# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Mekong River and its tributaries

Mekong is one of the main river in South East Asia and 11$^{th}$ longest river in the world (Kite, 2001). Its headwater is in the Himalaya Mountain in China and run through six countries to its mouth in Vietnam, at the South China Sea. The climates of Mekong River are range from cool temperate to tropical. In the higher peak of Tibetan Plateau are permanently snow-capped, and much of this part of the area is under snow in the winter. Whereas, the maximum temperature are inland of Lao PDR, Thailand and Cambodia in March and April of each year (MRC, 2003). The climate of the Mekong basin is dominated by two distinct monsoon seasons. The dry northeast monsoon is between October and March whereas the rainy southwest moon soon occurs during middle May and early October. In May and October, a precipitation falls are ranging from 1,000 mm in northeastern Thailand to more than 3,200 mm in mountainous regions in Laos (Kite, 2001). Mekong river basin comprises some 795,000 km$^2$; its the 21$^{st}$ largest river basin in the world. The mean annual discharge of the Mekong is approximately 475 x $10^9$ m$^3$. About 55 percent of water in the basin arises from the mountainous regions along the eastern margin of the basin, only 10 percent come from northeast part of Thailand (MRC, 2003).

The river provides water, food, transportation and economic sustenance to more than 50 million people. The Lower Mekong River is a large potential source of

hydropower energy. Electricity requirement in the region is increasing rapidly. It has been predicted more than 12,000 MW will be needed (Mekong secretariat, 1994). The development of hydropower in Lao PDR also raises the stream impacts. Upstream diversions and dam was decreased to the main river flow; this will have both rainy and dry season impacts. Moreover, the productivity of fisheries and rice paddy will decline, affecting Vietnam's most productive rice growing are in the Mekong delta and much of Cambodia. While in dry season lower flow of water will negative affect transport, commerce and fisheries, as well as reducing the amount of water available for industrial and domestic used (Bakker, 1999). In May 2007, the scientist reported the devastate impacts from Don Sahong Dam would have on the Mekong' fisheries and fishing based livelihood. Likewise, the Sabor Dam blocks the passageway for fish migrating to the upstream from the Tonle Sap to the Mekong River, that serious impacts for Cambodia's fisheries (TERRA, 2007). The reported of Pak Mun Dam affected on the Mekong in Thailand has been extremely damaging to fish population which declined from 1991 until 1994 (Robert, 1993b; 1995; Dudgeon, 1999). The impacts will extend beyond fish to other taxa (Dudgeon, 1999). The number of Irrawaddy dolphin (*Orcaella brevirostris*) in the Mekong River fallen because of declines in fish prey and death of animal trapped in gill net (Baird and Mounsouphom, 1994; Dudgeon, 1999). Fish is the important sources of animal protein. People in this basin consumed fish more than 30 kg per year (Sneddon, 2003). About 700,000 metric tons of fish are harvested from the Mekong River each year (Kite, 2001). The diversity of vertebrate fauna in the Mekong basin including 830 mammal species, 2,800 bird species, 1,500 fish species, 250 amphibians and 650 reptiles. When fishes are less available in dry season, aquatic invertebrates are an

importance source of food. About 30 taxa of aquatic invertebrates are consumed in northeastern Thailand. Moreover, the aquatic invertebrates have often been used as indicators of ecological health of rivers. They are comprises a large number of diversity, almost ubiquitous and relatively easy to sampling and preserve (MRC, 2003).

