The Mekong River Report Card On Water Quality

Volume 2: June 2010

Assessment of Potential Human Impacts on Mekong River Water Quality

Mekong River Commission

Background

The millions of people who live in different parts of the Lower Mekong Basin (LMB) rely on the water resources of the Mekong River Basin for their food supply and the sustainability of their livelihoods. The Mekong water and its related resources have the potential to contribute to the economic development of the Basin. Overall, the water quality of the Mekong River is good. This is reflected in the fact that the Mekong fisheries are among the most diverse and abundant of all the world's rivers.

The Mekong River is gradually changing. Despite the impressive economic growth in the riparian countries over the past decade, much of the Mekong Basin itself remains one of the world's poorest areas with poverty rates of up to 40 per cent in some parts. The Governments of the Basin countries are increasingly recognising that sustainable poverty alleviation and livelihood improvements can be achieved through the development of the economic potential of the Mekong River system (ADB 2009a).

Recently, the development of the water resources of the Mekong River Basin has accelerated, particularly in the hydropower and irrigation sectors which are supported by market forces and the private sector. Although the exploitation of these resources could be of tremendous benefit to the peoples of the Basin. if not properly planned, managed and monitored, it could also exert tremendous pressure on the Basin's ecological health, livelihoods and the water quality.

Poor water quality can result from natural processes, but may often be related to human activities. Although substances harmful to aquatic life may come from natural or human sources, the environmental impact of some human-produced chemicals far overshadows that from natural sources. The development and production of synthetic chemicals used in industry and agriculture has had profound effects on water quality. Further, urbanisation, population growth, and increased rates of consumption have led to increased resource extraction (e.g. mining and forestry), materials processing (e.g., melting, pulp and paper mills, and assembly plants), and energy demand (hydro-electrical impoundments and generating stations). The building of impoundments for hydroelectric power generation and water storage along water courses, while playing an important role in meeting human water demands, can significantly alter water quality. Climate change, the evolution of new waterborne pathogens, and the development and use of new chemicals for industrial, agricultural, household, medical, and personal use have raised concern as they have the potential to alter both the availability and the quality of water (IPCC, 1995 WHO 2003; Kolpin et al. 2002). All of these activities have costs in terms of water

quality, and the health and integrity of aquatic ecosystems (Meybeck 2004).

The assessment in this Mekong River Report Card is based primarily on the data and information available from the Member Countries' monitoring network but it has been supplemented by a certain amount of relevant secondary data and information. This Card reports on an assessment of those human activities with the potential of impacting on the Mekong water quality, and also updates the Mekong water quality status and trend as monitored by the Lower Mekong Member Countries during 2000 - 2008. It focuses on four key water quality parameters discussed and agreed on by the Member Countries in 2007. These parameters are indicators of potential human impacts on Mekong water quality (Ongley 2006). A comparison of the water quality in the Mekong mainstream and in some major tributaries is drawn. This Card provides a better understanding of the way in which the Mekong water quality is at risk of human impacts.

This River Report Card is the second volume in the series. The Mekong River Report Card on Water Quality Volume 1, published in September 2008, provided an overview of the water quality parameters and the changes of key environmental stressors that may affect the River's aquatic life (MRC 2008a).

Monitoring stations of Mekong River Monitoring Network (2009)

Human activities with potential impacts on Mekong water quality

- *Urban development*

The large cities of Vientiane in Lao PDR, Phnom Penh in Cambodia, and Can Tho in Viet Nam lie along the Mekong and the Bassac Rivers, and are home to significant numbers of people; approximately 500,000 in Vientiane, 1.3 million in Can Tho and 1.7 million in Phnom Penh (MRC 2008b). The population density in these cities results in increasing municipal wastewater discharge to the Mekong River and its tributaries. This wastewater may carry harmful substances together with high organic loads with potentially negative impacts on the Mekong water quality and aquatic ecosystems. Human settlement tends to lead to a gradual increase in the volume of domestic wastewater.

- *Industrial development*

In the past decade, industrial development in the Upper Mekong Basin has markedly increased. For example, in 2000, in the People's Republic of China, the provincial government of Yunnan, immediately upstream of the Chinese/Lao border, is reported to have inspected 1,042 industrial enterprises in the Basin and shut down four of these (CIIS 2002). Since 1986, the Simao Paper Plant and the Lanping Lead-Zinc Mine have been built on the banks of the Lancang (Mekong) River.

