**Mekong River Commission Lao National Mekong Committee**

# Annual Report on Water Quality Data Assessment

# Lao PDR – 2017

**Water Quality Monitoring Network in Mekong River Basin**

**Natural Resources and Environment Research Institute**

**Ministry of Natural Resources and Environment**

## Abbreviations and acronyms

| | |
|---|---|
| BOD | Biology Oxygen Demand |
| COD | Chemical Oxygen Demand |
| CIIS | China Information Services |
| DO | Dissolved Oxygen |
| MRC | Mekong River Commission |
| LNMC | Lao National Mekong Committee |
| T-P | Total Phosphorus |
| WQIal | Water Quality Index for aquatic life |
| WQIhh | Water Quality Index for human health |
| WQIag | Water Quality Index for agricultural uses |
| WQMN | Water Quality Monitoring Network |
| WHO | World Health Organization |
| MRC | Mekong River Commission |
| EC | Electrical conductivity |
| UNEP | United Nations Environmental Programme |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USGS | U.S Geological survey |
| EU | European Union |
| EPI | Environmental Performance Index |
| LMB | Lower Mekong Basin |
| NMC | National Mekong Committee |
| ISO | International Organization for Standardization |

**Summary**

Water quality is the key factors in determining environmental health. The livelihoods of most of the 60 million people who live in the Lower Mekong Basin (LMB) depend to some extent on the water resources of the Mekong River. These livelihoods rely on the environmental health of the Mekong River and its tributaries remaining in good condition. Under the guidance of the Mekong River Commission, the four lower riparian countries (the Lao PDR, Thailand, Cambodia and Viet Nam) have monitored the water quality of the LMB since 1985 (monitoring of the Cambodian component began in 1993).

The Water Quality Monitoring Network (WQMN) has been reviewed and improved in 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 Tran's boundary tributaries. The current WQMN includes water quality monitoring for 11 monitoring stations in Lao PDR.

This annual report on Water Quality Data Assessment provides an overview of water quality parameters and the changes of key environmental stressors that may impact on the Rivers aquatic life. It provides a summary of water quality monitoring data during the period from January to December 2017 and 2010-2017 for the water quality index both for ―Protection of aquatic life‖ and ―Human Health‖. The data are taken from 11 sampling stations in the Mekong River flow through the country such as: Houa khong, Luang Prabang, Vientiane, Savannakhet, Pakse, Ban Hatkham, Ban Hai, HouayMakHioa, Ban Kengdone, Sebangfai and Sedone Bridge. Current status and trend of water quality are reported in terms of temporal variation and spatial variation. The status of water quality is compared to the Lao National Environmental Standard (Surface Water Quality Standard) and MRC TG Target Value.

Trend of water quality for both temporal and spatial variations plotted the data of 2005-2017 by Fitted curve and ANOVA. Three categories of water quality indexes (WQI) are used: (1) for the protection of aquatic life (WQIal), (2) for human health (WQIhh) and (3) for agricultural use (WQIag).

Each WQI category is subdivided into classes according to the number of chemical parameters that meet guideline thresholds. The classes are: WQIal: High Quality, Good Quality, Moderate Quality, Poor Quality, Very Poor Quality, WQIhh: Excellent Quality, Good Quality, Moderate Quality, Poor Quality, Very Poor Quality and WQIag: No Restrictions, Some Restrictions and Severe Restrictions.

The water quality index and threshold value for protection of aquatic life of the Mekong mainstream and its tributaries are High Quality and Good Quality, except HouayMakHiao tributary the WQIal (for the protection of aquatic life) are classed as Moderate Quality. The WQIhh (for human Health) of the Mekong mainstreams and tributaries most of stations are Excellent Quality in 2017, there are only three stations are Good Quality such as: Savannakhet, Sebangfai and Ban Kengdone tributaries. WQIhh (for human health) at Houay MakHiao is classed as Moderate Quality in 2017.

The lower index values at Houay MakHiao reflect higher population densities, aquaculture and agriculture practice, sewage water, road contruction and industrial wastewater. In the future if there is no good management of wastewater in Vientiane Capital, it will be greater threats to the Mekong downstream of Vientiane.

In the Mekong mainstream and tributaries, the WQIag (for agricultural use) is consistently at the level of No Restrictions, however some station such as Houay MakHioa in 2011-2012, the WQIag has a maximum conductivity greater than the threshold value of Some Restrictions in WQIag (for general irrigation use).

Current status both for temporal and spatial variation of the basic parameters is good /acceptable of nearly most stations along the Mekong mainstreams.

Dissolved oxygen (DO) value of most stations of the Mekong River meet Lao National Environmental Standard (Surface Water Quality Standard) and threshold value for protection of aquatic life and human impact on water quality, which indicates excellent/acceptable water quality and COD value of most stations of the Mekong River meet Lao National Surface Water Quality Standard, which indicates excellent/acceptable water quality.

Houay MakHiao is less dissolved oxygen (DO) value, and high concentration of nutrients and organic matter.

# 1. Introduction

## 1.1 The Mekong River Basin.

The Mekong River is a longest river in Southeast Asia, the 7th longest in Asia, and the 12th longest in the world. It has a length of about 2,700 miles (4,350 km). Rising in southeastern Qinghai province, China, it flows through the eastern part of the Tibet Autonomous Region and Yunnan province, after which it forms part of the international border between Myanmar (Burma) and Laos, as well as between Laos and Thailand. The river then flows through Laos, Cambodia, and Vietnam before draining into the South China Sea at the south of Ho Chi Minh City. Vientiane the Capital of Laos and Phnom Penh, the Capital of Cambodia, both stand on its banks. About three-fourths of the drainage area of the Mekong lies within the four countries the river traverses on its lower course Laos, Thailand, Cambodia, and Vietnam.

The Mekong River drains more than 307,000 square miles (795,000 square km) of land, stretching from the Plateau of Tibet to the South China Sea. Among Asian rivers, only the Yangtze and Ganges have larger minimum flows.

The Mekong Basin can be divided into two parts: the 'Upper Mekong Basin in Tibet and China, and the Lower Mekong Basin from Yunnan downstream from China to the South China Sea. The Upper Basin makes up 24% of the total area and contributes 15 to 20% of the water that flows into the Mekong River. The catchment here is steep and narrow. Soil erosion has been a major problem and approximately 50% of the sediment in the river comes from the Upper Basin.

The livelihoods of most of the 60 million people who live in the Lower Mekong Basin (LMB) depend to some extent on the water resources of the Mekong River. These livelihoods rely on the environmental health of the Mekong River and its tributaries remaining in good condition. Water quality is a key factor in determining environmental health. Under the guidance of the Mekong River Commission, the four lower riparian countries (the Lao PDR, Thailand, Cambodia and Viet Nam) have monitored the water quality of the LMB since 1985 (monitoring of the Cambodian component began in 1993). Table 1.1 Basic data on country share of Mekong Basin territory and water flows.

Table 1.1 Basic data on country share of Mekong Basin territory and water flows

| | China | Myanmar | Lao PDR | Thailand | Cambodia | Vietnam | Total |
|---|---|---|---|---|---|---|---|
| **Area in Basin (km²)** | 165,000 | 24,000 | 202,000 | 184,000 | 155,000 | 65,000 | 795,000 |
| **Catchment as % of MRB** | 21 | 3 | 25 | 23 | 20 | 8 | 100 |
| **Flow as % of MRB** | 16 | 2 | 35 | 18 | 18 | 11 | 100 |


Figure1.1: The Mekong River Basin

The Mekong Water Quality Monitoring Network (WQMN) has been reviewed and improved in 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 Tran's boundary tributaries. The current WQMN includes water quality monitoring for 48 permanent monitoring stations; of which 11 are in Lao PDR, 8 are in Thailand, 19 are in Cambodia and 10 stations are in Viet Nam. (See map below)

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The Mekong's catchment is geographically diverse. The basin is mountainous in China, in north of the Lao PDR, and along the frontier between Viet Nam and the Lao PDR and Cambodia.


Figure1.2: MRC WQMN sampling stations of the MRC WQMN in the Mekong and Bassac

This current annual report provided the main parameters included in the database - basic parameters, nutrients, organic matter and Microbiology. This report does not include toxic chemicals (metals, pesticides, industrial chemicals, etc.).

## 1.2 Sources of pollution

### Upper Mekong Basin

The provincial government of Yunnan Province in the People's Republic of China, located immediately upstream of Chinese/Lao border, is reported to have inspected 1042 industrial enterprises in the basin in 2000, and shut down four of these (CIIS, 2002). Since 1986, the Simao Paper Plant and Lanping Lead-Zinc Mine have been built on the banks of the Lancang (Mekong) River. In addition to these industrial enterprises, a number of hydropower stations, including those at Manwan, Dachaoshan, and Jinhong have been built on the Lancang. Four more hydropower stations are under construction or are planned for the next 20 years (including Xiaowan, located 550 km upstream of the Chinese/Lao border and Nuozhadu). Chinese data for water quality of Lancang are not accessible and not shared with the MRC.

MRC (2007a) notes that Eco toxicological assessment carried out for the MRC on the Lao side of Chinese border suggests that at this site there is some toxicity that requires further investigation.

**Municipal wastewater**

The largest urban area at Vientiane in the Lao PDR is concern as it lies on the banks of the Mekong. Currently, Vientiane, a city less than 800,000 inhabitants, discharges its municipal sewage into That Luang Marsh - a wetland that discharges into the Mekong River some distance downstream of Vientiane. However, development of Vientiane Capital (including substantial land reclamation in the That Luang Marsh for urban and industrial purposes) is a concern, and may pose grater threats to the mainstream in the future.

**Agriculture and non-point source pollution**

**Fertilizer**

Fertilizer rates were very low in rainfed areas of Cambodia, Lao PDR and NE Thailand in 2007. This is a reflection of high risk of rice farming under rainfed conditions. Approximate fertilizer rates for the different scenarios are presented in Table 13.

Table 1.3 Use of fertilizers in the LMB, (MRC 2009)

| Country | Nitrogen (kg UREA/ha) | Phosphorus (kg DAP/ha) | Potassium (kg KCl/ha) | Manure (cart/ha) |
|---|---|---|---|---|
| | Wet season rice (irrigated and non-irrigated) (1st season) | | | |
| **Lao PDR** | 40 | 10 | | 5 |
| **Cambodia** | 40 | 20 | | 5 |
| **NE Thailand** | 40 | 20 | 20 | |
| **Vietnam** | 140 | 120 | 80 | |
| | Dry season rice (2nd season) | | | |
| **Lao PDR** | 80 | 50 | | |
| **Cambodia** | 80 | 60 | | |
| **NE Thailand** | 80 | 60 | | |
| **Vietnam** | 180 | 120 | 80 | |
| | Third season rice | | | |
| **Lao PDR** | 70 | 30 | | |
| **Cambodia** | | | | |
| **NE Thailand** | | | | |
| **Vietnam** | 160 | 120 | 80 | |

Note that the fertilizer rates for the Mekong Delta are much higher than for the other three LMB countries.

Irrigated rice yields are significantly higher than the rainfed areas and require more fertilizer to fulfill the crops potential. These irrigated crops are the main dry season crops in the LMB.Again, the current application rates in the Mekong Delta are significantly higher than other countries.

Some of this increase is due to cultivation of larger areas, but there has also been a major increase in use of fertilizers (Table1.3)

Agriculture, therefore, is a potential contributor of nutrients to rivers in LMB. In addition to the expansion and intensification of paddy rice production, there is also significant production of other crops such as maize, cassava and sugar cane.

**Non-pointsources**

There is anecdotal evidence of the use of mercury in artisanal placer gold extraction in the mainstream in the Lao PDR and in some tributaries of the Mekong. Discharge of human waste from all river vessels plying the Mekong, especially tour boats in the reach extending upstream from Luang Prabang (Lao PDR) to the China border, and accidental spills from river barge traffic, are water quality threats. Other types of pollution from non-point sources, such as residual dioxins/furans from use of Agent Orange during the American War, were detectable in bottom sediments at low level at some downstream sites (MRC, 2007a).

**Mining**

Mining development is expanding rapidly in the LMB, raising concern about serious impairment of receiving water quality. As documented of USGS in Minerals Yearbook Laos 2013, As of yearend 2011 (the latest year for which data were available), a total of 152 mining companies were operating in Laos, of which 70 were domestically owned and 82 were foreign enterprises. The 152 mining companies operated in 256 mining concessions across the country (Lao Voices, 2011).

**Hydropower**

Hydropower developments for the entire LMB will be overlain with GIS-format sub-basin map to show where water quality impacts may be occurring. Available information on dam location, type (i.e., run-of-river, reservoir), installed capacity, and design discharge will permit more detailed characterization of possible downstream tributary and Mekong mainstream impacts.

Impairment of water quality can occur both during construction and operation of hydropower schemes. Construction phase impacts are typically caused by quarrying activities, spoil disposal, construction camps and road building. Operation phase impacts are more pronounced during early years of dam operations (i.e., especially for schemes involving large reservoirs), with release of discharge water with high pH, low oxygen and high concentrations of hydrogen supplied, ammonia and methane impacting on downstream water quality. Water releases can also cause morphological changes in receiving rivers, with pronounced bank erosion often occurring during to temporal variation in discharge rates.

### 1.3 Overview of the Mekong River and Tributaries in Lao PDR

Laos lies almost entirely within the Lower Mekong Basin. Its climate, landscape and land use are the major factors shaping the hydrology of the river. The mountainous landscape means that only 16% of the country is farmed under lowland terrace or upland shifting cultivation. With upland shifting agriculture (slash and burn), soils recover within 10 to 20 years but the vegetation does not. Shifting cultivation is common in the uplands of Northern Laos and is reported to account for as much as 27% of the total land under rice cultivation. As elsewhere in the basin, forest cover has been steadily reduced during the last three decades by shifting agriculture and permanent agriculture. The cumulative impacts of these activities on the river regime have not been measured. However, the hydrological impacts of land-cover changes induced by the Vietnam War were quantified in two sub-catchments of the Lower Mekong River Basin.