Water depletion and degradation of water quality are still serious problems in Thailand (PCD, 2004; Getwongsa and Sangpradub, 2008). In 2003, water qualities of 49 main rivers in Thailand including 5 rivers are tributaries of Mekong River were investigated. Three rivers (Pong, Chee and Songkram) were classified in to class 2 water quality and explain to suitable used for conservation; fishery, domestic used and drinking but ordinary treatment are required. Whereas, Mun and Kok River were classified in to class 3 water quality and used for agriculture, domestic use and drinking but, ordinary treatment and processing are required (PCD, 2003). In the Mekong River the total suspended solid (TSS) was decreased from the Chiang Saen downstream caused by installation of dam in China and northern Lao PDR. While, trend in total of phosphorus and nitrogen were decreased in northeastern Thailand. But, there were increased in the delta of Mekong River in Vietnam (MRC, 2003). For the same river, the relationship between climatic, hydrological parameters and water quality was studied. The result showed significant between climatic, hydrological and water quality. The precipitation, mean water level and discharge flow had positive correlation with the following water quality; TSS, $NO_3^-$, $NO_4^{3-}$ total phosphorus (TP). However, dissolved oxygen (DO), pH, conductivity, alkalinity, Ca, Mg, Na, K, Cl, Si and $SO_4^{2-}$ showed negative correlation with all hydrological parameters. This study

showed TSS, alkalinity and conductivity were suitable uses for monitoring impacts of changing climate in the lower Mekong River (Prathumratana *et al*., 2008).

**2.2 Freshwater Macroinvertebrates**

Freshwater macroinvertebrates are a group of animals without backbones, just large enough to be seen by naked eyes (>0.5 mm) and live for at least a part of life cycle in freshwater. The major macroinvetebrate groups included the worms, crustaceans (shrimps and yabbies), mollusks (snail and bivalves) and some insects (larvae and adults) (Fong and Nou, 2001). The macroinvertebrates are offer many advantages as biomonitors. They are ubiquitous, and are therefore affecting by environmental disturbance in aquatic ecosystem. Then, the large number of species are offering a spectrum of response to environmental stresses. Moreover, they have long life cycle compare with other groups which allows elucidation temporal change cause by perturbation (Rosenberg and Resh 1993b; Merritt *et al.*, 2008).

Aquatic insects are typical organisms found in any habitats in any state of life cycle and often exhibit high diversity (Lehmkuhl, 1979; Hershey and Lamberti, 2001). There are including 13 orders of aquatic and semi aquatic insects in the world (Dudgeon, 1999; Sangpradub and Boonsong, 2006). In each order, the species diversity of aquatic insects are very high. River, stream, ponds and lakes can also exhibit very high diversity, depending on water quality condition and substrate characteristics (Hershey and Lamberti, 2001; Wang *et al.*, 2008). The study of the composition and structure of aquatic insects can be used in monitoring the change of water quality in aquatic ecosystems (Merritt *et al.,* 2008; Arimo and Ikomi, 2009).

The Mollusca is a common varied phylum with estimate 80,000-100,000 described species and total diversity might be possible as high as 200,000 species, they are second only to arthropod in species richness (Strong *et al.,* 2008). Freshwater mollusks consist of snails, mussels and clams that inhabit in land water. These organisms are components of all aquatic ecosystems and occur in almost every types of freshwater habitat from lakes, rivers and streams (Lee and Ackerman, 1999).

Freshwater bivalves (mussels and clams) are mollusk without head and they are generally suspension feeder in rivers and lakes (Bogan, 2008). Freshwater bivalves are found in 5 orders and divide among 19 families within the Class Bivavia (Deaton and Greenberg, 1991; Bogan, 2008). Two main areas of diversity and endemism of freshwater bivalves are southeastern United States and Oriental region such as in India, southern China and Southeast Asia (Bogan, 2008).

Gastropods (snails) are primary surface grazer in the water and they are found on every continent except Antarctica. Most live submerged, and many are specialized for particular habitats such as aquatic vegetation, stone, rock, other solid surfaces, or soft sediment. Likewise other invertebrates; freshwater gastropods presented high diversity in tropics, with decreasing species richness as well as decreasing endemicity at higher latitudes (Strong *et al.,* 2008). Within the Mekong Basin, freshwater gastropods (pomatiopsid and stenothyrid) are included 120 species, with at least 111 endemic to the river (MRC, 2003). As a primary consumer, mollusks are also used for environmental indicators (Lee and Ackerman, 1999).