In contrast, industrial development in the Lower Mekong Basin (LMB) is at an early stage; however the industrial sector is rapidly expanding. In the Basin in Thailand, the main industrial products are agricultural inputs and processed food. Other industries include the production of precious stones and jewellery, cement, sugar, refined oil, synthetic fibres, textiles, vehicle parts and assembly, paint and steel. Although in Lao PDR and Cambodia, the industrial sector is small and at an early stage of development, mining and hydropower, are growing rapidly, with the production of tin concentrates now being an important industrial activity. In Cambodia, the major water use is in small and medium scale industries such as food processing and textile production. There are not many industries in the Delta, partly because of a lack of infrastructure and transport facilities (ADB 2009b). Here, the industries are mostly agro-industries, such as rice milling and polishing, breweries and canneries, and plants processing aquatic foodstuffs. Up to now, industrial water pollution in the LMB has been concentrated around specific industrial establishments and downstream of major urban areas. However, growing industrialisation in the LMB may lead to more severe water discharge problems and increased inter-sectoral conflicts related to water quality demands.

- ***Agricultural Development***

Developments in the agricultural sector result in significant changes in land use with more land being given over to cultivation and farmland. Agricultural practices may result in the introduction of harmful substances, pollutants and nutrient loads to specific stretches of the Mekong River. The development of intensive agriculture is apparent in many of the Mekong floodplains. In general, agriculture in the uplands is less intensified than that in the Mekong floodplains and other lowland areas, where most of the crop production takes place. The flat nutrient rich floodplains are under extensive rice cultivation. Lowland rice farming systems include wet season rice, floating rice, flood recession rice, dry season irrigated rice and multi-crop production systems. Various LMB regions produce between one and three harvests a year. The main harvest is the wet season crop, with fewer farmers also planting in the dry season, both with and without irrigation. Within the Mekong Delta of Viet Nam, some farmers grow a third crop late in the year (MRC 2005a).

An Update on the Mekong River Water Quality Monitoring Network

The Mekong Water Quality Monitoring Network (WQMN) has been reviewed and improved over several years, and most recently in 2008 and 2009. The updated WQMN aims to provide timely data and information on the status and changes in the water quality of the Mekong mainstream and important transboundary tributaries. The current WQMN includes water quality monitoring at 48 permanent monitoring stations; of which 11 are in Lao PDR, 8 in Thailand, 19 in Cambodia and 10 in Viet Nam. Samples of surface water are taken from the river mid-stream every two months, i.e. six times a year starting from February. The Member Countries may increase the sampling frequency at a specific area of the Mekong River, though it is not more 12 times a year.

Table 1: List of WQMN parameters measured every two months (2009)

Temperature	Total Nitrite and Nitrate	Dissolved Oxygen
Conductivity	Total Suspended Solids	Chemical Oxygen Demand
pH	Total Nitrogen	Faecal Coliforms
Ammonium	Total Phosphorus	

An assessment of the human impacts on Mekong River water quality

Water quality index for "Human Impacts"

All the LMB Countries have established water quality standards to regulate and assess the status and trends. The set of key water quality parameters forming the Water Quality Indices (WQI) have been designed to protect aquatic life and to indicate pressure exerted by human activities on the water quality of the Mekong River.

Based on a review of the scientific literature and a statistical analysis of the MRC data, four parameters and their guideline values were selected to assess the "Human Impact" on water quality (WQIhl) in the Mekong River. These are Dissolved Oxygen (DO), Ammonium (NH4), Chemical Oxygen Demand (COD) and Total Phosphorus (TP) (Ongley 2006).

Table 2: provides the guideline values of the water quality parameter used. If the measured value for each parameter was within the guideline value on a sample day it was given a rating of 2, if not the rating is 0.

