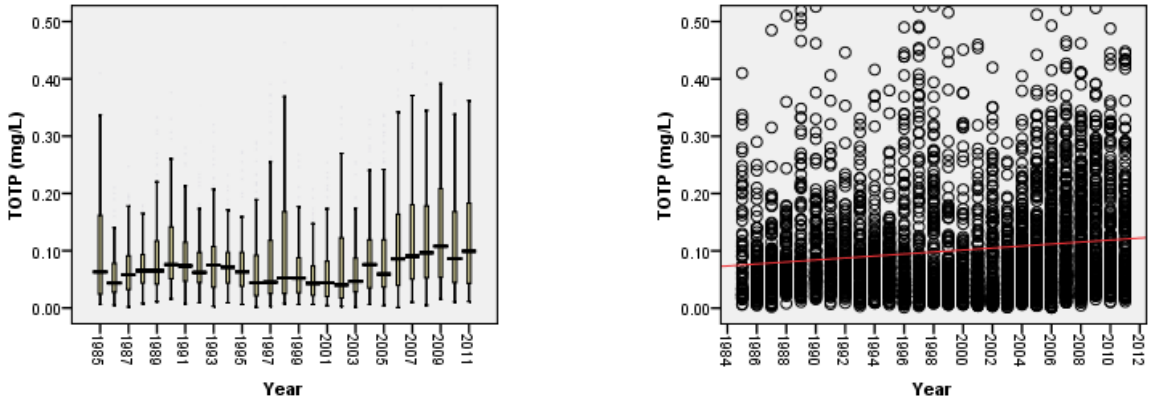
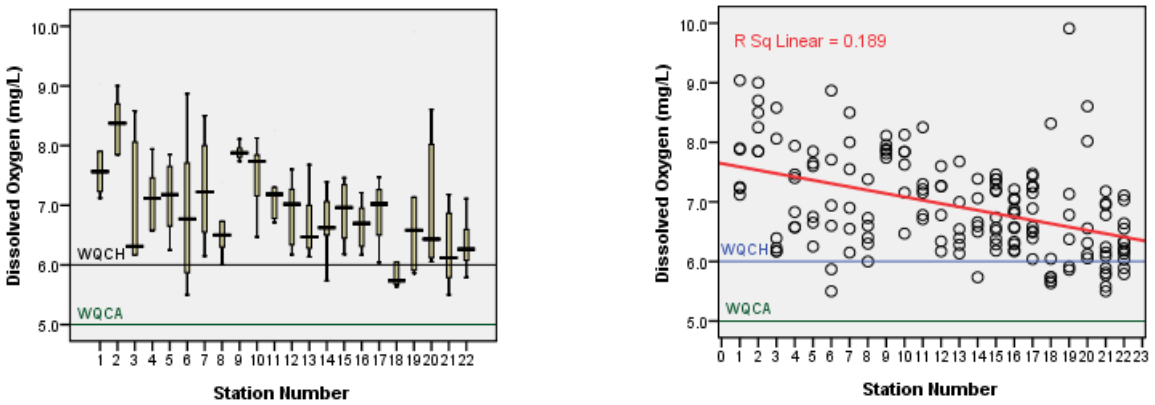


Figure 3.12. Variation in dissolved oxygen (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2011



as the Mekong River traverses downstream was likely the reason for the downstream increasing trend.

Between 1985 and 2011, total phosphorus concentrations in the Mekong River increased slightly (Figure 3-11). The temporal trend is similar to the trend observed for ammonium and likely a reflection of increase nutrient contaminated agricultural runoff and urban effluents.

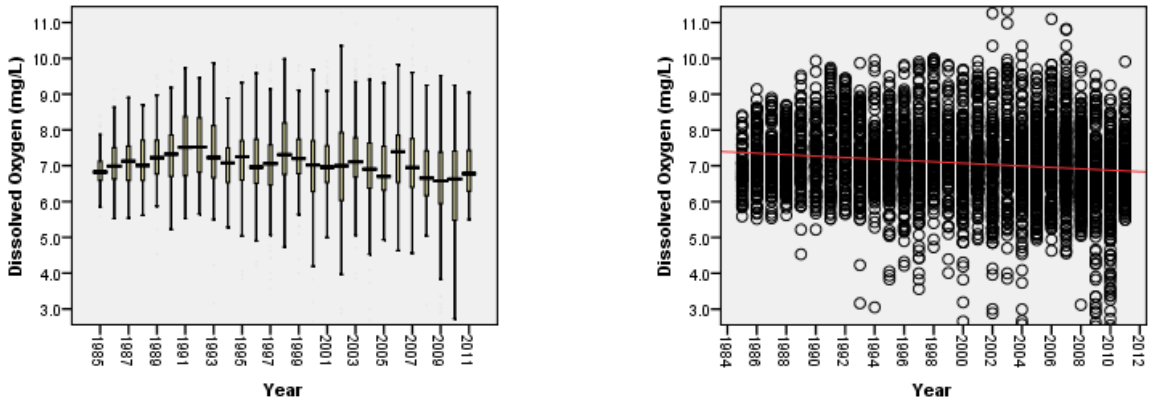
3.1.5 Dissolved Oxygen and Chemical Oxygen Demand

Dissolved oxygen (DO) is one of the key water quality parameters monitoring routinely by the MRC Water Quality Monitoring Network. To maintain acceptable/good water quality, having 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 water quality of the Mekong River, the MRC member countries have jointly established target values for the protection of human health (WQCH) (≥ 6mg/L) and aquatic life (WQCA) (> 5 mg/L).