### River Water

Main rivers of the Lao PDR dominantly consist of the first and second tributaries of the Mekong River. There are about 39 main tributaries in the Mekong river basin. Main rivers that have bigger catchment area of more than 5000 km², are the following 11 rivers: Nam Ou River Basin is located Northern region, Lao PDR; Nam Suang is located Northern region; Nam Khan is located Lang Prabang Province; Nam Ngum is located Northern-Central part; Nam Nhiep are located Phonesavan of Xiengkhuang province; Nam San is located Bolikhamxay province; Nam Theun/Kading is located Bolikhamxay Province; Sebangfay is located Khammouane Province; Sebanghieng is located Savannaket Plain; Sedone is located Southern part; and Sekong is located South-Eastern part of the country. Total watershed area of the main tributaries is estimated at about 183,000 km². On the other hand, only 2 main rivers, namely Nam Ma and Nam Ka rivers, are located outside of the Mekong river basin and expanded in the eastern area of Houaphan and XiengKhuang provinces. Both drain through Viet Nam directly to the South China Sea. Total watershed area of both rivers is approximately 13,000 km². Generally physical and hydrological characteristics of the main rivers and their catchment areas are as follows:

(1) ***Nam Ou River*** is the longest in the northern region of Lao PDR. It originates at Ban LantougGnai Village near the Lao-China border and flow to the south. It has a total length of 390 km to the confluent point with the Mekong River. The total drainage area is 25,000 km² covering Phongsaly province, one third of Oudomxay province, and one haft of LuangPrabang province. The annual discharge is 12,276,964,800 m³

(2) ***Nam Suang River*** with a length of 150 km has a source near Ban Sopkok Village at 1,482 meters, flows in a south-west direction for about 50 km and then turns to the west and finally south-west ward to enter the Mekong River. The drainage area is 5,800 km² with 76.4% of the catchment classified as mountainous, and 22.9% as hilly. The annual discharge is 3,654,076,320 m³

(3) ***Nam Khane River*** with a length of 935 km has its origin near Phou Nam Pa at an altitude of 1,828 m. It flows down steep slope in the east-west direction to meet the Mekong River at LuangPrabang City at an altitude of 300 m. The drainage area is 6,100. The annual discharge is 29,454,624,000 $m^3$.

(4) ***Nam Ngum River*** with a length of 1,403 km and draining as area of 17,000 $km^2$ is the largest river of Xiengkhouang and Vientiane provinces and one of the major tributaries of Mekong in Lao PDR. The river source is located in the Plain of Jars about 1,000-1,100 m above mean sea level. After joining with Nam Lik, the Nam Ngum flows down into the Vientiane Plain for about 80 km in southerly direction to ThaNgone, and then for another 80 km in an easterly direction to join the Mekong River at Pak Ngum District. The annual discharge is 23,021,280,000 $m^3$.

(5) ***Nam Nhiep River*** is a local name meaning Quiet River. It originates from Phonesavanh Village in Xiengkhuang plateau with an altitude of 1,050 m above mean sea level, flows in a southerly direction to meet an important tributary called Nam Siam near Ban Xiangkhong Village and changes to the southeast direction to meet another tributary, Nam Chian. From this point to outlet near Paksan City, the river flows southerly for a distance of about 95 km. The length of Nam Nhiep is 156 km and catchment area is 4,270 $km^2$. The annual discharge is 5,885,248,320 $m^3$.

(6) ***Nam Sane River,*** locally known as Steep River, originates from diamond of Phou Sam Soum Mountain with an altitude of 2,620 meters above mean sea level, flows to west-northwest through a group of villages around Ban Phouviang Village. It then flows down in the southwest to Ban Thathom Village, and continues to the south-southwest to meet the Mekong at Paksan City. The river is 120 km long with a catchment area of 2,230 $km^2$. The annual discharge is 4,271,235,840 $m^3$.

(7) ***Nam Theun/Kading River***, where the upper part is in Khammouane province while the middle and the lower areas are in Bolikhamxay province in central Lao PDR, has several tributaries: as illustrated on map of stream flow, the upper reaches in the plateau consist of Nam One, Nam Noy, and Nam Theun that have total length of 138 km and drain as area of 2,800 $km^2$, the annual discharge is 7,027,166,880 $m^3$. Nam Theun and its tributaries have many promising projects for flood control and hydropower.

(8) ***Sebangfay River*** mountainous with some peaks higher than 1,500 meters. Flat land appears around Mahaxay District of Khammoune province, where an important tributary Nam Gong/ kathangis 38.5 km long, drains to Gnommalath District. Downstream of the Sebangfay Bridge, an area of up to 70,000 ha of potential agricultural land exists with wetlands, consisting of freshwater lakes, river, ponds, rice paddy and some freshwater marchers, of around 125 $km^2$. It is believed that the constant year-round discharge of 13,623,552,000 $m^3$ released from Nam Theun powerhouse will change the river morphology of the Sebangfay from Mahaxay to the confluence with the Mekong.

(9) ***Sebanghieng River*** is situated in the southern part of Lao PDR, and adjoins the Sebangfay basin which extends immediately to the north. The two basins ranked as the largest basins of the country. The Sebanghieng originates in the Lao-Viet Nam borders at the elevations of 1,000 – 2,000 meters, flows westward with nine major tributaries, and then flows into the Mekong River at a point about 90 km downstream of Savannaket Province. It has a length of about 3,442 km. The total catchment area at the confluence with the Mekong is 21,516 km², and annual discharge is 15,673,392,000 m³.

(10) ***Sedone River*** is a total length of 1,475 km, has its origin in the north-eastern side of Bolaven Plateau near Thateng District at 800 m. The catchments area is 6,170 km², and annual discharge is 5,064,681,600 m³.

(11) ***Sekong River,*** the source of the river is near the Lao-Viet Nam borders at an elevation of 1,800 meters. The length of the mainstream to Attapue is about 170 km. The total catchments area is 10,500 km², and annual discharge is 16,146,432,000 m³.

Table 1.4 River Basin Area Sand Annual Runoff of the Major River Basin in Lao PDR

| **Basin** | **River Basin Name** | **No Watershed area [sq.km.]** | **Annual discharge [m³]** | **Length of main stream [km]** |
|---|---|---|---|---|
| **1.** | Nam Ou | 19,700 | 12,276,964,800 | 390 |
| **2.** | Nam Suang | 5,800 | 3,654,076,320 | 150 |
| **3.** | Nam Khane | 6,100 | 29,454,624,000 | 250 |
| **4.** | Nam Ngum | 16,500 | 23,021,280,000 | 1,403 |
| **5.** | Nam Nhiep | 4,270 | 5,885,248,320 | 156 |
| **6.** | Nam Sane | 2,230 | 4,271,235,840 | 120 |
| **7.** | Nam Theun/Cading | 3,370 | 7,027,166,880 | 138 |
| **8.** | Nam Sebangfay | 8,560 | 13,623,552,000 | 190 |
| **9.** | Nam Sebanghieng | 19,400 | 15,673,392,000 | 370 |
| **10.** | Nam Sedone | 6,170 | 5,064,681,600 | 1,574 |
| **11.** | Nam Sekong | 10,500 | 16,146,432,000 | 170 |

Sources: *Department of Hydrology and Meteorology,2004*

In general, the water quality of rivers within the Lao PDR, and the Mekong is considered to be good, based on international standards. The level of oxygen is high and the nutrient concentration is low. Sediment is the primary pollutant source affecting rivers. Sedimentation loads in tributaries vary considerably from 41 tones/km²/ year to 345 tones/km²/year. Tributaries and river reach with high sedimentation are the Sebanghieng, Sedone, Nam Ou, and the upper and lower stretches of the Mekong (Water Sector Study, ADB, 1998). With the pressure of rapid demographic growth, socio-economic development and urbanization, however, the water quality is increasingly exposed to deterioration. In 1999, it was estimated that 35% of liquid effluent disposal to inland surface waters from all sources was treated, while the quantity was unknown.

### 1.4 Objective of the report

This annual country report on Water Quality Data Assessment provides an overview of water quality parameters and the changes of key environmental stressors that may impact on the Rivers aquatic life. It provides a summary of water quality monitoring data during the period from January -December 2017 for current status, the period 2005-2017 for the trends and 2010-2017 for the water quality indices both for Protection of aquatic life and Human Health. The data are taken from 11 sampling sites in the Mekong River flow through the country such as: Houakhong, LuangPrabang, Vientiane, Savannakhet, Pakse, Ban Hatkham, Ban Hai, Sebangfai, Ban Kengdone, Sedone Bridge and Hoay MakHioa.

## 2. Methods

### 2.1 Sampling

#### Sampling station

Sampling stations in Lao PDR has been revised in 2009, cover only 11 stations, as shown in Figure 1.3 and list of the sampling sites and detail information see the Appendix No 2.

**WQMN Sampling Sites in Lao PDR**

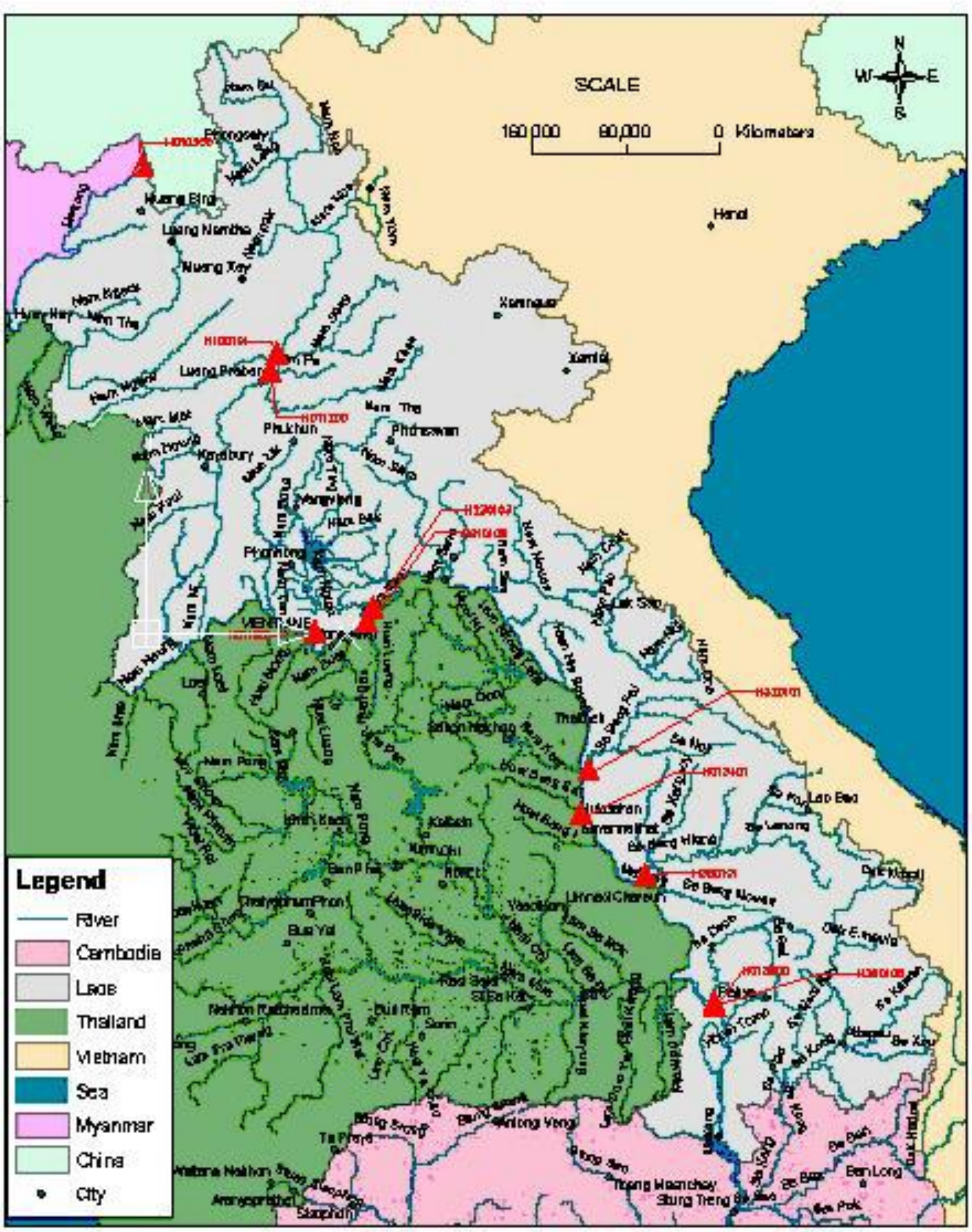



Figure 1.3 WQMN in Lao PDR indicating the sampling sites

### Sampling techniques

The Mekong River and its tributaries are generally well mixed; therefore, the monitoring involves sampling once a month by using a simple surface grab technique of from the edge of the river in a location where it is apparent that water is free flowing and well mixed. Water sample are taken at 30-50 cm depth below the surface.

Water sampling, sample preservation and transportation had been performed following the Standard Operating Procedure of the WQMN, which are applied for manual sampling of surface water. After preserving, all water samples were quickly transported to the laboratory. Details of sampling technique are described in Appendix 1.

### Sampling frequency and duration

Samplings were taken approximately in the middle of every month, which started in January 2017.

## 2.2 Parameters and analytical methods

Monitoring parameters are grouped as follows:

* Basic parameters: Temp, pH, EC, TSS, Alkalinity, and DO
* Major ions: $Na^+$, $K^+$, $Ca^{+2}$, $Mg^{+2}$, $SO_4^{-2}$, $Cl^-$
* Nutrients: $NH_4^+$, $NO_{2,3}^-$, T-N, T-P
* Organic matter: COD
* Microbiology: BOD (Vientiane station), Faecal coliforms

List of parameters and analytical methods are presented in Table 2.1 Table

2.1 List of parameters and analytical methods

| Parameters | Unit | Analytical Method | Standard Test Method |
|---|---|---|---|
| pH | none | Electrometric Method | ** |
| Conductivity | mS/m | Conductivity Meter | ** |
| Temperature | ºC | Laboratory and Field Method | ** |
| Ca | mg/L | Direct Air-Acetylene Flame Method | ** |
| Mg | mg/L | Direct Air-Acetylene Flame Method | ** |
| Na | mg/L | Flame Photometric Method | ** |
| K | mg/L | Flame Photometric Method | STM#19-02-007 |
| DO | mg/L | Membrane Electrode Method | STM#19-01-004 |
| Alkalinity | mg/L | Titrimetric Method | STM#19-02-002 |
| TSS | mg/L | Dried at 103-105 C | STM#19-01-008 |
| SO4 | mg/L | Turbidimetric Method | STM#19-01-005 |
| Cl | mg/L | Argentometric Method | STM#19-01-012 |

| | | | |
|---|---|---|---|
| NO3+NO2 | mg/L | Cadmium reduction Method | STM#19-01-010 |
| Total-P | mg/L | Persulfate digestion Method and Ascorbic Acid Method, | STM#19-01-007 |
| NH4 | mg/L | Phenate Method | STM#19-01-006 |
| $COD_{Mn}$ | mg/L | Permanganate Method | STM#19-01-009 |
| Total-N | mg/L | Persulfate Method and Cadmium Reduction Method, | STM#19-03-001 |
| Feacal coliform | MPN in 100 ml | Multiple-tube Fermentation Technique | STM#19-03-001 |
| BOD | mg/L | Azide Modification Method | STM#19-02-005.1 |

*Sources: Natural Resources and Environment Research Institute, 2013*

Remarks: * Refer to Standard Method for the Examination of Water and Wastewater, APHA/AWWA/WEF

** Instrument Operation Manual

*** Refer to Analytical method used by the Water Quality Monitory Network Project

### 2.3 Data assessment methodology

#### 2.3.1 Data reporting

Current status and trend of water quality are reported in terms of temporal variation and spatial variation. For current status, temporal variation employed a box plot (month and parameter). Spatial variation employed a line plot (station and parameter). The status of water quality is compared to the Lao National Water Quality Standard and MRC Water Quality Procedure. Trend of water quality for both temporal and spatial variations plotted the data of **2005 – 2017** by Fitted curve and ANOVA.