Table 2: Water quality parameters used in the classification system for the "Human Impact" on water quality

Parameter	Units	Value	Parameter	Units	Value
Dissolved Oxygen	mg/l	≥ 6	Chemical Oxygen Demand	mg/l	< 4
Ammonium	mg/l	< 0.05	Total Phosphorus	mg/l	<0.08

The WQI for each station was calculated using Formula 1 given below.

$$WQI = \frac{\sum (p1 + p2 \ldots\ldots pn)}{M} \times 10 \quad (1)$$

Where:

- "p" is the number of points scored per sample day, If DO, NH4 ,Chemical Oxygen Demand and Total Phosphorus meets the guideline in Table 2, it scores 2 points, otherwise it scores 0.
- "n" is the number of sample dates in the year.
- "M" is the maximum possible number of points for the measured parameters in the year.

Table 3 outlines the rating system for those values. Water samples with values within the range in Table 2 were given a higher rating, while those with values outside the range were given a lower rating, depending on how many values were outside the range.

Table 3: Rating system for "Human Impact" on water quality

Class	Rating Score
A - No impact	$10 \geq A \geq 9.5$
B – Slight Impact	$9.5 > B \geq 8.5$
C - Impact	$8.5 > C \geq 7$
D – Severe Impact	$D < 7$

Human impacts on the spatial and temporal variations in Mekong water quality (2000 - 2008)

The degree of the impact of human activities on the water quality at the 17 mainstream and five tributary monitoring stations ranged from "no impact" to "severe" (see Tables 4 and 5). The stations downstream from Phnom Penh to the Mekong Delta of Viet Nam were classed as experiencing an "impact" or a "severe impact", which may be attributable to the higher population densities along this stretch of the river. However, the mainstream stations of Houa Khong, Chiang Sean, Nakhon Phanom and Khong Chiam were also classed as experiencing an "impact" or a "severe impact".

Table 4: Water Quality Class of Mekong mainstream stations for the "Human Impact" on water quality 2000 - 2008

No	Station Name	Country	Class								
			2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Houa Khong	Lao PDR	ND	ND	ND	ND	B	C	B	B	B
2	Chiang Sean	Thailand	B	B	B	C	D	C	C	B	C
3	Luang Prabang	Lao PDR	B	B	B	C	C	C	B	C	C
4	Vientiane	Lao PDR	B	C	B	C	B	C	B	C	C
5	Nakhon Phanom	Thailand	C	B	B	B	D	C	D	C	D
6	Savannakhet	Lao PDR	ND	B	B	B	B	C	C	C	C
7	Khong Chiam	Thailand	C	B	B	C	D	B	C	B	C
8	Pakse	Lao PDR	B	B	B	B	C	B	B	B	B
9	Stung Treng	Cambodia	ND	ND	ND	ND	ND	C	B	B	B
10	Kratie	Cambodia	B	A	A	A	A	C	B	B	B
11	Kampong Cham	Cambodia	B	C	B	A	A	B	B	B	A
12	Chroy Chanvar	Cambodia	B	B	A	A	A	B	B	C	B
13	Neak Loung	Cambodia	B	B	A	A	B	C	C	C	B
14	Krom Samnor	Cambodia	ND	ND	ND	ND	ND	C	B	B	C
15	Tan Chau	Viet Nam	C	B	C	B	B	D	D	C	D
16	My Thuan	Viet Nam	B	B	C	C	C	C	D	D	D
17	My Tho	Viet Nam	ND	B	C	B	D	C	D	D	D

Note: ND: No data

Key water quality parameters indicating human impacts on Mekong water quality

- ***Suspended material (estimated by Total Suspended Solids)***

Various human activities; such as those involving agriculture, forestry, urbanisation, mining, and industry can contribute to transport of suspended material into the riverine environment. An overall increase in the suspended material transport in the river would result from river bank erosion caused by degradation or removal of bank vegetation. Also in places where river channels had been established in developing irrigation systems along with the removal of the natural land cover and its replacement by man-made structures (e.g., roads and buildings) increased inputs of suspended material would take place. During the construction of dams suspended particles may be generated altering the natural sedimentation regime of water courses. These suspended particles tend to accumulate in downstream reservoirs. Trapping of sediments behind hydropower and irrigation dams means that ecosystems downstream of reservoirs are often depleted of natural sediment fluxes and riverbank scouring increases.