2011 dissolved oxygen data was compared with the MRC water quality criteria for the protection of human health and aquatic life. The results of the analysis reveal that Savannakhet, Krom Samnor, Takhmao, Khos Khel , Chau Doc, and Can Tho stations have dissolved oxygen levels below the MRC water quality criteria for the protection of human health (WQCH) (≥ 6mg/L). Despite the violation of the MRC water quality criteria for the protection of human health, dissolved oxygen for all mainstream stations were above the MRC water quality criteria for the protection of aquatic life.

At Savannakhet, the average dissolved oxygen concentrations was reported to be about 6.9 mg/L while the maximum and minimum dissolved oxygen concentrations were recorded at 8.9 and 5.5 mg/L, respectively. The average dissolved oxygen concentrations at Krom Samnor was reported

Figure 3.13. Temporal variation in dissolved oxygen concentration in the Mekong River from 1985 to 2011



to be about 6.7 mg/L while the maximum and minimum dissolved oxygen concentrations measured at the station in 2011 were recorded at 7.4 mg/L and 5.7 mg/L, respectively.

At Takhmao, about 83% of dissolved oxygen values measured were reported to be lower than the MRC water quality criteria for human health with the maximum, average and minimum values of 8.3 mg/L, 6.2 mg/L, and 5.6 mg/L, respectively. The minimum measured dissolved oxygen concentration at Khos Khel was 5.9 mg/L which was slightly below the MRC water quality criteria for the protection of human health (6 mg/L) while average and maximum concentrations were reported to be 7.0 mg/L and 9.9 mg/L, respectively.

At Chau Doc and Can Tho, the average dissolved oxygen concentrations were reported to be about 6.2 and 6.4, respectively, while the minimum measured values at the two stations were 5.5 and 5.8 mg/L, respectively. The maximum measured dissolved oxygen values at Chau Doc and Can Tho were 7.2 and 7.1 mg/L, respectively.

The analysis of spatial variation of dissolved oxygen along the mainstream reveals that on average dissolved oxygen concentration decreased as the Mekong River flows downstream (Figure 3-12). Upstream stations were generally observed to have higher dissolved oxygen concentrations which are likely reflection of fast-flowing water and relatively low organic contents (as seen in Figure 3-14). Among the mainstream stations, Savannakhet Station was observed to have widest DO range with minimum and maximum DO concentrations of 5.5 mg/L and 8.9, respectively.

A temporal analysis of dissolved oxygen in the Mekong River from 1985 to 2011 reveals that dissolved oxygen concentrations in the mainstream did not change significantly during the time period. Figure 3.13 also shows that there was no significant difference in the median value of dissolved oxygen between 1985 and 2011.

Figure 3.14. Variation in COD (mg/L) at 22 stations along the Mekong (1-17) and Bassac (18-22) Rivers in 2011