#### 2.3.2 Group of parameters

1. General parameters: Temp, pH, EC, TSS and DO

2. Nutrients: NH4+, NO2,3 -, T-P

3. Organic matter: COD

#### 2.3.3 Water-Quality Index

Another way for evaluation the water body adequacy and impact are considered by water quality indices (WQI). The WQI is one of the most widely used of all existing water quality procedures. Water Quality indices were related to water quality in some physical-chemical properties. They have scales which reflect in term of protection of aquatic life, human health on water quality and a range of potential water use. In order to amalgamate water chemistry data various indices are frequently used. 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: a. WQIal for the protection of aquatic life b. WQIhh for human Health on water quality c. WQag for agriculture uses which is divided into three parts

* For general irrigation
* Irrigation of paddy rice
* Livestock and poultry

These indices have been calculated using a special program. Data for most stations and years are complete and will allow a high quality of the index values.

**Water Quality Index for the Protection of Aquatic life**

The Water Quality Index for the Protection of Aquatic Life is calculated using Equation 2-1. The index has been developed as an open-ended index which would allow more parameters to be added once data becomes available (Campbell, 2014). In this annual water quality report, only six parameters are included. These parameters, together with their target values, are listed in Table 3.4 (Appendix 3). The classification system for the Water Quality Index for the Protection of Aquatic Life is summarized in Table 3.5 (Appendix 3).

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

Where,

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

**Water Quality Index for the Protection of Human Health**

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

The Human Health Acceptability Index utilizes parameters of indirect impact, as identified by the HH while the human health risk index utilizes direct impact parameters. The rating score for both indices can be calculated using Equation 2-2, which is based on the Canadian Water Quality Index (CCME 2001). It should be noted that since the monitoring of direct impact parameters has not commenced, Member Countries have agreed to adopt only the human health acceptability index. Furthermore, due to the lack of data availability at the time of the preparation of this report, of the parameters included in TGH as indirect impact parameters, total coliform, phenol, temperature, oil and grease, and biochemical oxygen demand are not included in the calculation of the rating score for the human health acceptability index. The list of the approved parameters to be included in the calculation of the rating score for the human health acceptability index, together with their target values are listed in Table 3.6 (Appendix 3). The classification system for the Water Quality Index for the Protection of Human Health Human Acceptability Index is summarized in 3.7 (Appendix 3).

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

Where, $F_1$ is the percentage of parameters which exceed the guidelines and can be calculated by Equation 2-3.

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

$F_2$ is the percentage of individual tests for each parameter that exceeded the guideline, and can be calculated by Equation 2-4.

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

$F_3$ is the extent to which the failed test exceeds the target value and can be calculated using Equation 2-5.

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

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

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

The excursion is calculated by Equation 2-7.

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

**Agriculture Use**

Water Quality for irrigation purposes is a complex issue reflecting crop type, irrigation practices, influence on soil characteristics, and status of the crop (emergent, mature, etc.). Generally, water for irrigation is assessed for: * Salinity * Sodicity1 (expressed as SAR value): Sodicity is highly dependent upon the conductivity of the irrigation water, chemistry of the irrigation water, on soil structure and soil geochemistry, and irrigation technique. Because it is highly variable, sodicity is beyond the scope of a basin-wide water quality assessment. * Specific Ion Toxicity: Specific ion toxicity is focused on sodium and chloride and on other trace elements such as boron. It is not possible to generalize about specific ion toxicity because this is not only due to irrigation water chemistry but also due to complex and site-specific interactions amongst soil, water, type of irrigation and crop type.

1. Sodicity is measured as the SAR (sodium adsorption ratio) value and is used to assess water penetration and percolation in the soil and to calculate permissible levels of salinity in source water (Rhoades et al., 1992)

### 2.3.4. Quality Assurance and Quality Control program

The laboratory has been participated in the implementation of the Quality Assurance and Quality Control system in 2012. There is the main Quality manual work and procedures in water quality laboratory. The laboratory quality work is carried out according to the principles of the International Organization for Standardization ISO/IEC 17025.

During 2013-2017, The MRC has been organized the External audit and assistance in the implementation of QA/QC and participate the Proficiency Testing Study.

The laboratory has made significant improvement in management and technical requirements. The numbers of operating procedures have been completed: data control, sampling (handling, preservation and transportation), preparation of standard and control samples, chemical control, calibration analytical balances and pipettes, and analytical equipment’s, log books for all equipment’s.

The laboratory carries out quality control system; the duplicated samples. Control sample, Field blank samples, Spike sample, and Control chart.

The laboratory also completed the calculation of uncertainty and detection limit for all of analytical parameters.

Proficiency testing study from 2013-2017: remarkable increasing on the numbers of acceptable results.

Water quality data control system:

* External control: yearly participate on the PT study, Certify Reference Material

* Internal Control: field blank sample, duplicated samples, Control samples, Spike sample, Control Chart, Reliability Score Test and data validation.

* Reliability Score Test: ion balance test, EC cation test, EC anion test, EC ion test, Nutrient test (NO32-N, NH4-N, Total-N and Tot-P) and specific ratios for surface freshwater (Ca/Mg, Na/k and Cl/SO4).

## 3. Results and Discussions:

### 3.1 Basic parameters

#### 3.1.1 Temperature

The temperature of a body of water influences its overall quality. Water temperatures outside the "normal" range for a stream or river can cause harm to the aquatic organisms that live there. If the water temperature changes by even a few degrees, it could indicate a source of unnatural warming of the water or thermal pollution.

Thermal pollution caused by human activities is one factor that can affect water temperature. Many industries use river water in their processes. The water is treated before it is returned to the river, but is warmer than it was before. Runoff entering a stream from parking lots and rooftops is often warmer than the stream and will increase its overall temperature.

Shade is very important to the health of a stream because of the warming influences of direct sunlight. Some human activities may remove shade trees from the area which will allow more sunlight to reach the water, causing the water temperature to rise.

Another factor that may affect water temperature is the temperature of the air above the water. The extent of its influence has a great deal to do with the depth of the water. A shallow stream is more susceptible to changes in temperature than a deep river would be.

While many factors can contribute to the warming of surface water, few cause it to be cooled. One-way water can be cooled is by cold air temperatures. A second, natural method of cooling a river or lake comes from the introduction of colder water from a tributary or a spring.

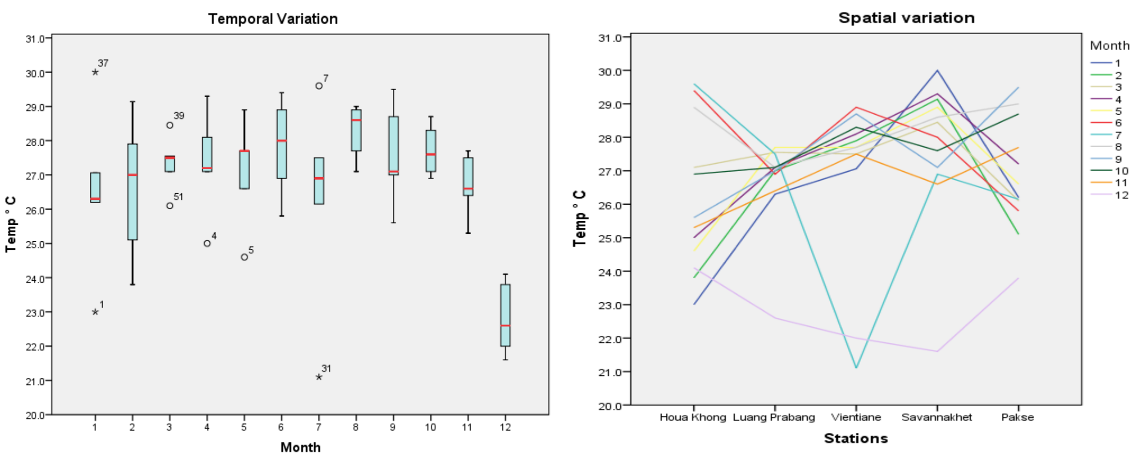
One important aspect of water temperature is its effect on the solubility of gases, such as oxygen. More gas can be dissolved in cold water than in warm water. Animals, such as salmon, that require a high level of dissolved oxygen will only thrive in cold water.

Increased water temperature can also cause an increase in the photosynthetic rate of aquatic plants and algae. This can lead to increased plant growth and algal blooms, which can be harmful to the local ecosystem.

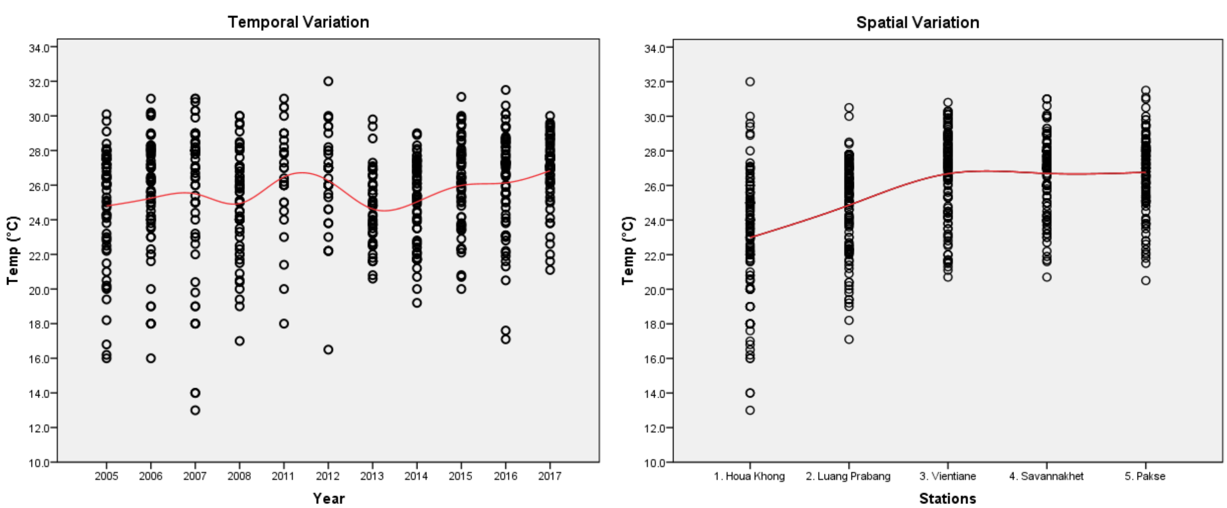
A change in water temperature can affect the general health of the aquatic organisms, thus changing the quality of the stream. When the water temperature becomes too hot or too cold, organisms become stressed, lowering their resistance to pollutants, diseases, and parasites.

***Current status***

Water temperature in the river system varies with seasonal changes and even throughout the day, warming in the daytime with cooling trends in the evening and overnight. Water temperature can have an adverse effect on water quality and the water's ability to hold dissolved oxygen. As water warms, it has a reduced ability to retain oxygen.




***Trends***



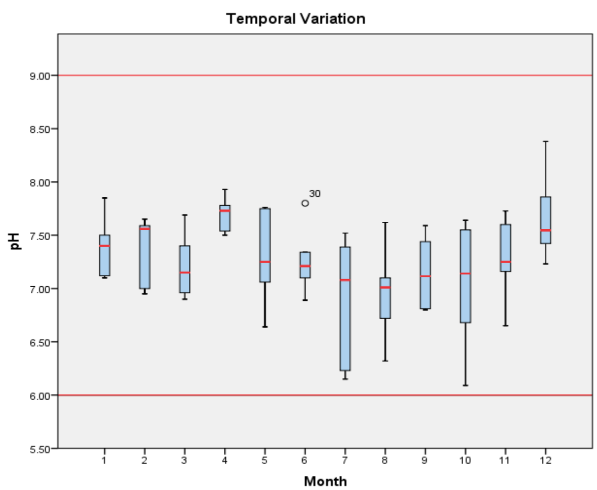

The temperature of the Mekong mainstream varies from 21.1- 30.0° C (Appendix 5). The red fitted curve shows Scatter plot showing a variation of temperature of five stations along the

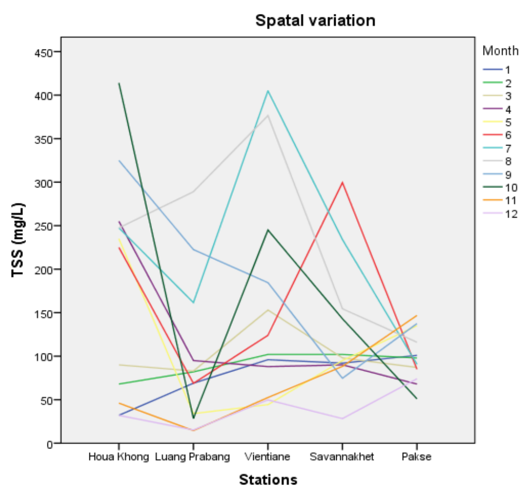
Mekong mainstreams. The trend of temperature was slightly significant changed during 2005-2017.