Table 5: Water Quality Class of Mekong tributary stations (Bassac River) for the "Human Impact" on water quality 2000 - 2008

No	Station Name	Country	Class								
			2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Takhmao	Cambodia	D	C	B	C	C	C	C	D	D
2	Khos Khel	Cambodia	D	C	B	C	C	C	C	D	C
3	Khos Thom	Cambodia	ND	ND	ND	ND	ND	C	B	C	C
4	Chau Doc	Viet Nam	B	B	D	B	C	D	D	D	D
5	Can Tho	Viet Nam	B	B	C	C	C	B	D	B	D

Note: ND: No data

In the Mekong River transportation of naturally occurring suspended sediments and the associated nutrients are the key to the high productivity of the floodplains thought to be responsible for the fish productivity and the river banks on which gardening takes place during the dry season. The flood pulse of sediments and nutrient deposits on the flood plains and river banks during the flood recession. Sediment trapping caused by human activities of considerable concern (MRC 2010).

Many toxic organic contaminants, such as pesticides or their breakdown products, are closely associated with silt, clay and organic carbon transported by rivers. The suspended particles act as agents in the process of eutrophication and the resulting toxicity to aquatic organisms (Ongley 1996; Boatman et al. 1999; Owens et al. 2005). High concentrations of suspended particles in surface waters can also increase thermal pollution by increasing the absorption of light, thereby increasing water temperatures. Finally, high concentrations of suspended particles can impair navigation and water retention facilities by causing the silting-up of watercourses and the filling-in of reservoirs and irrigation systems which in turn results in the need for costly dredging or a shortening of their useful life (Owens et al. 2005).

Figure 1 shows the characteristics of the Mekong mainstream and tributaries at the 22 sampling stations, and demonstrates that suspended solid concentrations are relatively higher and more variable at the upstream stations from Houa Khong (1) to Pakse (8). In contrast, the concentrations abruptly reduce at the downstream stations from Stung Treng (9) to My Tho (17) in the Mekong River and from Takhmao (18) to Can tho (22) in the Bassac River. The reason for the high concentrations at upstream stations is the naturally high inputs from the upper Mekong Basin. Figure 2 and an ANOVA analysis shows that there were no significant differences in the median values of 2000 - 2006 and those of 2007 and 2008.

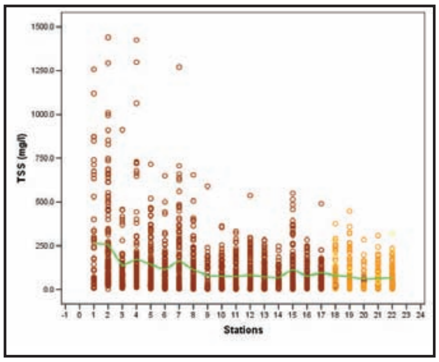

Figure 1: Scatter plot showing variations in total suspended solids of 17 stations (shown as brown dots) along the Mekong River and of 5 stations (shown as orange dots) along the Bassac River. The green line shows median variations.

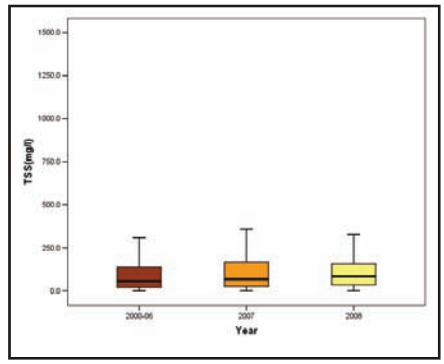

Figure 2: Box whisker plots of a comparison of three populations of concentrations of total suspended solids for 22 stations on the Mekong and Bassac Rivers for 2000 -2006, 2007 and 2008.

- *Nutrients (represented by nitrate plus nitrite, ammonia and total phosphorus)*

Nutrients are essential elements for life. In a river environment, nitrogen and phosphorus are the two limiting factors that most commonly control the maximum biomass of algae and aquatic plants (primary producers). The productivity of aquatic ecosystems can, thus, be managed by regulating the direct or indirect inputs of nitrogen and phosphorus with the aim of either reducing or increasing primary production.