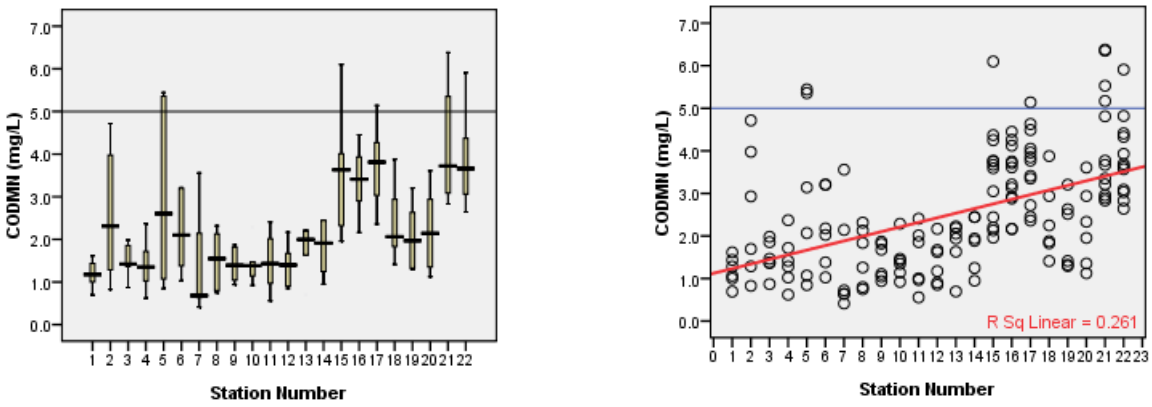
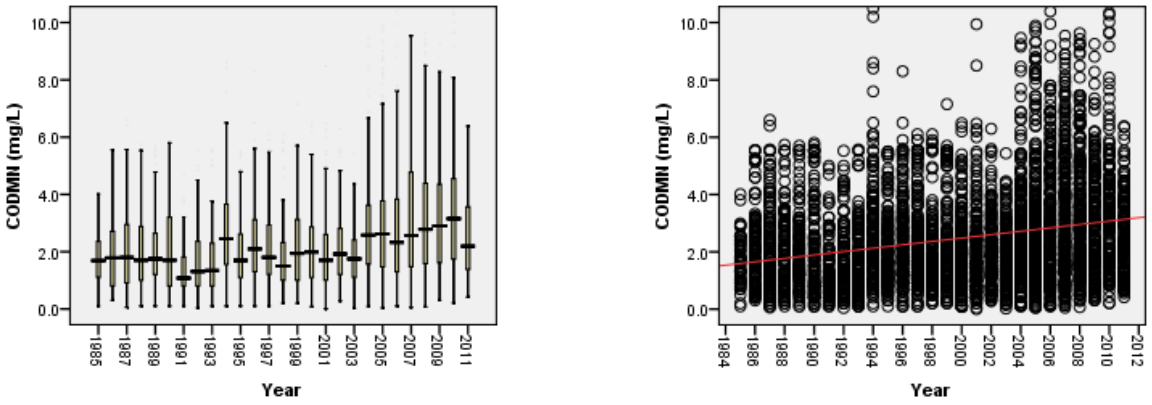


Figure 3.15. Temporal variation in COD concentrations in the Mekong River from 1985 to 2011



Dissolved oxygen levels in water are influenced by many factors. Among them are organic matters 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 mortality of aquatic organisms. The amount of oxygen needed to oxidize 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 3-14 shows spatial variations in COD along the Mekong and Bassac Rivers in 2011. The spatial variations observed for COD were directly opposite of the trends observed for dissolved oxygen. COD concentration increased as the Mekong River flowed downstream to the Mekong Delta, whereas dissolved oxygen levels decreased as the river flowed downstream to the Delta. The variations in COD are also consistent with the trends observed for total phosphorous, nitrate-nitrite and ammonium (Figures, 3-5, 3-7 and 3-9, respectively).

Compared to the MRC Water Quality Criteria for the Protection of Human Health (WQCH), the analysis of 2011 COD data reveals that Nakhon Phanom (5), Tan Chau

(15), My Tho (17), Chau Doc (21) and Can Tho (22) have chemical oxygen demand levels that exceeded the WQCH of 5 mg/L. No COD threshold value has been set for the MRC Water Quality Criteria for the Protection of Aquatic Life (WQCA).

Figure 3-15 reveals that COD concentrations in the Mekong River have increased slightly since it was first monitored in 1985. The trend was also consistent with trends observed for total phosphorous and ammonium (Figures 3-9 and 3-11, respectively) and was likely a reflection of increased organic and inorganic pollutants in surface runoff.

3.2 WATER QUALITY INDICES

In an attempt to provide a better understanding of the results of the water quality monitoring activities and assist in the management of water quality of the Mekong River, the MRC Environment Programme, in 2006, adopted Water Quality Indices of Mekong River using a combination of different water quality criteria to describe the overall condition of water quality. Three water quality indices were adopted as follows:

- Human impact
- Protection of aquatic life
- Agricultural use

The analysis of water quality indices in this Annual Water Quality Data Assessment Report is based on data measured from 2007 to 2011.

3.2.1 Human Impact Index on Water Quality

The MRC Water Quality Index for "Human Impacts" was developed with the intention of quantifying pressure exerted by human activities on water quality of the Mekong River (MRC, 2010b). As such, the results obtained from the Water Quality Index for "Human Impacts" do not provide an indication of how polluted the Mekong River water quality is; rather it provides evidence of human pressure on water quality (Ongley, n.d.).

The analysis of the 2011 water quality data using the MRC Water Quality Index for "Human Impacts" reveals that the degree of human impact or pressure exerted by human activities on water quality of the Mekong and Bassac Rivers stations ranged from "not impacted" to "severely impacted". In 2011, 6 stations were classified as "severely impacted" by human activities, of which 5 are located in the Delta, in both the Mekong (My Tho) and Bassac Rivers (Takhmao, Khos Khel , Chau Doc, and Can Tho). The main culprit was the exceedance in total phosphorus levels, with 4 of the 5 stations reported exceedance in total phosphorus levels in 80% or more of the total sampling occasions.

The other station classified as "severely impacted" is located in Nakhon Phanom where elevated total phosphorus levels were observed for 4 out of the 6 months monitored. Additionally, elevated COD levels were also observed during the wet season in Nakhon Phanom.