**2.3 Diversity of macroinvertebrates**

The diversity of macroinvertebrates have been studied in many parts of the world. Shama and Rawat (2009) found 32 genera of macroinvertebrates in the Asan

wetland, India. From this study, the macroinvertebrates were represented by aquatic insects and mollusca (Gastropoda). The density of macroinvertebrates was recorded significant different between sampling sites. This different may be attributed to the anthropogenic disturbance caused by boating and tourist movement.

Skoulikidis *et al.* (2008) studied a diversity of macroinvertebrate fauna from sixty-four streams in Greece. Ninety families were collected from the undisturbed sites. Baetidae was the most abundance family which was 21% of the total taxa collected, followed by Elmidae (Colroptera)7.6%, Heptageniidae (Ephemeroptera) 6.8%, Chironomidae (Diptera) 5.7%, Hydropsychidae 5.3% (Trichoptera) and Nemouridae (Plecoptera) 4.1% respectively. While, Principe and Corigliano (2006) compared drifting zone with marginal zone of macroinvertebrate assemblage in Ctalamochita River, Argentina. They found 73 taxa of macroinvertebrate. The most common orders of insect were Heteroptera, Coleoptera, Diptera, Odonata and Ephemeroptera. Benthos included mostly of Coleoptera and Oliochaeta. Whereas, drift insect orders consisted of Ephemeroptera, Trichoptera and Dipetra. In marginal zone found Coleoptera, Odonata, Trichoptera and Ephemeroptera. The species richness of macroinvertebrate in marginal zone was higher than drift and benthos zone.



Aagaard *et al*. (2004) found 256 species of aquatic insects in Atna River, Norway from 1987-2002. *Baetis rhodani* (Baetidae) was dominant species in all sampling localities, while the grazer was dominated by treeless in alpine region. In addition to natural lake, the zoobenthos community in and below lake outlet was dominated by collectors (filter feeder). Apart from those diversity and functional

feeding studies, the effects of human activities on aquatic insects were also investigated. The effect of trout farm effluent on the taxa richness of benthic macroinvertebrates was studied by Loch *et al.* (1996). The result showed 116 taxa of aquatic insects order Ephemeroptera, Plecoptera and Trichoptera. The taxa richness in unaffected site was higher than affected site. So the benthic macroinvertebrates communities depend on environmental condition. Therefore, the main environmental factors for benthic macroinvertebrates are stream substrate, water depth, flow velocity and water quality (Wang *et al.*, 2008).

In Thailand the studied on macroinvertebrates are widespread. One hundred and twenty three species from three phyla (Arthropoda, Annelida and Mollusca) were reported from Pong River (tributary of Mekong River), Khon Kaen province, northeastern Thailand by Hunjavanit and Tangpirotewong 2007. Moreover, 7 orders and 23 families of aquatic insects were identified from Mekong River and its 5 tributaries. The dominant insect family of this study was Baetidae (Thani and Phalaraksh, 2008). In addition, 9 genera from 3 families of Plecopteran were found in 2 streams from Nam Nao National Park (Chaisamsaeng, 2004). Parnrong *et al*, 2002 reported that *Behningia* sp., *Rhoenanthus speciosus* and *Prosopistoma wouterae* were new records of family Behningiidae, Potamanthidae and Prosopistomatidae (Ephermeroptera) of Thailand respectively. These three species were found in Klong Namkub, Phitsanulok Province, Kao Nam Kang National Park, Songkhla province and Boripat Waterfall, Songkhla province respectively. While, the Heptageniid mayflies *Asionurus* and *Thalerosphyrus* are newly recorded from northeastern Thailand (Sangpradub *et al*., 2002). Moreover, the new species of mayfly (*Gratia narumonae*; Ephemeroptera) was discovered from Mae Kong River, northeastern