Causes of nutrient loading or eutrophication of aquatic ecosystems can be attributed to agriculture, urbanisation, forestry, impoundments, and industrial effluents. Surface water may be affected by nutrient enrichment. The consequences of eutrophication

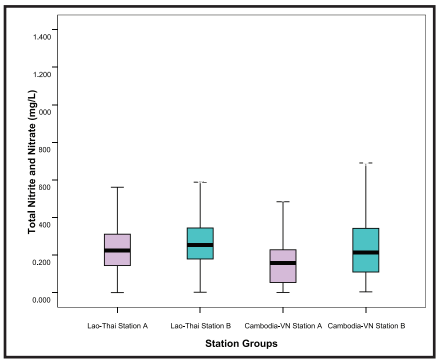

Figure 3: Box whisker plots showing the variations in total nitrate and nitrite at selected stations in the middle and lower part of the Mekong River. Lao PDR and Thailand are compared with Cambodia and Viet Nam. The green plots represent the stations with high population densities and intensive agriculture. The violet plots represent the stations with lower population densities and less intensive agriculture.

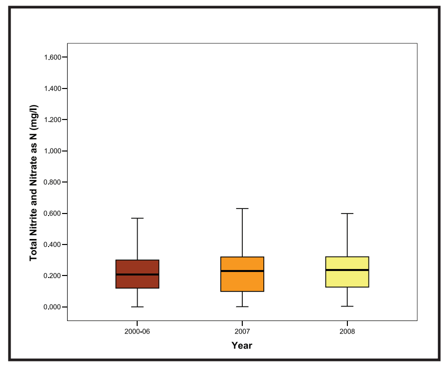

Figure 4: Box whisker plots of a comparison of three populations of the concentration of total nitrite and nitrate for 22 stations on the Mekong and Bassac Rivers for 2000 -2006, 2007 and 2008.

for humans are a bad taste and odour in public water supplies. The accompanying production of cyano-bacterial toxins can threaten animal and human health, and result in the in-filling or clogging of irrigation canals with aquatic weeds, and the loss of recreation use due to slime, weed infestations and noxious odours. Furthermore, there are economic losses due to the disappearance of species targeted by commercial and sport fisheries (Ongley, 1996). In addition, nitrates in drinking water have been linked to human health problems such as methaemoglobinaemia (blue-baby syndrome) (Boatman et al., 1999), stomach cancer and negative reproductive outcomes.

Phosphorus is present in natural waters primarily in the form of phosphates, which may be either inorganic or organic. Phosphates can enter aquatic environments from the natural weathering of minerals in the drainage basin, from biological decomposition, and as runoff from human activities in urban and agricultural areas.

Figures 3 and 5 show similar spatial patterns of the concentrations of total nitrate–nitrite and total phosphorus between the stations with higher population densities and intensive aqua-cultural or agricultural practices which contribute higher concentrations of total phosphorus and nitrite-nitrate. Similarly, the concentrations of nitrate and nitrite, and total phosphorus in 2000 - 2006, 2007 and 2008, increased slightly (Figures 4 and 6). The ANOVA statistical test of water samples collected during 2007 and 2008 showed a slight increase in the median values of total nitrate-nitrite from 0.200 mg/l in 2000 - 2006 to 0.230 mg/l in 2007 - 2008. In contrast, in recent years, the total phosphorus level increased more dramatically from 0.065 mg/l in 2000 - 2006 to 0.085 mg/l in 2007 and 0.090 mg/l in 2008.

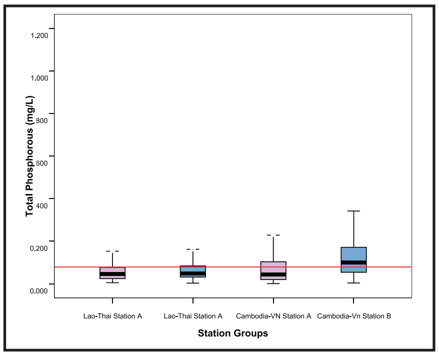

Figure 5: Box whisker plots of the variations of total phosphorus at selected stations. The blue box plots indicate the stations with higher population densities and intensive agriculture/aquaculture, the violet box plots indicate the stations with lower population densities and less intensive agriculture/aquaculture. The red horizontal line is the values for total phosphorous at 0.08 mg/l (Table 2)