### 3.1.2 pH

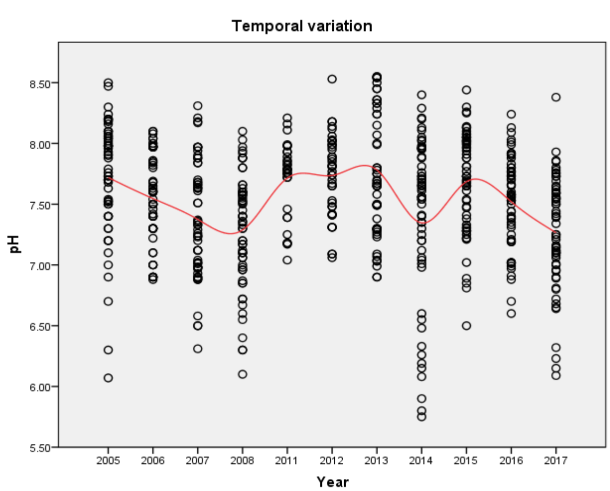
***Current status***

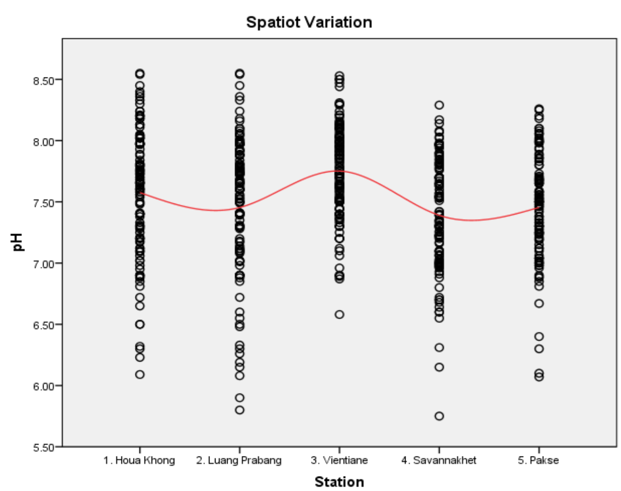
A pH (potential of Hydrogen) measurement reveals if a solution is acidic or alkaline (also base or basic). In chemistry, pH is a measure of the activity of the (solvated) hydrogen ion, which measure the hydrogen ion concentration is closely related to, and is often written as, pH. Pure water has a pH very close to 7 at 25°C. If the solution has an equal amount of acidic and alkaline molecules, the pH is considered neutral. Very soft water is commonly acidic, while very hard water is commonly alkaline, though unusual circumstances can result in exceptions.




***Trends***



The pH scale is logarithmic and runs from 0.0 to 14.0 with 7.0 being neutral. Readings less than 7.0 indicate acidic solutions, while higher readings indicate alkaline or base solutions. Some extreme substances can score lower than 0 or greater than 14, but most fall within the scale. Measurement of pH for aqueous solutions can be done with a glass electrode and a pH meter, or using indicators. pH measurements are important in medicine, biology, chemistry, agriculture, forestry, food science, environmental science, oceanography, civil engineering, chemical engineering, and many other applications.

The horizontal line shows the threshold value for protection of aquatic life and human health pH value 6.00 - 9.00. In dry season pH value is higher and decreased during wet season of all stations of the Mekong mainstream. The highest value found in Houakhong station pH 8.38 in December. Most of stations of the Mekong mainstream have range from 6.09 – 8.38 (Appendix 5) along the Mekong River, which indicated the very good/acceptable water quality compared to the Lao National Environmental Standard (Surface Water Quality Standard) NO:81/GOV, Vientiane Capital, date 21 Feb 2017, (Appendix 4).

The red fitted curve shows the median variation of pH. The trends of temporal variation slightly changed from 2015-2017.

### 3.1.3 Conductivity (Cond.)

***Current status***

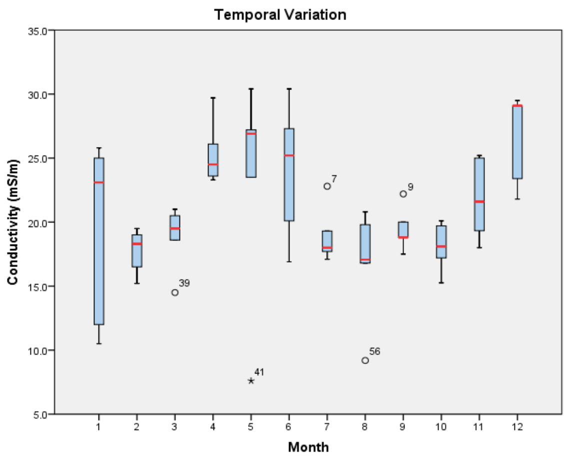
Conductivity measure the water's ability to conduct electricity, which provides a measure of what is dissolved in water. This is an indicator of the concentration of dissolved electrolyte ion in the water. It does not identify the specific ions in the water. However, significant increases in conductivity may be an indicator that polluting discharges have entered the water.

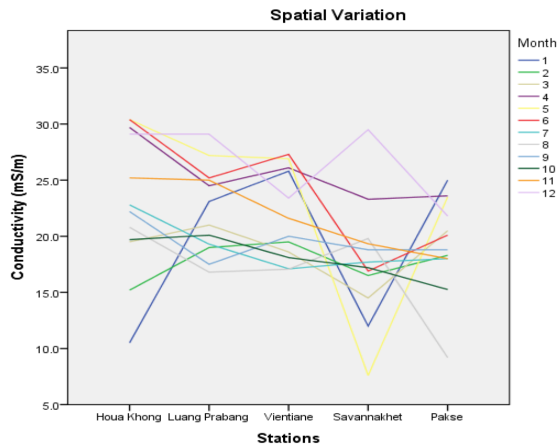
Every creek will have baseline conductivity depending on the local geology and soils. Higher conductivity will result from the presence of various ions including nitrate, phosphate, chloride, sulfate, sodium, calcium, and magnesium.

The basic unit of measurement for conductivity is micromhos per centimeter (µmhos/cm) or micro-Siemens per centimeter (µS/cm). Either can be used, they are the same. It is a measure of the inverse of the amount of resistance an electric charge meets in traveling through the water.

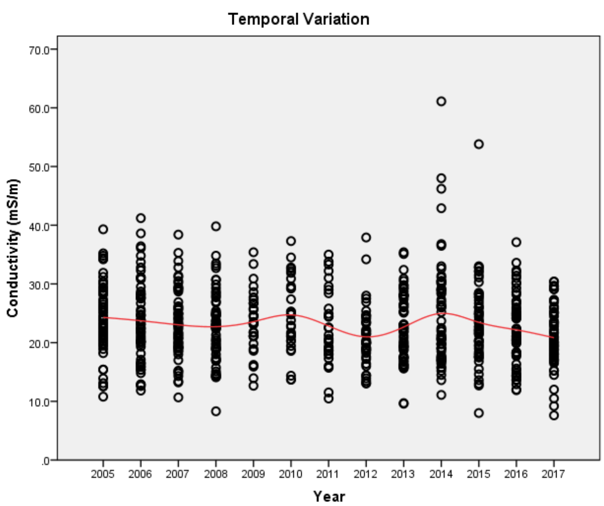
Distilled water has a conductivity ranging from 0.5 to 3µS/cm, while most streams range between 50 to 1500µS/cm. Freshwater streams ideally should have conductivity between 150 to 500µS/cm to support diverse aquatic life.

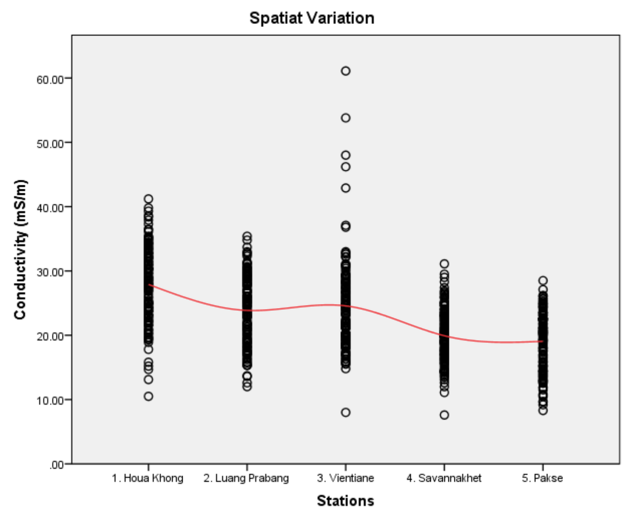
For the current status of the conductivity in the Mekong mainstream is high concentration during dry season and low concentration in wet season, cause of the diluting of the water volume.




***Trends***




The conductivity of the Mekong mainstream has ranges from 7.60– 30.4mS/m (Appendix 5). These values are less than 150mS/m of the threshold value for protection of aquatic life and human health; it is good/acceptable water quality for protection of aquatic life and human health of the Mekong River.

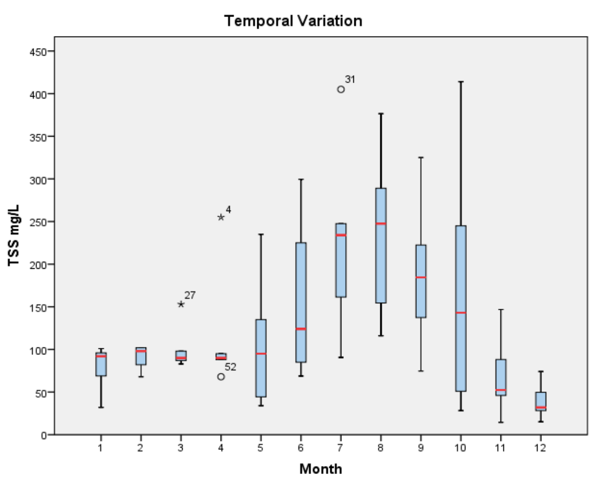
The red fitted curve shows the median value. The trend of conductivity in temporal, there was slightly significant changed in 2005 to 2017. The trend of conductivity in spatial variation decreased respectively from HouaKhong station to Pakse station.

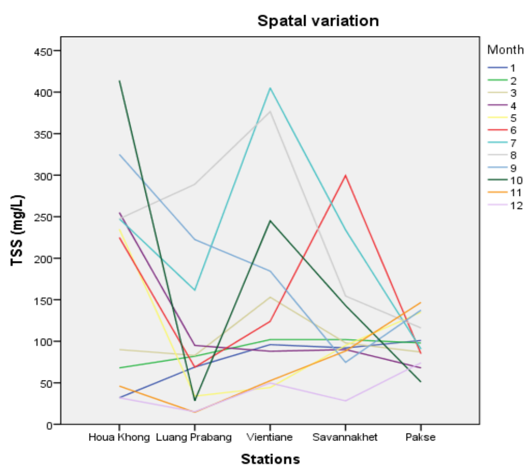
### 3.1.4 Total Suspended Solids (TSS)

Total Suspended Solids (TSS) is solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

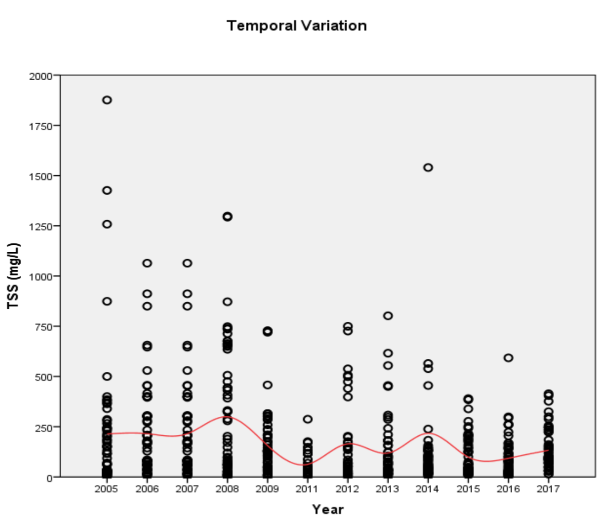
High TSS can block light from reaching submerged vegetation. As the amount of light passing through the water is reduced, photosynthesis slows down. Reduced rates of photosynthesis cause less dissolved oxygen to be released into the water by plants. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. As the plants are decomposed, bacteria will use up even more oxygen from the water. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO), and can harm aquatic life in many other ways. High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. The flow rate of the water body is a primary factor in TSS concentrations. Fast running water can carry more particles and larger-sized sediment. Heavy rains can pick up sand, silt, clay, and organic particles (such as leaves, soil, and tire particles) from the land and carry it to surface water. A change in flow rate can also affect TSS; if the speed or direction of the water current increases, particulate matter from bottom sediments may be resuspended.

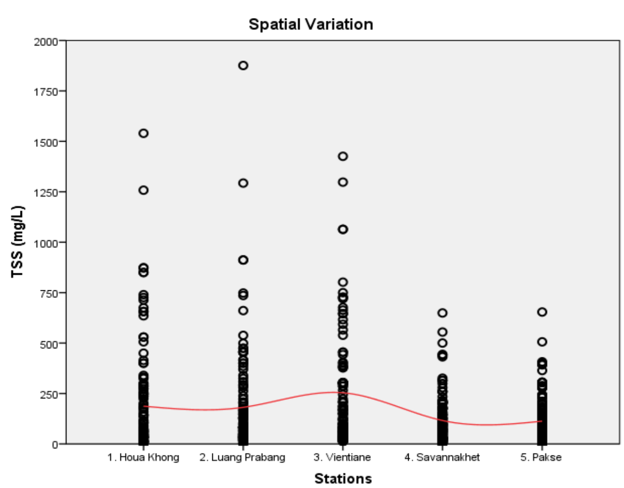
***Current status***




***Trends***



The current status of TSS concentration is high value in wet season. HouaKhong station is high value during September and October and the highest among Mekong mainstreams in Lao PDR. The high levels of TSS in HouaKhong during Wet season 325.0mg/L in September and 414.0mg/L in October. TSS in HouaKhong come from construction of bank protection and road, agriculture practice and urbanization development.

Vientiane station was a high value of TSS 405.0mg/L during July TSS in Vientiane come from road construction and 299.5mg/L of TSS in Savannakhet station during June.

Most of stations along the Mekong mainstream of the Lao PDR are high value of TSS about 96% of the data in 2017 higher than 25mg/L of the maximum allowable concentrations of selected water quality variables for different uses of fisheries and aquatic life of European Community (WATER QUALITY ASSESSMENTS, Second Edition 1996© 1992, 1996 UNESCO/WHO/UNEP). However, the concentration of TSS of the Mekong River ranges from 14.5 – 414.0 mg/L (Appendix 5)

Scatter plot showing a variation of total suspended solid of five stations along the Mekong mainstreams with the period 2005-2017, the red fitted curve shows median variation.

The trends of 2008 have been slightly increased cause the fluctuation in suspended solids, rates of erosion are associated by vegetative cover, the increasing intensive agriculture results in large increases in erosion, but decrease during 2009 and 2011 and slightly changed during 2011 to 2017.

### 3.1.5 Dissolved Oxygen (DO)

Dissolved oxygen is oxygen gas molecules present in the water. Plants and animals can not directly use the oxygen that is part of water molecule, instead depending on dissolved oxygen for respiration. Oxygen enters streams from the surrounding air and as a product of photosynthesis from aquatic plants. Consistently high levels of dissolved oxygen are the best for a healthy ecosystem. Levels of dissolved oxygen vary depending on factors including water temperature, time of day, season, depth, altitude, and rate of flow. Water at higher temperatures and altitudes will have less dissolved oxygen. Dissolved oxygen reaches its peak during the day. At night, it decreases as photosynthesis has stopped while oxygen consuming processes such as respiration, oxidation, and respiration continue, until shortly before dawn.