Table 3-3. Levels of human impacts on water quality of the Mekong River (1-17) and Bassac River (18-22) from 2007-2011

Station No	Station Names	River	Country	Class[5]				
				2007	2008	2009	2010	2011
1	Houa Khong	Mekong	Lao PDR	C	B	B	C	B
2	Chaing Sean	Mekong	Thailand	B	C	C	C	C
3	Luang Prabang	Mekong	Lao PDR	B	C	B	C	B
4	Vientiane	Mekong	Lao PDR	C	C	B	C	A
5	Nakhon Phanom	Mekong	Thailand	D	D	C	C	D
6	Savannakhet	Mekong	Lao PDR	C	C	C	B	C
7	Khong Chaim	Mekong	Thailand	C	C	B	C	B
8	Pakse	Mekong	Lao PDR	B	B	B	C	A
9	Stung Trieng	Mekong	Cambodia	C	C	C	C	C
10	Kratie	Mekong	Cambodia	C	C	C	C	C
11	Kampong Cham	Mekong	Cambodia	C	C	C	C	C
12	Chrouy Changvar	Mekong	Cambodia	C	C	C	B	C
13	Neak Loung	Mekong	Cambodia	C	C	C	C	C
14	Krom Samnor	Mekong	Cambodia	C	D	C	C	C
15	Tan Chau	Mekong	Viet Nam	C	D	D	D	C
16	My Thuan	Mekong	Viet Nam	C	D	D	D	C
17	My Tho	Mekong	Viet Nam	D	D	D	D	D
18	Takhmao	Bassac	Cambodia	D	D	D	D	D
19	Khos Khel	Bassac	Cambodia	D	D	D	D	D
20	Khos Thom	Bassac	Cambodia	D	D	D	D	C
21	Chau Doc	Bassac	Viet Nam	D	D	D	D	D
22	Can Tho	Bassac	Viet Nam	C	D	D	D	D

A: Not impacted; **B:** Slightly impacted; **C:** Impacted; **D:** Severely impacted

Other than Savannakhet, Nakhon Phanom and Chaing Sean monitoring stations, all stations on the Mekong River upstream of Pakse are either "slightly" or "not" impacted by human activities.

Compared to water quality data between 2007 and 2010, the degree of human impact on water quality of the Mekong and the Bassac Rivers improved slightly in 2011, with 8 stations showing a lesser degree of impact compared to the previous years. Nakhon Phanom, Savannakhet and Chrouy Changvar monitoring stations are the only stations that reported higher degree of human impact when compared to the previous years which was mainly caused by elevated total phosphorus levels. Chrouy Changvar station also reported exceedance in ammonium levels in 50% of the total sampling occasion (6 sampling occasions in 2011).

Overall, the degree of human impact on water quality of the Mekong River tend to be more severe in the Delta, with the degree of human impact ranging from "slightly impacted" to "severely impacted" which may be attributable to higher population densities and intensive agricultural activities. Given the fact that the stations located in the Delta are downstream stations receiving flow from upstream, the stations are likely to be accumulatively affected by human activities at both the Delta and upper and middle part of the Lower Mekong Basin. The water quality data from 2007 to 2011 indicate that elevated total phosphorus levels were the main culprit and while phosphorus can enter aquatic environment from the natural weathering of minerals, it can also enter the aquatic environment as runoff from man-made sources, including sewage effluent, agricultural runoff and industrial discharge (MRC, 2010b). In addition to the elevated total phosphorus levels, the water quality data also show somewhat re-

[5] The results for 2007 and 2008 are different from those reported in Volume 2 of the Mekong River Report Card on Water Quality (MRC, 2010b) due to the use of different target values for the assessment.

duced dissolved oxygen levels and slightly elevated chemical oxygen demand levels in the Delta. Elevated COD level can be attributed to excessive inputs of organic matter from the drainage basin, such as those that may occur downstream of a sewage outfall (MRC, 2010b).

3.2.2 Water Quality Index for the Protection of Aquatic Life

Despite 17 stations being rated as either "impacted" or "severely impacted" by human activities in 2011, all but 2 stations are rated as "excellent" for the protection of aquatic life, with the exception being My Tho and Can Tho. My Tho and Can Tho are the last monitoring stations on the Mekong River and the Bassac River, respectively. These two stations were the only two stations rated as "good" for the protection of aquatic life. The slight impairment at My Tho and Can Tho stations can be attributable to both the elevated total phosphorus concentrations (human impact) and salinity intrusion, causing elevated electrical conductivity levels (natural occurrence).

Between 2007 and 2011, water quality of the Mekong and the Bassac Rivers remain relatively unchanged and suitable for all aquatic life with only a minor degree of threat or impairment observed in the Delta. Water quality in the upper reach upstream of Kampong Cham is rated as "excellent" for the protection of aquatic life. Compared to 2010, water quality for the protection of aquatic life improved from "good" to "excellent" at two stations (My Thuan and Chau Doc), where dissolved oxygen levels were observed to be greatly improved compared to the levels observed in 2010.