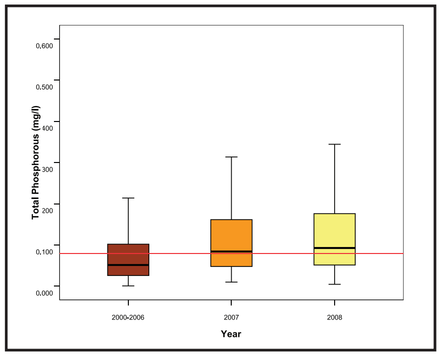

Figure 6: Concentrations of total phosphorus for 22 stations on the Mekong and Bassac Rivers, Comparisons between 2000 – 2006, and 2007 and 2008. The red horizontal line is the value for total phosphorous at 0.08 mg/l (Table 2).

- *Organic matters (estimated by the Chemical Oxygen Demand)*

Excessive inputs of organic matter from the drainage basin, such as those that may occur downstream of a sewage outfall, can upset the balance of an aquatic system and lead to excessive bacterial production and consumption of dissolved oxygen that could compromise the integrity of the ecosystem and lead to favourable conditions for the growth of less than ideal species. The Chemical Oxygen Demand (COD) is one of two common measures (namely, the Biological Oxygen Demand and the Chemical Oxygen Demand) of water quality that reflect the degree of organic pollution of a water body.

Approximately 62% of the monitoring data of 2000 - 2006 and of 2007 - 2008 show COD values lower than 4 mg/l. Figure 7 shows that both higher population densities and more intensive agricultural practices in the lower part of the Mekong River contribute to higher COD concentrations. Figure 8 shows the median COD concentrations for 2007 and 2008, both are higher than those of 2000 - 2006.

- *Comparison of water quality in the Mekong mainstream and its tributaries*

Spatial variations in water quality for the selected tributary and mainstream stations for 2000 -2008 are shown in Figures 9 and 10. The trend is that COD concentrations at tributary stations are always higher than at mainstream stations. This is also true for total phosphorus at the stations within the boundary of Cambodia and Viet Nam (see Figure 10). For the stations along the Lao-Thai border, total phosphorus in the mainstream stations is higher than in the tributary stations. This indicates that, especially in the Delta, Mekong water quality in sparsely populated mainstream areas may be less impacted by human activities than the quality in relatively densely populated tributary areas.

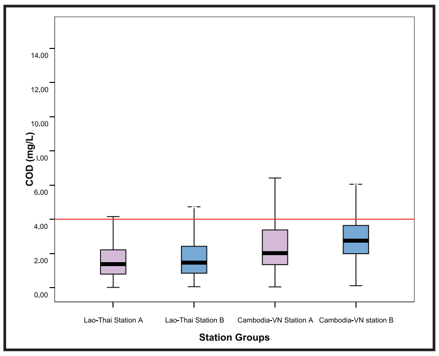

Figure 7: Box whisker plots comparing COD variations at selected stations The blue box plots indicate the stations with higher population densities and intensive agriculture/aquaculture, the violet box plots indicate the stations with lower population densities and intensive agriculture. The red horizontal line is the values for COD at 4 mg/l (Table 2).

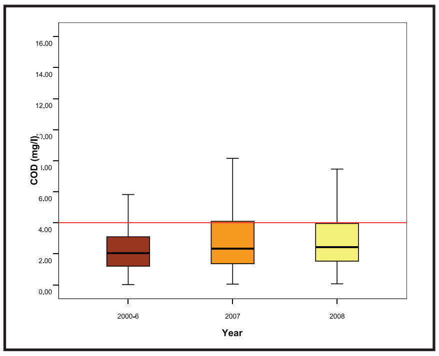

Figure 8: Box whisker plots of COD concentrations for 22 mainstream stations allowing comparisons between 2000 -2006, and 2007 and 2008. The red horizontal line is the values for COD at 4 mg/l (Table2).