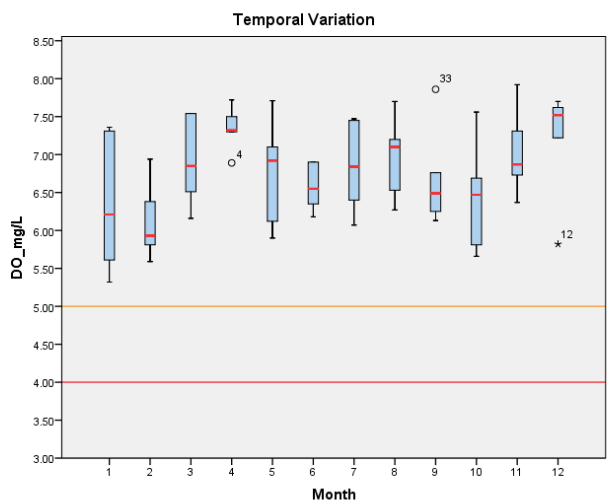
Human factors that affect dissolved oxygen in streams include addition of oxygen consuming organic wastes such as sewage, addition of nutrients, changing the flow of water, raising the water temperature, and the addition of chemicals.

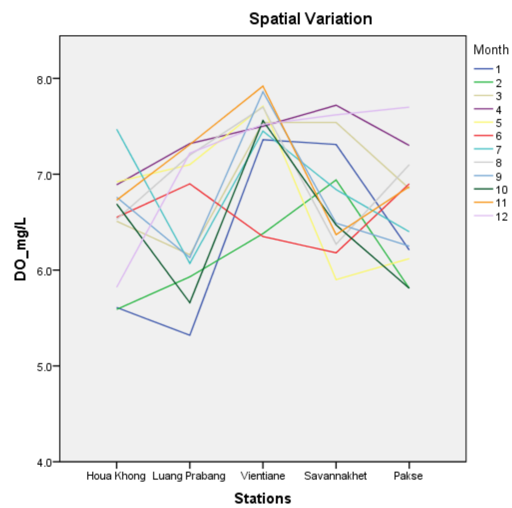
Dissolved oxygen is measured in mg/L. 0-2mg/L: not enough oxygen to support life. 2-4mg/L: only a few fish and aquatic insects can survive. 4-7mg/L: good for many aquatic animals, low for cold water fish 7-11mg/L: very good for most stream fish.

*Current status*

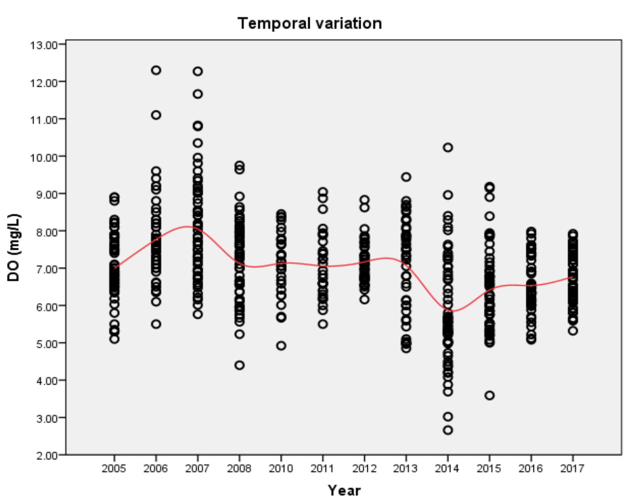
The orange horizontal line shows the threshold value for aquatic life DO ≥ 5mg/L and the red horizontal line shows the threshold value for human health DO ≥ 4mg/L. (Appendix 3)

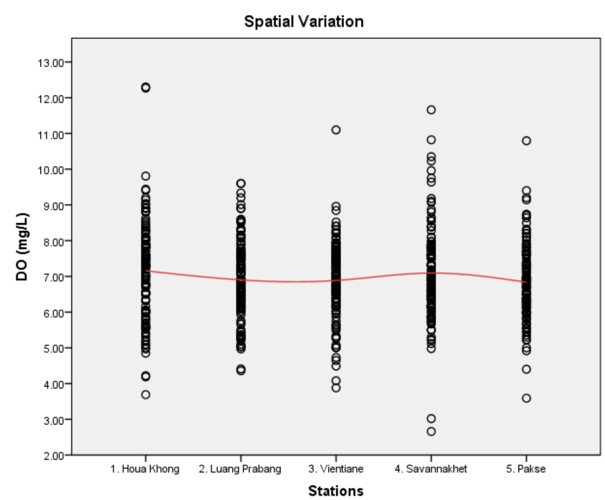
The lowest value found in Luang Prabang station DO was 5.32 mg/L during May. Most stations of Dissolved oxygen (DO) concentration of the Mekong mainstream have range from 5.32mg/L – 7.92mg/L (Appendix 5).




*Trends*




Scatter plot showing a variation of dissolved oxygen of five stations along the Mekong mainstreams. The red fitted curve shows median variation. The trend of DO was not significant changed during 2008-2013, decreased in 2014 and slightly changed during 2015-2017.

### 3.2 Nutrients

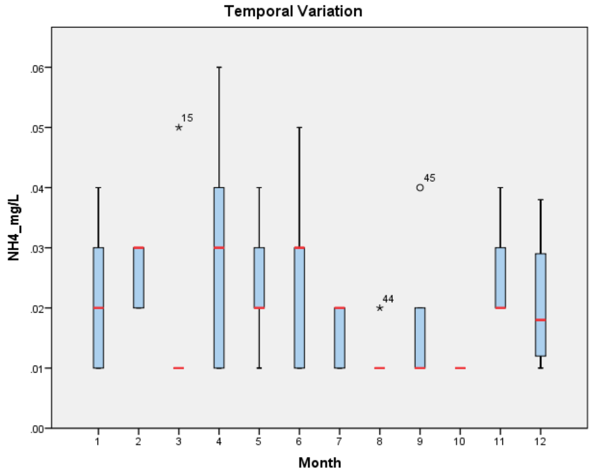
Aquatic plants need many types of nutrients for growth, including nitrogen and phosphorus. However, increased levels of these nutrients in water bodies can cause excessive plant growth rates. This can lead to blooms of algae and nuisance weeds. Excessive algal or weed growth can reduce the recreational and aesthetic value of water bodies and affect fish and other aquatic animals. The level of nutrients in our rivers is influenced by natural factors such as catchment geology, rainfall and river flow patterns. However, land use also has a large influence. The main source of nutrients in urban waterways is human wastewater (sewage) while in rural environments, agricultural fertilizers and stock manure and urine are the major non-point-sources of nitrogen and phosphorus. Monitoring nutrient levels therefore helps us understand land-use influences on water quality.

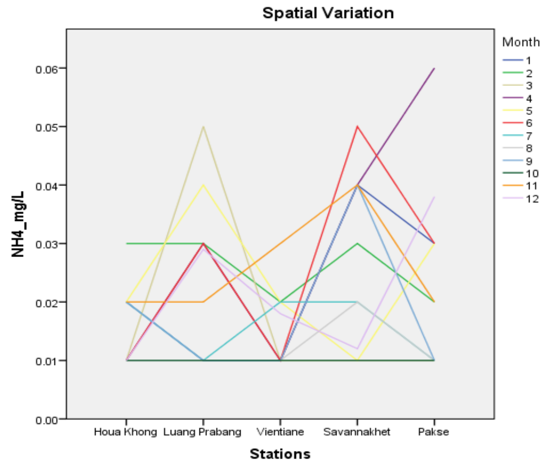
### 3.2.1 Ammonium (NH4+)

Ammonia is considered one of the most important pollutants in the aquatic environment not only because of its highly toxic nature, but also its ubiquity in surface water systems. Ammonia can enter the aquatic environment via anthropogenic sources or discharges such as municipal effluent discharges, agricultural runoff, and natural sources such as nitrogen fixation and the excretion of nitrogenous wastes from animals. The chemical form of ammonia in water consists of two species, the more abundant of which is the ammonium ion (NH4+) and the less abundant of which is the non-dissociated or unionized ammonia (NH3) molecule; the ratio of these species in a given aqueous solution is dependent upon both pH and temperature. Unpolluted waters contain small amounts of ammonia and ammonia compounds, usually < 0.1mg/L as nitrogen. Total ammonia concentrations measured in surface waters are typically less than 0.2mg/L-N but may reach 2–3 mg/L-N.

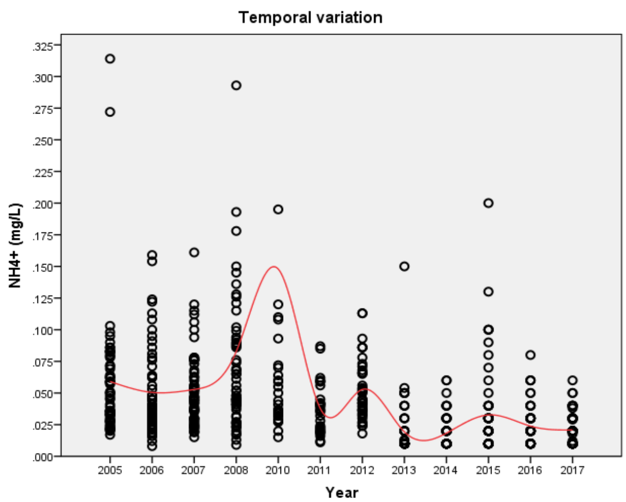
Higher concentrations could be an indication of organic pollution such as from domestic sewage, industrial waste and fertilizer run-off. Ammonia is, therefore, a useful indicator of organic pollution. Natural seasonal fluctuations also occur as a result of the death and decay of aquatic organisms, particularly phytoplankton and bacteria in nutritionally rich waters.

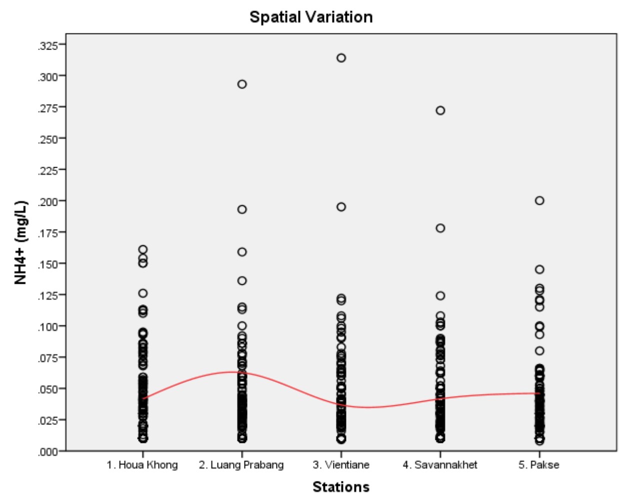
Current status of the five stations along the Mekong river NH4+ ranges from 0.01 – 0.06mg/L (Appendix 5), the highest value was found in Pakse station during April. This value is good/ acceptable water quality compare to the Standard of European Community for Fisheries and aquatic life use NH4+ is 0.04 - 1.0mg/L (WATER QUALITY ASSESSMENTS, Second Edition 1996. © 1992, 1996 UNESCO/WHO/UNEP).




## *Trends*



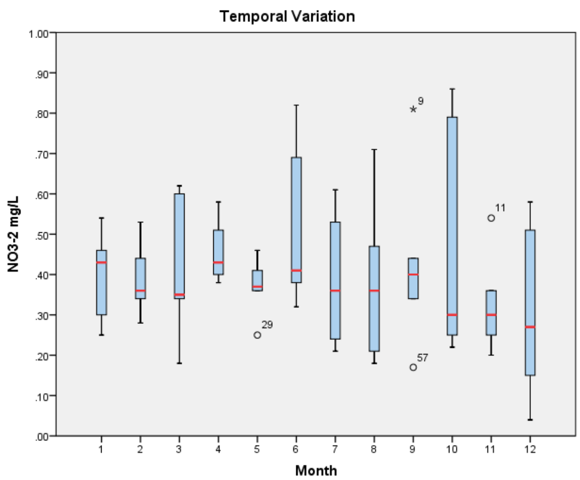



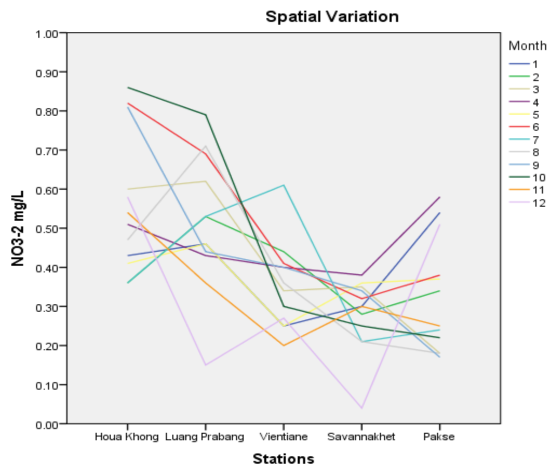

Scatter plot showing a variation of NH4+ of the Mekong mainstreams, the red fitted curve shows median variation. The trends of 2010 have been increased and decreased in 2011 and slightly changed during 2013 to 2017. The trend of spatial variation of NH4+ value of five stations is not significant changed.

### 3.2.2 Nitrite and Nitrate (NO2, 3 –)

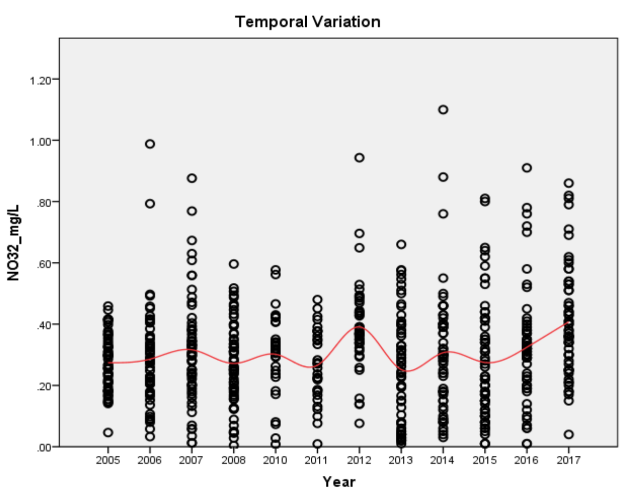
Nitrate is a compound containing nitrogen, can exist in the atmosphere or as a dissolved gas in water, and at elevated levels can have harmful effects on humans and animals. Nitrate reactions [NO3-] in fresh water can cause oxygen depletion. Thus, aquatic organisms depending on the supply of oxygen in the stream will die. The major routes of entry of nitrogen into water bodies are municipal and industrial wastewater, septic tanks, feed lot discharges, animal wastes (including birds and fish) and discharges from car exhausts. Bacteria in water quickly convert nitrites [NO2-] to nitrates [NO3-].