Table 3-4. Water quality class of the Mekong River (1-17) and Bassac River (18-22) for the protection of aquatic life 2007-2011

Station No	Station Names	Rivers	Countries	Class				
				2007	2008	2009	2010	2011
1	Houa Khong	Mekong	Lao PDR	A	A	A	A	A
2	Chaing Sean	Mekong	Thailand	A	A	A	A	A
3	Luang Prabang	Mekong	Lao PDR	A	A	A	A	A
4	Vientiane	Mekong	Lao PDR	A	A	A	A	A
5	Nakhon Phanom	Mekong	Thailand	A	A	A	A	A
6	Savannakhet	Mekong	Lao PDR	A	A	A	A	A
7	Khong Chaim	Mekong	Thailand	A	A	A	A	A
8	Pakse	Mekong	Lao PDR	A	A	A	A	A
9	Stung Trieng	Mekong	Cambodia	A	A	A	A	A
10	Kratie	Mekong	Cambodia	A	A	A	A	A
11	Kampong Cham	Mekong	Cambodia	A	A	A	A	A
12	Chrouy Changvar	Mekong	Cambodia	A	A	A	A	A
13	Neak Loung	Mekong	Cambodia	A	A	A	A	A
14	Krom Samnor	Mekong	Cambodia	A	A	A	A	A
15	Tan Chau	Mekong	Viet Nam	A	A	A	A	A
16	My Thuan	Mekong	Viet Nam	A	A	B	B	A
17	My Tho	Mekong	Viet Nam	B	B	B	B	B
18	Takhmao	Bassac	Cambodia	A	A	A	A	A
19	Khos Khel	Bassac	Cambodia	A	A	A	A	A
20	Khos Thom	Bassac	Cambodia	A	A	A	A	A
21	Chau Doc	Bassac	Viet Nam	A	A	B	B	A
22	Can Tho	Bassac	Viet Nam	A	A	B	B	B

A: Excellent quality; **B:** Good quality; **C:** Moderate quality; **D:** Poor quality

3.2.3 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 three indices were adopted by the MRC to assess the level of impairment of water quality for general irrigation, paddy rice irrigation and livestock and poultry, all indices for agricultural use can be assessed against threshold values for electrical conductivity (Table 2-7).

Table 3-5. Water quality class of the Mekong River (1-17) and Bassac River (18-22) for agricultural use for 2007-2011

Station No	Station Name	River	Country	Class				
				2007	2008	2009	2010	2011
1	Houa Khong	Mekong	Lao PDR	A	A	A	A	A
2	Chaing Sean	Mekong	Thailand	A	A	A	A	A
3	Luang Prabang	Mekong	Lao PDR	A	A	A	A	A
4	Vientiane	Mekong	Lao PDR	A	A	A	A	A
5	Nakhon Phanom	Mekong	Thailand	A	A	A	A	A
6	Savannakhet	Mekong	Lao PDR	A	A	A	A	A
7	Khong Chaim	Mekong	Thailand	A	A	A	A	A
8	Pakse	Mekong	Lao PDR	A	A	A	A	A
9	Stung Trieng	Mekong	Cambodia	A	A	A	A	A
10	Kratie	Mekong	Cambodia	A	A	A	A	A
11	Kampong Cham	Mekong	Cambodia	A	A	A	A	A
12	Chrouy Changvar	Mekong	Cambodia	A	A	A	A	A
13	Neak Loung	Mekong	Cambodia	A	A	A	A	A
14	Krom Samnor	Mekong	Cambodia	A	A	A	A	A
15	Tan Chau	Mekong	Viet Nam	A	A	A	A	A
16	My Thuan	Mekong	Viet Nam	A	A	A	A	A
17	My Tho	Mekong	Viet Nam	A	A	A	A	A
18	Takhmao	Bassac	Cambodia	A	A	A	A	A
19	Khos Khel	Bassac	Cambodia	A	A	A	A	A
20	Khos Thom	Bassac	Cambodia	A	A	A	A	A
21	Chau Doc	Bassac	Viet Nam	A	A	A	A	A
22	Can Tho	Bassac	Viet Nam	A	A	A	A	A

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

A spatial trend analysis carried out for electrical conductivity along the Mekong and Bassac Rivers (Section 3.1.2 and Figure 3-3) reveals that all electrical conductivity values obtained from the water quality monitoring in 2011 were well within the threshold of Water Quality Index for General Irrigation Use of 70 mS/m, with the maximum value being measured at Houa Khong Station at 35 mS/m.

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

3.3 ECOLOGICAL HEALTH MONITORING

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 the Lao PDR, Thailand, and Viet Nam, and 17 stations in Cambodia). Of the 41 stations monitored in 2011, 22 stations are located at the same sites or close to the water quality monitoring stations of the MRC Water Quality Monitoring Network, of which 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 3-16.