Thailand (Boonsoong *et al.,* 2002). Whereas, the altitude distribution of Trichoptera species were studied in Mae Klang catchment, Doi Inthanon, northern Thailand. One hundred and seventy one species were found from the elevation between 400 to 2,300 meters above sea level. The highest diversity species of caddisflies was in the elevation between 1200m-1700m. Lower temperature was favorable for existence of many species (Malicky and Chantaramongkol, 1993). The number of Trichoptera species in northern Thailand (Doi Inthanon National Park and Doi Suthep Pui) was updated from 1993 to 2003. These studies were continued by graduate students (Sompong, 1998; Thani, 1998; Prommi, 1999; Kaewtapee, 2001; Thamsenanupap, 2001) under the supervision of Chantaramongkol P. and Malicky H and including new records from mornitoring during 2001 to 2003. On Doi Inthanon National park, the Trichoptera species was increased from 171 to 249. While, Doi Suthep Pui increased from 131 to 199 species (Thapanya *et al*., 2004). Moreover, Jacobus and McCafferty (2006) discovered *Uracanthella oriens* a new species of Ephemerellidae (Ephermeroptera) in Doi Inthanon and some provinces (Mae Hong Son, Lampang and Phrae) from northern Thailand. *Eotrechus kalidasa* (Gerridae:Hemiptera) was previously only known from India and Myanmar. This species was a first record of Thailand in 2002 from Phu Hin Rongkla National Park; Central Thailand. Moreover, at the same place the two new species of *Eotrechus* (*E. elongates* and *E. romglao*) were discovered. Moreover, *Eothechus siamensis* was discovered as new species in the world in Doi Inthanon, Chiangmai Province, northern Thailand (Vitheepradit and Sites, 2007).

**2.4 Biological Indicator**

The organism can provide an indication of the quality of their environment. Indicator species may be used and understood in difference way. Some species are known to have specific requirement with relationship to levels of dissolved oxygen or nutrients in the water (Merritt *et al*., 2008). The presences of the species in their habitat indicate that the given determinant is within the tolerance limits of that species, which the term of indicator is used here (Hellawell, 1986; Jeffries and Mill, 1990; Munoz *et al*., 1995). Aquatic ecological health is reflected in the chemical, physical and biological integrity of surface water (Butcher *et al*., 2003). Biological indices to assess water quality based on macroinvertebrates offer advantages over those using other organism because it is easy to sample and with regard to quantitative measurement or relative abundance. Moreover, the identification keys of macroinvertebrates are available for most orders. For many orders, there are world wide information concerning pollution tolerance (Muñoz *et al*., 1995). In the stream, macroinvertebrate species richness is influence by a large number of environmental factors such as pH, conductivity and specific ions or elements (Voelz and McArthur, 2000; Compin and Céréghino, 2003). They are very sensitive to changes in several abiotic parameters of the aquatic habitats (Sharma and Rawat, 2009).

The species richness is sensitive to the impact of human activity on stream, particularly aquatic insects in order Ephemeroptera, Plecoptera and Trichoptera (EPT). A number of EPT is often used in United States as a “biological indicator” of water quality in a given area (Rest and Jackson, 1993).

Compin and Céréghino (2003) studied sensitivity of aquatic insect species richness to disturbance in the Adour-Garonne stream system in France. Number of

species of insect order Ephemeroptera, Plecoptera, Trichoptera and Coleoptera (EPTC) were used to determine the species richness. The result showed 283 species was given. Ephemeroptera, Plecoptera, Trichoptera and Coleoptera (EPTC) were occurred in 47 study sites. The EPTC species richness was significant correlated with overall macroinvetebrates in both disturbed and undisturbed sites. Whereas the relative abundance of orders varied among stream types. Ephemeroptera and Trichoptera were widespread from mountain to plain areas. Plecopteran existed in cold and fast flowing of the upper section of the stream system. Coleopteran was found as the highest species richness in downstream section, where water was warmer and lower of velocity.