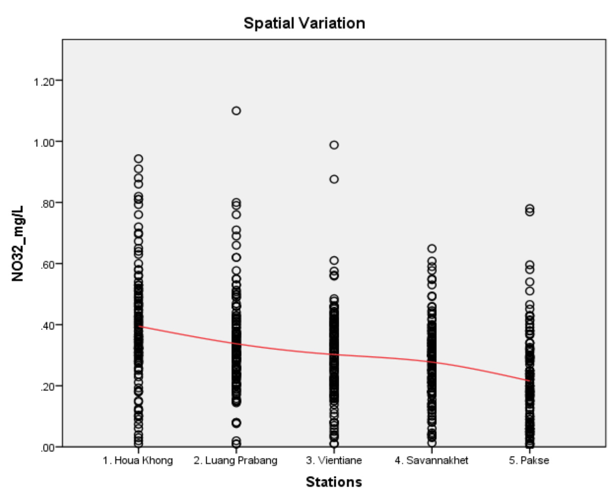
Nitrites can produce a serious condition in fish called "brown blood disease." Nitrites also react directly with hemoglobin in human blood and other warm-blooded animals to produce methemoglobin. Methemoglobin destroys the ability of red blood cells to transport oxygen. This condition is especially serious in babies under three months of age. It causes a condition known as methemoglobinemia or "blue baby" disease. Water with nitrite levels exceeding 1.0mg/l should not be used for feeding babies. Concentrations over 10mg/L will have an effect on the freshwater aquatic environment. 10mg/L is also the maximum concentration allowed in human drinking water by the U.S. Public Health Service.




***Trends***




Current status of Nitrite and Nitrate in the five stations of the Mekong River from Houa Khong station to Pakse station ranges from 0.04 - 0.86mg/L (Appendix 5).

Most of stations of the Mekong mainstream along the Mekong River, which indicated the very good/acceptable water quality compared to the Lao National Environmental Standard (Surface Water Quality Standard) NO:81/GOV, Vientiane Capital, date 21 Feb 2017, (Appendix 4).

This value of some stations is higher than the threshold value for protection of aquatic life NO3,2- < 0.5mg/L (Appendix 3) and less than the threshold value for protection of human health NO3,2- < 5mg/L (Appendix 3).

For five sampling stations, the results are slightly different and are within water quality standard criteria both in dry and rainy season.

Scatter plot showing a variation of nitrate-nitrite of five stations in the Mekong mainstreams, the red fitted curve shows median variation.

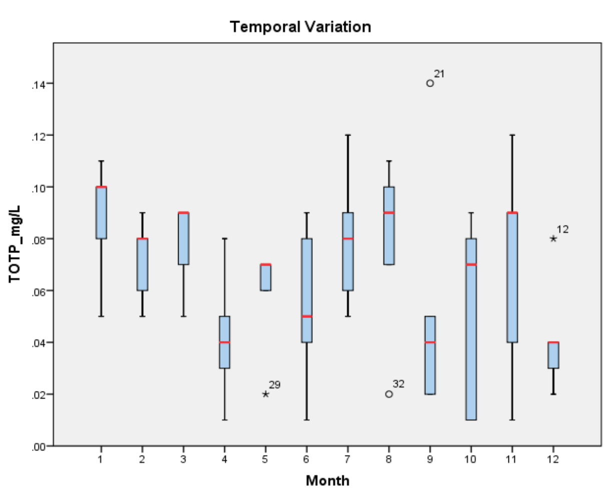
### 3.3.3 Total Phosphorus (T-P) Phosphorus compounds

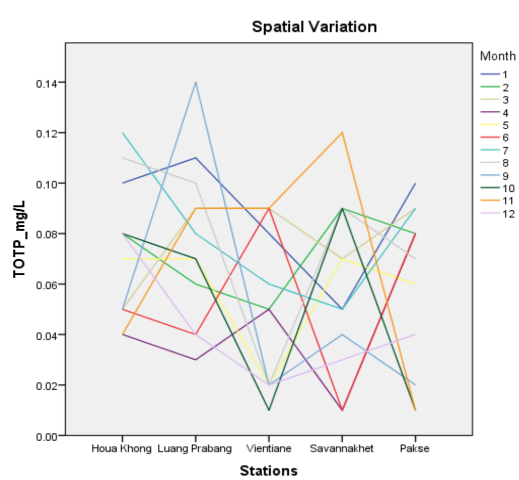
Phosphorus in small quantities is essential for plant growth and metabolic reactions in animal and plants. It is the nutrient in shortest supply in most fresh water, with even small amounts causing significant plant growth and having the large effect on the aquatic ecosystem. Phosphate-induced algal blooms may initially increase dissolved oxygen via photosynthesis, but after this blooms die more oxygen is consumed by bacteria aiding their decomposition. This may cause a change in the type of plants which live in the ecosystem.

Sources of phosphate include animal wastes, sewage, detergent, fertilizer, disturbed land, and road salts used in the winter.

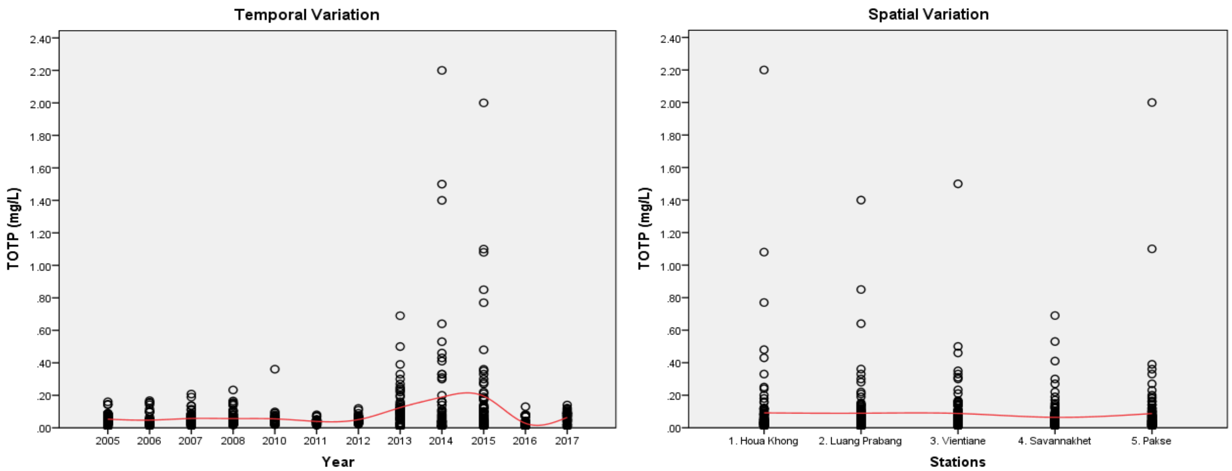
Phosphates do not pose a human or health risk except in very high concentrations. It is measured in mg/L. Larger streams may react to phosphate only at levels approaching 0.1mg/L, while small streams may react to levels of $PO_4^{-3}$ at levels of 0.01mg/L or less. In general, concentrations over 0.05mg/L will likely have an impact while concentrations greater than 0.1mg/L will certainly have impact on a river.

***Current status***



*Trends*




Current status of the five stations along the Mekong river total phosphorus ranges from 0.01 – 0.14mg/L (Appendix 5), The high concentration of total phosphorus was found in Luang Prabang station 0.14mg/L during Wet season.

The high concentration of total phosphorus can indicate the presence of pollution. Domestic wastewater, particularly those containing detergents, fertilizer run-off contributes to elevated levels in surface waters.

The red fitted curve shows median variation. Scatter plot showing a variation of Tot-P of five stations in the Mekong mainstreams. The trend of was not significant changed during 2005-2012 and 2012-2015 have been slightly increased and start decreased during 2016 and 2017.

The trend of spatial variation of total phosphorus value of five stations along the Mekong mainstream is not significant changed.

## 3.3 Organic matter

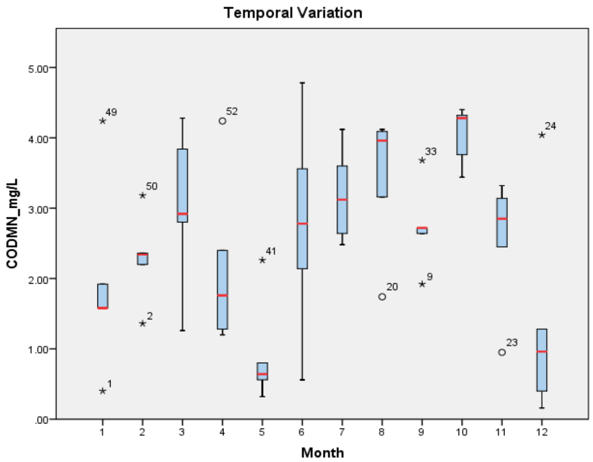
### 3.3.1 Chemical Oxygen Demand: COD (Mn)

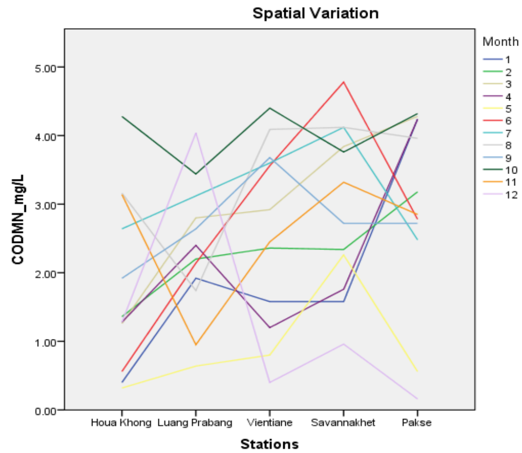
The concentration of organic matter (CODMn) mirrors dissolved oxygen (DO), where a high concentration of CODMn is accompanied by low DO. Organic matter is oxidized by bacteria while consuming oxygen.

In environmental chemistry, the chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water. Most applications of COD determine the amount of organic pollutants found in surface water (e.g. lakes and rivers) or wastewater, making COD a useful measure of water quality.

Chemical oxygen demand (COD) is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals such as ammonia and nitrite. COD measurements are commonly made on samples of waste waters of natural waters contaminated by domestic or industrial wastes.

***Current status***



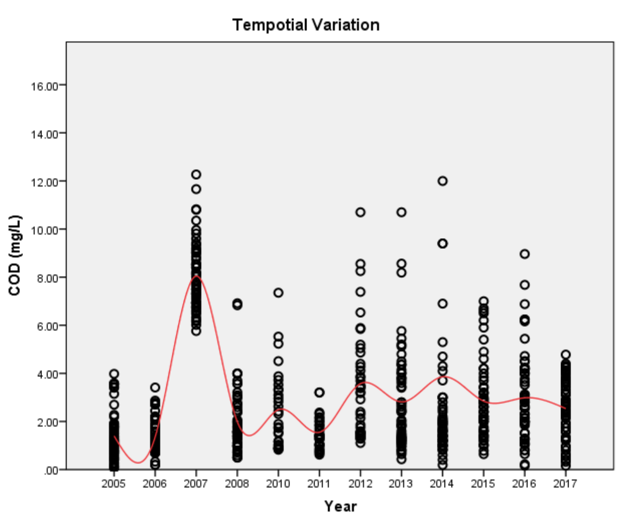



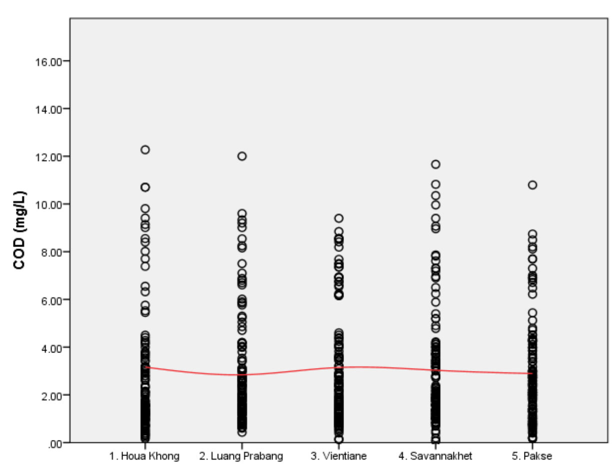

***Current status***:

Current status of the five stations along the Mekong river CODMn ranges from 0.16 – 4.78mg/L (Appendix 5), Savvanakhet station has high value of CODMn during rainy season, the highest was 4.78mg/L which indicated an upstream source such as urbanization development, agricultural land and urban wastewater, In October Houa Khong station the value of CODMn was 4.28mg/L, 4.04mg/L at Luang Prabang, 4.40mg/L at Vientiane and 4.32mg/L at Pakse station during October.

Five stations along the Mekong Mainstream 100% of data lower value of chemical oxygen demand lower than the threshold value for human health on water quality (COD < 5mg/L).

***Trends***



Scatter plot showing a variation of CODMn of five stations of the Mekong mainstreams, they are slightly changed during 2008 - 2017, only 2007 was increased. The red fitted curve shows median variation.
The trend of spatial variation of CODMn value of five stations along the Mekong mainstream is not significant changed.

### 3.3.2 Comparison of chemical oxygen demand and dissolved oxygen between mainstream and tributary stations.

Graph

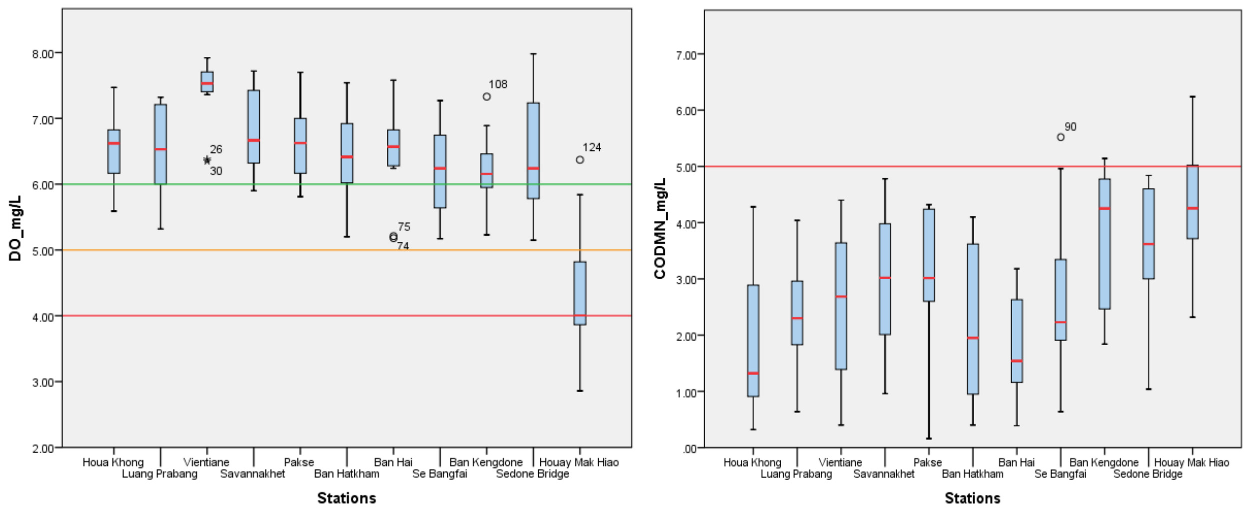



Figure 2.1 Comparison of CODMN and DO between mainstream and tributary stations 2017

*The green horizontal line shows the threshold value for Lao National Environmental Standard (Surface Water Quality Standard) NO:81/GOV, Vientiane Capital, date 21 Feb 2017, DO > 6 mg/L (Appendix4), the orange horizontal line shows the threshold value for protection of aquatic life DO > 5 mg/L (Appendix3), the red horizontal line shows the threshold value for human health on water quality index DO > 4 mg/L (Appendix3).*
*The red horizontal line shows the threshold value for human health on water quality index COD < 5 mg/L (Appendix3) and Lao National Environmental Standard (Surface Water Quality Standard) NO:81/GOV, Vientiane Capital, date 21 Feb 2017, COD < 5 mg/L (Appendix4).*

Most stations of the Mekong River are high concentration of dissolved oxygen, indicating the good/acceptable water quality for Human health on water quality DO ≥ 4 mg/L (Appendix 3) and for the Protection of Aquatic Life DO ≥ 5 mg/L (Appendix 3) and DO ≥ 6 mg/L of the Lao National Environmental Standard (Surface Water Quality Standard) NO:81/GOV, Vientiane Capital, date 21 Feb 2017 (Appendix 4), Chemical oxygen demand of Five stations along the Mekong Mainstream the value lower than 5 mg/L.