As part of the EHM, 4 biological groups, namely benthic diatoms, zooplankton, littoral macro-invertebrates and benthic macro-invertebrates were monitored. For each

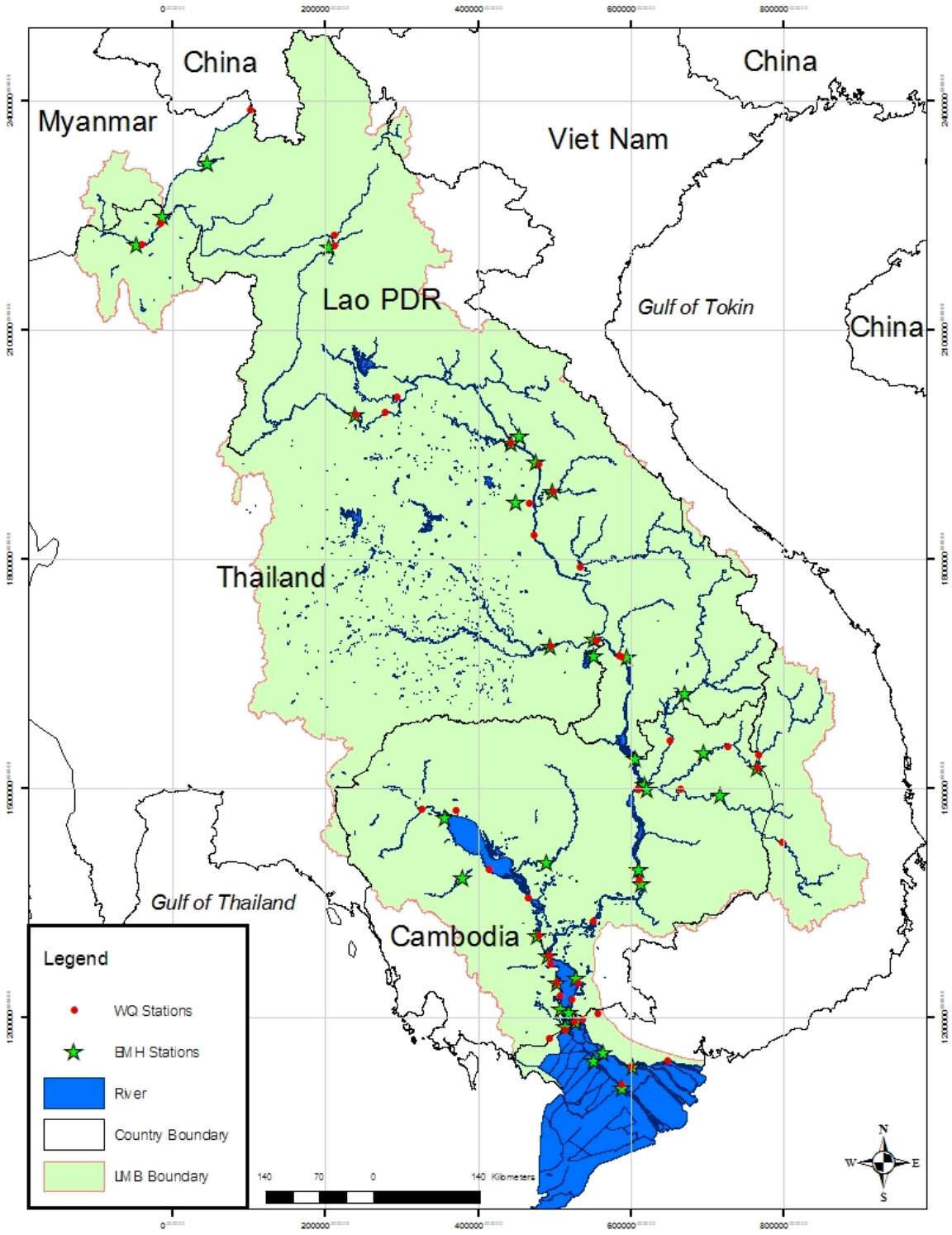


Figure 3.16. Locations of the EHM in relation to the location of the WQMN

Table 3-6. Results of the Ecological Health Monitoring 2005-2008 and 2011

Station Name	Country	River	2005	2006	2007	2008	2011
Chiang Sean	Thailand	Mekong				B	B
Luang Prabang	Lao PDR	Mekong			B	C	C
Vientiane	Lao PDR	Mekong	A			B	A
Nakhon Phanom	Thailand	Mekong				C	B
Kong Chiam	Thailand	Mekong				A	B
Kratie/Kampi Pool	Cambodia	Mekong		A		A	A
Neak Loung	Cambodia	Mekong					B
Tan Chau/Thuong Thoi	Viet Nam	Mekong				C	B
My Thuan	Viet Nam	Mekong				C	C
Khos Khel	Cambodia	Bassac		B		C	B
Can Tho	Viet Nam	Bassac		C		B	B
Chau Doc/Da Phuoc	Viet Nam	Bassac				C	B
Chiang Rai	Thailand	Mae Kok	A			A	B
Ban Chai Buri	Thailand	Song Kham			C	A	C
Se Bang Fai Bridge	Lao PDR	Se Bang Fai			B	B	C
Na Kae	Thailand	Nam Kam			C	B	B
Se Bang Hieng Bridge	Lao PDR	Se Bang Hieng			A	C	B
Se Done Bridge/Ban Hae	Lao PDR	Se Done			B	B	B
Ubon	Thailand	Mun				A	A
Phum Phi (Phi Village)	Cambodia	Se San	A	A	A	B	A
Prek Kdam	Cambodia	Tonle Sap					B
Phnom Penh Port	Cambodia	Tonle Sap					B

biological group, 3 biological metrics namely abundance, average richness and the Average Tolerance Score per Taxon (ATSPT) were measured. Thus, a total of 12 biological indicators were used to evaluate each site. The quality of each site was classified into one of the four following groups (MRC, 2008):

- 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 that 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 that 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 provides results of the ecological health monitoring in the Mekong and Bassac Rivers at stations where water quality monitoring were also carried out. In addition to providing the 2011 ecological health monitoring results, the table also provides results of the monitoring between 2005 and 2008 for trends comparison. Key observations of the ecological health monitoring results at these stations are as follows:

- Of the 22 sites listed in Table 3.4, all but four 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 four stations rated as "moderate" two are located in the Mekong mainstream (Luang Prabang and My Thuan).
- Despite many water quality monitoring stations in the Mekong and Bassac Rivers being rated as either "impacted" or "severely impacted" by human activities in 2011 (Table 3-2), the results of the ecological health monitoring reveal that water quality is still either "good" or "excellent" for support of fish and other freshwater functions, with the exception of the two stations (Luang Prabang and My Thuan) where it was rated as "moderate" for support of fish and other freshwater functions. It should be noted that results of the 2011 water quality monitoring reveal that water quality at Luang Prabang station was "slightly impacted" by human activities while water quality at My Thuan station was "severely impacted" by human activities which likely alter the habitat of aquatic fauna.