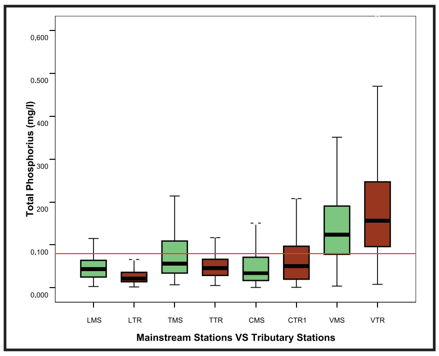

Figure 9: Box whisker plots comparing COD concentrations at the mainstream stations (green box plots) and the tributaries (brown box plots). LMS and LTR are respectively mainstream and tributary stations in Lao PDR; TMS and TTR mainstream and tributary stations in Thailand, CMS and CTR mainstream and tributary stations in Cambodia, and VMS and MTR mainstream and tributary stations in Viet Nam. The red horizontal line is the values for COD at 4 mg/l (Table 2)

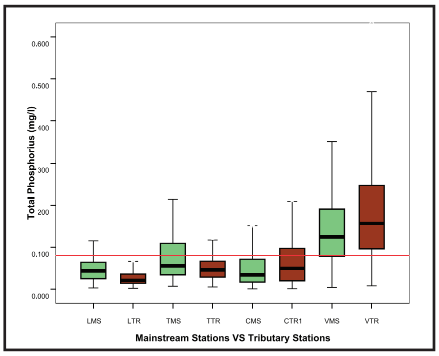

Figure 10: Box whisker plots comparing Total Phosphorus concentrations for mainstream stations (green box plots) and the tributaries (brown box plots). LMS and LTR are respectively mainstream and tributary stations in Lao PDR; TMS and TTR mainstream and tributary stations in Thailand, CMS and CTR mainstream and tributary stations in Cambodia, and VMS and MTR mainstream and tributary stations in Viet Nam The red horizontal line is the values for total phosphorous at 0.08 mg/l (Table 2).

Important Note and Outlook

The maintenance of good or acceptable water quality to promote the sustainable development of the Mekong River is of paramount concern basin wide, and it has become evident that Integrated Water Resources Management (IWRM) is needed. If water resources are not properly managed and water quality deteriorates, then human health and aquatic life may be compromised.

The potential human impacts on Mekong water quality are assessed by the WQI for Human Impact and four key water quality parameters. While monitoring results in 2000 - 2008 found that water quality at the monitoring stations in the uppermost part of the LMB reflect lower human impacts, the water quality of those in the downstream part of LMB; from Chroy Chanvar station to the Mekong Delta, reflect relatively higher human impacts.

There has been little temporal variation in the four key water quality parameters i.e. total suspended solids, total nitrate and nitrite, total phosphorus and COD, for the years of 2000 - 2006, 2007 and 2008. The water quality classification shows some temporal trends of human impacts in the part of Basin indicating deterioration of water quality through 2000 - 2008.

Human impacts on Mekong water quality are also investigated by a comparison of the four key water quality parameters in the Mekong mainstream and some tributaries. For the most part, the findings show that the Mekong mainstream water is likely to be less impacted than in tributaries. This reflects the relatively greater extent of human activities in the tributaries resulting in more degradation of the Mekong water quality than in the mainstream.

The potential increase in the development of both agricultural practices (e.g. increased use of fertilizers) and rapid urbanisation are expected to result in changes in the water quality in the Mekong River Basin. The evaluation of water quality between 2000 - 2008 shows only a few cases where nutrients (nitrate-nitrite, ammonium, and total phosphorus) and organic matter (COD) are gradually and steadily increasing.

Water quality monitoring for the protection of human health, aquatic life and monitoring of trends, impacts, and improvements are issues of concern to the countries of the LMB. Although it is not always possible to predict all of the potential

human threats to aquatic ecosystems, baseline water quality monitoring must be maintained to facilitate the early detection of such threats. Water quality managers should review their water quality monitoring programme to take these threats into account. Some issues may simply require the maintenance of routine monitoring programmes, while others will require additional specific diagnostic programmes to identify target water quality parameters and/or contaminants. For several years, there has been a successful collaboration through the Mekong WQMN, however there is a general understanding that an improved and revised targeting for a more effective and sustainable monitoring programme is needed with full involvement of the respective Member Countries.

The future of water quality in the Mekong River Basin depends on investments from individuals, communities, and governments at all political levels to ensure that water resources are protected and managed in a sustainable manner. This includes not only technological solutions to water quality problems, but changes in human behaviour through education and capacity building to better preserve aquatic resources. Cooperation in integrated water resources management activities is also required at multiple levels in terms of both political and economic structures.

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