Nearly all stations of tributaries are high concentration of dissolved oxygen, there are Houay MakHiao station DO less than 4mg/L, indicated the good of water quality for protection of aquatic life but this value is lower than the threshold values for the human health on water quality DO ≥ 5mg/L (Appendix 3) and Lower than the threshold values of the Lao National Environmental

Standard DO ≥ 6mg/L. Houay MakHiao station is high concentration of chemical oxygen demand 6.24mg/L, low dissolved oxygen 2.86mg/L and high nutrients such as: 5.51mg/L of nitrate- nitrite and 0.26mg/L of total-P.

Houay MakHiao tributary discharge the wastewater to the Mekong River and significantly impacted to the Mekong downstream of Vientiane. The green horizontal line shows the target value for Lao National Environmental Standard (Surface Water Quality Standard) NO:81/GOV, Vientiane Capital, date 21 Feb 2017, DO ≥ 6 mg/L (Appendix4), the orange horizontal line shows the threshold value for protection of aquatic life DO > 5 mg/L (Appendix3), the red horizontal line shows the threshold value for human health on water quality index DO > 4 mg/L (Appendix3).

## 3.4 Water Quality Indices

### 3.4.1 Assessing water quality for protection of aquatic life.

WQIal for protection of aquatic life, there are classified as: High Quality, Good Quality, Moderate, Poor Quality and Very Poor Quality. Water Quality Class of Mekong mainstreams and tributaries stations for Protection of Aquatic Life in 2010-2012 (table 3.1) shows the water quality of all stations along the Mekong River and its tributaries in Lao PDR were rated as High Quality, except some stations such as: Sedone Bridge station was rated as Good Quality in 2011. But 2013-2015 (table 3.1) shows the water quality of all stations were rated as Good Quality except some stations such as in 2013 and 2015 Vientiane, Ban Hatkham, Ban Hai station were High Quality, In 2016 most of stations of the Mekong river and its tributaries were rated as High Quality, except Houakhong rated as Good Quality.

**Table 3.1: Water Quality Class of Mekong mainstreams and tributaries stations for protection of aquatic life 2010-2017.**

| No | Code | Station Name | Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| 1 | H010500 | Houakhong | A | A | A | B | B | B | B | B |
| 2 | H011200 | LuangPrabang | A | A | A | B | B | B | A | B |
| 3 | H011901 | Vientiane | A | A | A | B | B | A | A | A |
| 4 | H013401 | Savannakhet | A | A | A | B | B | B | A | A |
| 5 | H013900 | Pakse | A | A | A | B | B | B | A | A |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | H100101 | Ban Hatkham | A | A | A | A | B | B | A | A |
| 7 | H230103 | Ban Hai | A | A | A | B | B | A | A | B |
| 8 | H320101 | Sebang Fai | A | A | A | B | B | B | A | A |
| 9 | H350101 | Ban Kengdone | A | A | A | B | B | B | A | B |
| 10 | H390105 | Sedone Bridge | A | B | A | B | B | B | A | B |
| 11 | H910108 | HouayMakHiao | D | D | D | C | C | C | B | C |

In 2017 there are only five stations were rated as High Quality except some stations such as Houa Khong, Luang Prabang, Ban Hai, Ban Kengdone, Sedone Bridge stations were rated as Good Quality.

Houay MakHiao station was Poor Quality in 2010-2012 and Moderate Quality of water protection of aquatic life in 2013-2015, only 2015 was rated as Good Quality. This station received the wastewater from Vientiane capital and surrounding area of Houay MakHiao. It is located not so far from the Mekong River about 1 Km the wastewater discharge directly to the Mekong River. It has been significantly impacted to the Mekong River downstream of Vientiane Capital.

### 3.4.2 An assessment of the Mekong River water quality affected by human health.

**Table 3.2: Water Quality Class of Mekong mainstream and tributaries stations for Human Health on Water quality 2010-2017**

| No | Code | Station Name | Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| 1 | H010500 | Houakhong | C | B | C | B | C | A | A | A |
| 2 | H011200 | LuangPrabang | C | B | C | B | B | B | B | A |
| 3 | H011901 | Vientiane | C | A | C | B | B | B | B | A |
| 4 | H013401 | Savannakhet | B | C | C | B | C | B | B | B |
| 5 | H013900 | Pakse | C | A | B | B | A | B | B | A |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | H100101 | Ban Hatkham | B | C | C | B | B | B | A | A |
| 7 | H230103 | Ban Hai | C | C | C | B | B | A | A | A |
| 8 | H320101 | Sebang Fai | C | B | B | B | B | A | B | B |
| 9 | H350101 | Ban Kengdone | C | D | C | B | C | B | B | B |
| 10 | H390105 | Sedone Bridge | D | D | D | B | B | B | B | A |
| 11 | H910108 | HouayMakHiao | D | D | D | C | D | C | C | C |

WQIhh for protection of human health, there are classified as: Excellent Quality, Good Quality, Moderate, Poor Quality and Very Poor Quality.

The water quality at 11 stations which includes five mainstreams and six tributaries monitoring stations is classified from Good Quality to Moderate Quality by human activities from the period 2010 to 2017 (Table 3.2).

The Mekong mainstream station is classified as slightly impacted and impacted, due to high population density and agricultural practice, urbanization, mining and industrial activities.

Between 2011, 2013 and 2015-2017 the level of Human health on water quality of Hua Khong station increased in 2010, 2012 and 2014 compared to the last year, it was caused of the upper part of Houa Khong station was a high population density, urbanization and hydropower development.

In 2017 Luang Prabang station is improving water quality it was Excellent Quality compare with the period 2010 to 2016 which has been Good Quality and Moderate Quality on water quality of human health it may cause of the major affect was the growing population of the town and it was increasing popularity as a tourism destination.

Vientiane station the human health of water quality it was Excellent Quality in 2011 and 2017, the water quality it was Good Quality during 2013-2016 and Moderate Quality on water quality by human health in 2010, 2012 in the part of Vientiane capital which included aquaculture, agriculture runoff, industrial discharge.

Human health on water quality in Savannakhet station was Good Quality during 2010, 2013, 2015-2017 and has been Moderate Quality in 2011, 2012, 2014, due to the high population density, urbanization and industrial development and popularity as a tourist destination.

In 2010 Pakse station has been Moderate Quality, due to upper part of Pakse used the intensive fertilizer for the mega project of rubber plantation. During 2012, 2013, 2015-2016 it was Good Quality. And improving water quality in 2011, 2014 and 2017 it was Excellent Quality.

Ban Hatkham station has been Moderate Quality in 2011-2012 by human activities, it was caused of the mining activities in this area, intensive agriculture activities. And during 2010, 2013-2015 Nam Ou at Ban Hatkham has been Good quality and Excellent Quality in 2016-2017.

During 2010 to 2012 Ban Hai station was Moderate Quality and 2013 improving to Good Quality till 2015, it was not impacted and Excellent Quality during 2016-2017 for human health on water quality.

Sebangfai station was classed as Good Quality in 2011-2014 and 2016-2017, and Excellent Quality in 2015, except 2010 it was Moderate Quality on water quality by human health.

Ban Kengdone station was Poor Quality in 2011 and Moderate Quality in 2010, 2012, 2014 and 2013, 2015 to 2017 has been Good Quality on water quality by human health. it was caused of the domestic, urbanization and industrial development.

Sedone Bridge station has been Poor Quality during 2010-2012, it was caused of intensive fertilizer on the agriculture area, during 2013-2016 it is classed as Good Quality and Excellent Quality in 2017.

Houay MakHiao was Poor Quality and Moderate Quality by human health on water quality in the river; it was caused of urbanization development, agricultural land and urban wastewater from Vientiane Capital. This station was a low concentration DO 2.68mg/L and high level of nutrients as well as $NO_{2,3}$ 5.51mg/L, 0.26mg/L of total-P, and also organic matter 6.24mg/L of COD. The high value of nutrients and organic matter and low dissolved oxygen can be indicated eutrophic condition; it was severely impacted to the Mekong downstream of Vientiane Capital.

**Table 3.3: Water Quality Class of Mekong mainstream and tributaries stations for Agricultural Use 2010-2017**

| No | Code | Station Name | Class | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| 1 | H010500 | Houakhong | A | A | A | A | A | A | A | A |
| 2 | H011200 | LuangPrabang | A | A | A | A | A | A | A | A |
| 3 | H011901 | Vientiane | A | A | A | A | A | A | A | A |
| 4 | H013401 | Savannakhet | A | A | A | A | A | A | A | A |
| 5 | H013900 | Pakse | A | A | A | A | A | A | A | A |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | H100101 | Ban Hatkham | A | A | A | A | A | A | A | A |
| 7 | H230103 | Ban Hai | A | A | A | A | A | A | A | A |
| 8 | H320101 | Sebang Fai | A | A | A | A | A | A | A | A |
| 9 | H350101 | Ban Kengdone | A | A | A | A | A | A | A | A |
| 10 | H390105 | Sedone Bridge | A | A | A | A | A | A | A | A |
| 11 | H910108 | HouayMakHiao | A | B | B | A | A | A | A | A |

The methodology for calculating the WQIag follows that used for aquatic life. The conductivity data are evaluated for each station, for each type of agricultural use.

Because of agriculture, especially irrigated rice, the assessment included an index for agricultural uses, based on FAO (1985) salinity (conductivity) guidelines in agriculture, is given in (Table 3.8). The threshold value of conductivity for water quality indices of the General Irrigation Use is less than 70 mS/m. The threshold value of conductivity for water quality indices of the General Irrigation Use, Paddy Rice Irrigation and Livestock and Poultry, it is can be evaluated that there is no restrictions for all types of agricultural use of all stations along the Mekong mainstreams.

Houay MakHiao tributary was some restrictions in 2011-2012, caused of the high level of salinity-conductivity can be indicated there is the municipal, agriculture, industrial discharges can contribute ions to receiving waters or can contain substance that are poor conductors changing the conductivity of the receiving waters. Thus, specific conductance can also be used to detect pollution source, but for the water quality index for agriculture use of Paddy Rice Livestock. But in 2013 to 2017 there was General Irrigation (Table 3.8).

## 4. Conclusions and Recommendations

### 4.1 Conclusions

The WQMN in Lao PDR has been monitored 11 primary stations in 2009 until now and 2013-2017 was collected samples once a month from January to December. The laboratory has been analyzed physical, chemical parameters and microbiology.

This report is assessed the data recorded from 2017 for the current status of temporal variation and spatial variation and some assessment of data record from 2005-2017 for the trend both temporal and spatial variation.

The assessment of data has been recorded from 2010-2017 for the water quality index of the Mekong mainstream and its tributaries. The assessment has been used three mains WQI such as: (1) for the protection of aquatic life (WQIal), (2) for human health (WQIhh) and (3) for agricultural use (WQIag). Each WQI category is subdivided into classes according to the number of chemical parameters that meet guideline thresholds. The classes are: WQIal: High Quality, Good Quality, Moderate Quality, Poor Quality, Very Poor Quality and WQIhh: Excellent Quality, Good Quality, Moderate Quality, Poor Quality, Very Poor Quality, WQIag: No Restrictions, Some Restrictions and Severe Restrictions.

The data of general parameters such as: Temperature, conductivity, pH is normal distribution for the current status of both temporal and spatial variation of the Mekong mainstreams and its tributaries.

The current status of total suspended solid, nutrients and chemical oxygen demand is high value in the Mekong mainstreams during wet season. These high values of total suspended solid, nutrients and chemical oxygen demand can be evaluated the upper part of each station has the influenced by human activities, including aquaculture and agriculture practice, mining activities, urbanization development such as construction activities, unpaved surface and waste management and erosion of natural deposits.

Dissolved oxygen concentration of all stations of the Mekong mainstream and its tributaries is good/acceptable water quality for protection of aquatic life. Except Houay MakHiao station is low value of dissolved oxygen and high nutrients, chemical oxygen demand which can be indicated the poor quality of water and impacted to the Mekong downstream of Vientiane.

The trends of TSS of the Mekong mainstreams increased respectively from 2012 to 2014 and decreased in 2015 till 2017. The trends of dissolved oxygen decreased in 2014 and slightly increased during 2015-2017.

The nutrients level increased slightly in 2012-2015 of total phosphorus and nitrate nitrite decreased in 2013-2015 and slightly increased during 2016-2017 but the trend of ammonium is not significant changed from the last year. The trend of chemical oxygen demand of 2017 is the same trends as 2015 and 2016.

The water quality index and threshold value for protection of aquatic life of the Mekong mainstream and tributaries in 2017 have high and good water quality, except Houay MakHiao is classified as moderate water quality.

The water quality index and threshold value for human health on water quality of the Mekong mainstreams and tributaries in 2017 is not impacted, there is only Houay MakHiao is classified as severely impacted on water quality by human activities such as sewage water, urbanization development, and the use of agricultural land. In the future if there is no good management of wastewater in the city, it will be affected to the Mekong downstream of Vientiane.

The water quality index of all types of agriculture use of all stations in the Mekong mainstream and tributaries is classified no restriction except Houay MakHiao tributary was some restrictions in 2011 – 2012.