4. CONCLUSIONS AND RECOMMENDATIONS

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Based on the results of the 2011 water quality monitoring, it can be concluded that the water quality of the Mekong and Bassac Rivers is still of good quality with only a few numbers of dissolved oxygen and chemical oxygen demand samples exceeding the MRC Water Quality Guidelines for the Protection of Human Health and Aquatic Life. The majority of exceeding values of dissolved oxygen and chemical oxygen demand 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 20 mS/m.

Compared to previous years, nutrient levels increased slightly in 2011 with total phosphorus and ammonium levels showing increasing trends from 1985 to 2011 while the nitrate-nitrite levels remain relatively constant. While the dissolved oxygen levels remained relatively constant from 1985 to 2011, chemical oxygen demand levels increased slightly during the same time frame. Total suspended solids level showed a noticeable decrease between 1985 and 2011, from an average value of 389 mg/L to 82 mg/L and the median value of 244 mg/L to 55 mg/L.

The levels of human impact on water quality of the Mekong and Bassac Rivers improved slightly in 2011 compared to the levels calculated for 2010, with 8 stations showing a lesser degree of impact from human activities or pressure. Only 3 stations reported higher degrees of impact when compared to the 2010 water quality monitoring results while the rest of the stations remained relatively unchanged. In general, the majority of stations rated as “impacted” or “severely impacted” by human activities are located in the Delta (for both the Mekong and Bassac Rivers) where higher population densities and intensive agricultural activities were observed. The stations in the Delta were also likely to be cumulatively impacted by human activities in the upper and middle parts of the Lower Mekong Basin.

Despite many stations being rated as either “impacted” or “severely impacted” by human activities in 2011, the assessment of the Water Quality Index for the Protection of Aquatic Life revealed that all stations were rated as either “excellent” or “good” for the protection of aquatic life. In fact, 20 of the 22 stations located in Mekong and Bassac Rivers were rated as “excellent” for the protection of aquatic life while the only two downstream most stations (My Tho and Can Tho) were rated as “good” for the protection for water quality.

The biodiversity and ecological capability of the Mekong and Bassac Rivers to sup-

port fish and other aquatic functions was also reported to be mostly excellent with many ecological health monitoring stations being classified as either "excellent" or "good". Of the mainstream stations located at the same locations as the water quality monitoring stations, only two were reported to be "moderate" for support of fish and aquatic functions. These 2 stations were rated by the Water Quality Index for Human Impacts as "slightly impacted" and "impacted" by human activities.

4.2 RECOMMENDATIONS

The 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 has adopted the Procedures for Water Quality with an objective of establishing a cooperation framework for the maintenance of acceptable/good water quality of the Mekong River to promote the sustainable development of the Mekong River Basin. With a view to achieving the objective of the Procedures for Water Quality, Member Countries have agreed to:

- Make every effort to maintain acceptable/good water quality on the mainstream;
- Strengthen the existing and, if necessary, establish new joint programs for monitoring and assessing the water quality of the Mekong River;
- Jointly develop the Technical Guidelines for the Implementation of the Procedures for Water Quality (TGWQ); and
- Conduct research to refine the Technical Guidelines for an effective implementation of the Procedures for Water Quality.

Member Countries' effort to maintain acceptable/good water quality of the Mekong River has led to the development of Technical Guidelines for the Implementation of the Procedures for Water Quality, 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 on water quality, including population growth, intensive agricultural and aquaculture, navigation, hydropower and industrialisation, which can often increased input of chemicals and ultimately affect the aquatic ecosystem and human health.

In this regard, to improve future monitoring of water quality under the MRC Water Quality Monitoring Network, the following aspects need to be considered:

- Provide timely data to assure the currency and validity of data for the protection of aquatic life and human health;
- Allow for the determination of the relationship between water quality conditions and land use within the Lower Mekong Basin;
- Expand coverage of the WQMN to include additional key tributaries of the Mekong River ensuring the establishment of water quality baseline conditions at these tributaries;
- Include water quality indicators listed in the draft Chapters 1 and 2 of the TGWQ

which include heavy metals and persistent and non-persistent organic substances in addition to the already monitor conventional water quality parameters; and

- Improve water quality risk assessment and methods for communicating results of the water quality monitoring, including reviewing the adequacy and currency of the MRC Water Quality Indices.

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APPENDIX A.
The MRC Water Quality Guidelines for the Protection of Human Health

Parameters	Symbol	Unit	Value
Total Arsenic	Total As	mg/l	0.01
Cadmium	Cd	mg/l	0.005[1]
Chromium Hexavalent	Cr	mg/l	0.05
Cyanide	CN	mg/l	0.01
Lead	Pb	mg/l	0.05
Total Mercury	Total Hg	mg/l	0.002
Oil and Grease	Should not occur in such a way that: • It can be observed as an oil film, sheen or discolouration; • One can smell its odour; or • It can be seen as oily deposits on the river bank and/or at the river bottom.		
Phenol	C_6H_5OH	mg/l	0.005
Total Organochlorine Pesticide		mg/l	0.05
Faecal Coliforms		MPN/100ml	1000[2]
Ammonia as N	NH_3 as N	mg/l	0.5[3]
Biological oxygen demand	BOD_5	mg/l	4
Chemical oxygen demand	COD_{Mn}	mg/l	5
Conductivity	EC	mS/m	70-150
Dissolved Oxygen	DO	mg/l	≥ 6[4]
Total Nitrite and Nitrate as N	$(NO_2 + NO_3)$ as N	mg/l	5
pH	pH		6-9
Temperature	T	°C	Natural
Total Coliform		MPN/100ml	5000

Note:

(1) When the water hardness is less than 100 mg/l as $CaCO_3$

(2), (3) and,(4)An interim target value. The TBWQ with support from the Mekong River Commission Secretariat will continue to study this issue in order to reconsider the interim target value.

APPENDIX B.
The MRC Water Quality Guidelines for the Protection of Aquatic Life

Parameters	Symbol	Unit	Value
Arsenic	Total As	mg/l	0.01
Cadmium	Cd	mg/l	0.005[1]
Chromium Hexavelent	Cr (VI)	mg/l	0.05[2]
Copper	Cu	Mg/l	0.1
Cyanide	CN	mg/l	0.005
Lead	Pb	mg/l	0.05[3]
Total Mercury	Total Hg	mg/l	0.001[4]
Oil and Grease[5]	Should not occur in such a way that: • It can be observed as an oil film, sheen or discolouration; • One can smell its odour; or • It can be seen as oily deposits on the river bank and/or at the river bottom.		
Phenol	C_6H_5OH	mg/l	0.005
Total Organochlorine Pesticide		mg/l	0.05
Ammonia	NH_3 as N	mg/l	0.2
Biological oxygen demand	BOD_5	mg/l	3[6]
Dissolved Oxygen	DO	mg/l	> 5
pH	pH		6 – 9
Temperature		°C	Natural
Nitrite[7]	NO_2 as N		
Nitrate	$NO_{3\ as}$ N	mg/l	5
Phosphate[8]	PO_4 as P		

Note:

(1) When the water hardness is less than 100 mg/l as $CaCO_3$

(2), (3),(4),(5) and (6)An interim target value. The TBWQ with support from the Mekong River Commission Secretariat will continue to study this issue in order to reconsider the interim target value.

(7) An interim target value. The TBWQ with support from the MRC Secretariat will continue to study this issue in order to reconsider the interim target value. Thailand proposes 0.5 mg/l; Viet Nam proposes 0.1 mg/l.

(8) Target values will be proposed in the future when the national standard target values for Lao PDR and Thailand are available.

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