### 4.2 Recommendation

1. Should be built the wastewater treatment system in Vientiane Capital.

2. Capacity building for the laboratory staff on the analysis.

3. Due to the purchasing chemical and maintenance budget is limited so we would like to ask MRC to provide the support.

4. Should have technical exchange with MRC member country.

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©1992,1996 UNESCO/WHO/UNEP

Lao National Surface Water Quality Standards, N0:2734/PO-WREA, date 07/Dec/2009, Vientiane City.

Standard Method for the Examination of Water and Wastewater, APHA/AWWA/WEF

**Appendix 1**

**Title: Sampling technique**

**Surface Water-Sampling Collection and Preparation**

**1. Summary of Method**

Samples can be taken from rivers, lakes and similar surface waters either manually or through use of a water sampler. Providing that necessary precautions are taken to prevent sample contamination, sampling by hand is appropriate for surface water samples collected up to a depth of 1 m. For sampling at depths greater than 1m, grab samples are to be collected using an appropriate sampling device that can retrieve a sample from a predetermined depth. The depth sampler, which is sometimes called a grab sampler, can retrieve a sample from any predetermined depth. As the sampler is lowered to the required depth with the lowering rope, water passes through the open ends so that, at any depth, the water in the sampler is the water from that depth. When the desired depth is reached, the messenger weight is dropped down the rope, the latch is tripped and the end flaps close. The sampler is brought to the surface and its contents are transferred to a sample bottle. An appropriate size sampling device should be used to allow for collection of a sufficient volume of water required to complete all the physical and chemical analyses that will be done for an individual sampling station.

**2. Interferences**

There are two primary interferences or potential problems with surface water sampling. These include cross-contamination of samples and improper sample collection. Cross-contamination problems can be eliminated or minimized through the use of pre-cleaned sampling equipment. Improper sample collection can involve using contaminated equipment, disturbance of the stream or impoundment substrate, and sampling in an obviously disturbed area. Following proper decontamination procedures and minimizing disturbance of the sampling station will eliminate these problems.

**3. Sample Collection – Preparation**

**3.1 At the Office**

(1) Determine the extent of the sampling effort, the sampling methods to be employed, and which equipment and supplies are needed.

(2) Obtain necessary sampling and monitoring equipment.

(3) Decontaminate or pre-clean equipment and preparation of sample container to ensure that it is in working order.

**3.2 At the Sampling Station**

*Be sure that: all people who involve in sample collection and preservation should wearing flour free rubber gloves to avoid sample contamination.*

All supporting information should be recorded in the field log sheet before leaving the sampling station. Such conditions as ambient air temperature, the weather, the presence of dead fish floating in the water or of oil slicks, growth of algae, or any unusual sights or smells should be noted, no matter how trivial they may seem at the time. These notes and observations will be of great help when interpreting analytical results.

## 4. Sample Collection

### 4.1 Samples for bacteriological analysis (Thermo tolerant faecal coliforms)

Sampling procedures are as follows:

(1) Care must be exercised to prevent contamination of the inside of the sterile glass bottles by touching with the fingers or any non-sterile tools or other objects.

(2) Bottles in which samples for bacteriological analyses are to be collected (or transported) should be reserved exclusively for that purpose.

(3) Use a sterile sampling screw-cap glass bottle to collect the water sample. Bacteriology samples should be obtained first before sampling for other parameters.

### 4.2 Samples for physical and chemical analyses

For sampling stations that are accessible by wading to mid-stream or by small boat, surface water sampling procedures should be followed:

(1) Sample bottles should be immersed by hand to just below the surface, typically 0.25-0.5m depth.

(2) When sampling from a boat it is important to face it into the current and take the sample from the front of the bow to minimize contamination from the boat itself.

For sampling stations that are assessable by boat or structure such as a bridge or pier, and where samples at depth are required, normally the river depth is more than 3 meters. A grab sampler may be used. Sampling procedures are as follows:

(1) Using a properly decontaminated grab sampler

(2) Set the sampler so that the water can pass unimpeded through the sampling tube.

(3) At mid-stream or -river, lower the sampler to the pre-determined depth. Avoid bottom disturbance. Do not lower a sampler too rapidly.

(4) Lower the sampler to mid-depth.

(5) Let it remain at the required depth for about several seconds before triggering the sampler by using the messenger weight which is dropped down and the latch is tripped and the end flaps close.

(6) Retrieve the sampler and discharge the first 10 to 20 ml to clear any potential contamination on the faucet.

(7) Transfer the samples to the appropriate sample bottles immediately after collection if they are to be transported. If field measurements are to be made they should be started as soon as possible.

(8) Sample should be rinsed three times with portions of the sample before being filled. Rinsing should not be done if the sample bottles already contain a preservative chemical.

(9) A small air space should be left in the sample bottle to allow the sample to be mixed before analysis.

(10) At any time that the sample bottles are not closed, their tops must be kept in a clean place.

(11) All measurements taken in the field must be recorded in the field data collection form before leaving the sampling station.

**5. Field Analysis**

Field analysis (*in-situ* Measurement) will be done for temperature, pH, dissolved oxygen and conductivity. Other parameters will be analyzed in Laboratory by using analysis methods presented in SOP (SOP#23.2) Series. Person who conducts water quality sampling should have a sampling skill and know how to make an in-situ measurement.

**6. Personal Health and Safety**

For Personal Safety during surface water sampling (1) If at any time you feel uncomfortable about the condition or your surroundings, stop monitoring and leave the site at once. Your safety is more important than the data! (2) Never drink the water in stream. Assume it is unsafe to drink, so bring your own water. After monitoring, wash your hands with antibacterial soap.

**7. Data and Records Management**

All data and information (e.g., sample collection method used) must be documented on field log sheet with permanent ink and should be signed and dated at the time of recording.

**8. Quality Control and Quality Assurance**

All required field QA/QC samples, field blanks, bottle blanks, and should be collected as specified.

**Appendix 2**

Table 2.2 Sampling station and code

| No | Code | Station Name | River Name | Latitude | Longitude |
|---|---|---|---|---|---|
| **1** | H010500 | HouaKhong | Mekong River | 21° 32‘40.3’’ | 101° 09‘34.3’’ |
| **2** | H011200 | LuangPrabang | Mekong River | 19° 57‘43.0’’ | 102° 14‘42.7’’ |
| **3** | H011901 | Vientiane | Mekong River | 17° 58‘09’’ | 102° 33‘02’’ |
| **4** | H013401 | Savannakhet | Mekong River | 16° 33‘30’’ | 104° 45‘08’’ |
| **5** | H013900 | Pakse | Mekong River | 15° 07‘29.4’’ | 105° 47‘17.3’’ |
| **6** | H320101 | Sebangfai | Sebangfai | 17° 04‘48.1’’ | 104° 59‘04.8’’ |
| **7** | H350101 | Ban Kengdone | Sebanghieng | 16° 11‘01.1’’ | 105° 19‘00.0’’ |
| **8** | H230103 | Ban Hai | Nam Ngum | 18° 10‘49.4’’ | 103° 03‘28.6’’ |
| **9** | H390105 | Sedone Bridge | Sedone | 15° 07‘16.7’’ | 105° 48‘42.0’’ |
| **10** | H910108 | HouayMakHiao | HouayMakHiao | 18° 00‘15.7’’ | 102° 54‘51.4’’ |
| **11** | H100101 | Ban Hatkham | Nam Ou | 20° 05‘06’’ | 102° 15‘08’’ |

**Appendix 3**

**Water quality indices and guideline**

**Water Quality Index for the Protection of Aquatic life**

Table 3.4 Water Quality Indices and threshold values for Protection of Aquatic Life in the Mekong River and its tributaries.

| No | Parameters | Symbol | Unit | Threshold values |
|---|---|---|---|---|
| **1** | pH value | pH | - | 6.0 - 9.0 |
| **2** | Conductivity | EC | mS/m | < 150 |
| **3** | Ammonia | $NH_3$ | mg/L | 0.1 |

| | | | | |
|---|---|---|---|---|
| **4** | Dissolved Oxygen | DO | mg/L | ≥ 5 |
| **5** | Nitrite and Nitrate | NO23 | mg/L | 0.5 |
| **6** | Total Phosphorous | Total-P | mg/L | 0.13 |

Table 3.5 Rating system for Protection of Aquatic Life

| Class | Rating Score |
|---|---|
| **A- High Quality** | 9.5 ≤ WQI ≤ 10 |
| **B- Good Quality** | 8.0 ≤ WQI < 9.5 |
| **C- Moderate Quality** | 6.5 ≤ WQI < 8.0 |
| **D- Poor Quality** | 4.5≤ WQI < 6.5 |
| **E- Very Poor Quality** | WQI < 4.5 |

**Water Quality Index for the Protection of Human Health**

Table 3.6 Water Quality Indices and threshold values for Human Health on water quality in the Mekong River and its tributaries.

| No | Name | Symbol | Unit | Threshold values |
|---|---|---|---|---|
| **1** | pH value | pH | - | 6.0 - 9.0 |
| **2** | Conductivity | EC | mS/m | < 150 |
| **3** | Ammonium | NH4 | mg/L | 0.5 |
| **4** | Dissolved Oxygen | DO | mg/L | ≥ 4 |
| **5** | Chemical Oxygen Demand | COD | mg/L | 5 |
| **6** | Nitrate and Nitrite | NO32 | mg/L | 5 |

Table 3.7 Rating system for Human Health on water quality

| Class | Rating Score |
|---|---|
| **A- Excellent Quality** | 95 ≤ WQI ≤ 100 |
| **B- Good Quality** | 80 ≤ WQI < 95 |
| **C- Moderate Quality** | 65 ≤ WQI < 80 |
| **D- Poor Quality** | 45 ≤ WQI < 64 |
| **E- Very Poor Quality** | WQI < 45 |

**Agricultural Uses**

Table 3.8 Salinity Guidelines for Agricultural Uses of water. Adapted from FAO, 1985.

Adapted from FAO, 1985

1. None = 100% of yield. Some = 50-90% of yield. Severe = < 50% of yield.

2. There are differences between livestock and poultry. Poultry are less tolerant than livestock to salinity.

| Agricultural Use | Units | Degree of Restriction | | |
|---|---|---|---|---|
| | | **None[1]** | **Some[1]** | **Severe[1]** |
| **Salinity- conductivity** | | | | |
| **General Irrigation** | mS/m | < 70 | 70 - 300 | > 300 |
| **Paddy rice Irrigation** | mS/m | < 200 | 200 - 480 | > 480 |
| **Livestock & Poultry[2]** | | < 500 | 500 - 800 | > 800 |
| **Weight factor** | | 2 | 1 | 1 |

Table 3.9 Rating system for Agricultural Uses of water

| Class | Rating Score |
|---|---|
| **A- No Restrictions** | 10 - 8 |
| **B- Some Restrictions** | < 8 - 7 |
| **C- Severe Restrictions** | < 7 |

**Appendix 4: Lao National Environmental Standard (Surface Water Quality Standard)** N0: 81/GOV, Vientiane Capital, date 21 Feb 2017.

| **No** | **Name of parameters** | **Formula** | **Units** | **Standard Value** |
|---|---|---|---|---|
| **1** | Color, Odor & Test | Color, Odor & Test | - | N |
| **2** | Temperature | T | °C | N |
| **3** | pH | pH | - | 6-8 |
| **4** | Dissolved Oxygen | DO | mg/L | 6 |
| **5** | Conductivity | EC | µS/cm | ≥1000 |
| **6** | Chemical Oxygen Demand | COD | mg/L | 5-7 |
| **7** | Total Suspended Solid | TSS | mg/L | ≥25 |
| **8** | Total Coliform Bacteria | Total Coliform Bacteria | MPN/100ml | 5000 |
| **9** | Faecal Coli form Bacteria | Faecal Coliform Bacteria | MPN/100ml | 1000 |
| **10** | Nitrate Nitrogen | NO3 -N | mg/L | 5.0 |
| **11** | Ammonia Nitrogen | NH3 -N | mg/L | ≥1.5 |
| **12** | Phosphate | PO4 | mg/L | 0.5 |
| **13** | Phenols | C6H5-OH | mg/L | 0.005 |
| **14** | Copper | Cu | mg/L | 0.1 |

| | | | | |
|---|---|---|---|---|
| **15** | Nickel | Ni | mg/L | 0.1 |
| **16** | Manganese | Mn | mg/L | 1.0 |
| **17** | Zinc | Zn | mg/L | 1.0 |
| **18** | Cadmium | Cd | mg/L | 0.003 |
| **19** | Chromium Hexavalent | $Cr^{6+}$ | mg/L | 0.05 |
| **20** | Lead | Pb | mg/L | 0.01 |
| **21** | Mercury | Hg | mg/L | 0.001 |
| **22** | Arsenic | As | mg/L | 0.01 |
| **23** | Cyanide | $CN^-$ | mg/L | 0.07 |
| **24** | Radioactivity- Alpha | α | Becquerel/L | 0.1 |
| **25** | Radioactivity- Beta | β | Becquerel/L | 1.0 |
| **26** | Total Organo-Chlorine | - | mg/L | 0.05 |
| **27** | DDT | $C_{14}H_9Cl_5$ | mg/L | 1.0 |
| **28** | Alpha- BHC | αBHC | mg/L | 0.02 |
| **29** | Dieldrin | $C_{12}H_8Cl_6O$ | mg/L | 0.1 |
| **30** | Aldrin | - | mg/L | 0.1 |
| **31** | Heptachlor & Heptachlor epoxide | - | mg/L | 0.2 |
| **32** | Endrin | - | mg/L | None |

**Appendix 5**

**Statistic Record**

**Descriptive Statistics**

| Parameters | Unit | Mean | Std. Deviation | Minimum | Maximum | Median |
|---|---|---|---|---|---|---|
| TEMP_°C | °C | 26.8 | 2.04064 | 21.1 | 30.0 | 27.1 |
| pH | - | 7.27 | 0.46285 | 6.09 | 8.38 | 7.30 |
| TSS | mg/L | 133.3 | 97.98223 | 14.5 | 414 | 95.5 |
| COND | mS/m | 20.8 | 5.11111 | 7.60 | 30.4 | 20.1 |
| NO3-2 | mg/L | 0.41 | 0.17895 | 0.04 | 0.86 | 0.38 |
| NH4N | mg/L | 0.02 | 0.01257 | 0.01 | 0.06 | 0.02 |
| TOTP | mg/L | 0.06 | 0.03205 | 0.01 | 0.14 | 0.07 |
| DO | mg/L | 6.77 | 0.67623 | 5.32 | 7.92 | 6.85 |
| CODMn | mg/L | 2.53 | 1.28033 | 0.16 | 4.78 | 2.64 |