Dinakaran and Anbalagan (2006) compared water quality and species richness of aquatic insects in 6 streams effected by human activities in India. The Biological Monitoring Working Party (BMWP score) was used to assess water quality. Two streams which are least exposed of anthropogenic impacts showed higher of taxonomic richness and BMWP score than another four streams which influenced by a high degree of human impact cause by discharge of domestic effluence, and by community bathing for personal hygiene. This impact might change the macroinvertebrate habitats.



Castela *et al.* (2007) used Iberian Biological Monitoring Working Party (IBMWP) score to assess water quality of Botao stream in Portugal. Samples were collected from 4 study sites. Two sites were located in the upstream of the village, one was located in the village and the last site was located downstream of the village. The 2,294 individuals and 38 families of benthic macroinvertebrates were identified. The IBMWP biotic index indicated that sites upstream of the village were very good water

quality whereas, study site at the village was good and site downstream was moderate quality. Leunda *et al*. (2008) evaluated water quality of Erro River, Spain by IBMWP and Iberian Average Score Per Taxon (IASPT). The IBMWP scores presented unpolluted water. The IASPT values varying between 4.82-6.82 which indicated good to very good water quality.

The BMWP score has been developed in many parts of the world. Kusza (2005) modified BMWP score system, call BMWP-PL for investigate water quality of the lower Nysa Klodzka River, Poland. The values of BMWP-PL score varied from 27 to 93, in water quality heavily polluted to slightly polluted. The BMWP-PL was well correlated with chemical water quality (DO: 0.6814, $p<0.001$; nutrient compound: from -0.5017, $p<0.05$ to -0.7111, $p<0.001$). In 2003, this index was modified by Roldán for evaluated water quality in Columbia. Moreover, this modified index was used to assess the water quality in the Dos Novillos River, Coata Rica. The result showed the value of BMWP was higher than 120 and classified to excellence quality water (Stein *et al*., 2008). Mustow (2002) developed $BMWP^{THAI}$ which used to evaluate water quality of Thai rivers. This index was used to evaluate water quality of Mae Kham River, Chiang Rai province. From this study, 10 orders and 86 families of aquatic insects were indentified. Water quality of Mae Kham River assessed by using $BMWP^{THAI}$ and $ASPT^{THAI}$ was from polluted to good water quality (Chiangthong and Phalaraksh, 2007).



Some researches in Thailand used the biological index to study macroinvertebrates assemblage and assessed water quality. Especially diversity index, Sripongpun (2003) used Shannon's-Wiener Diversity Index (H') to assess water quality of Thachin River from June 1999 to May 2000. The water quality of this river

showed moderate pollution to very pollution water quality and showed lower of species diversity. The result was likely with Chiangthong and Phalaraksh (2007), the H' index indicated moderate polluted water quality of Mae Kham watershed. Moreover, the Family Biotic Index (FBI) can be used to assess the water quality base on family level of macroinvertebrates. For the Pipestone creek, Minnesota, USA, Piets (2003) used FBI index to evaluate water quality. The result showed the value of FBI was increased from 1989 to 2001. Increasing FBI value is the result of increasing pollution tolerant families and their higher tolerant value.

The impact of river impoundment on benthic macroinvertebrteaes was reduced value of taxa richness and lost of general diversity of fauna in the stream (Ogbeibu and Oribhabor, 2002). The pattern of heavy metals accumulation was different in larvae of three insect orders in the river. The accumulation of Cu in insect order Ephemeroptera and Plecoptera were about 5 times higher than in Trichoptera. In case of Zn and Cd accumulation rate, Ephemeroptera were about 5 and 10 times higher than other insect orders respectively (Sjobakk *et al*., 1996).

Freshwater mollusks are generally used to monitor environmental pollution. Their abundance, wide distribution and filtering activity make them a good choice to evaluate the contamination of freshwater. For example, Zebra mussels (*Dreissena polymorpha*) were used to indicate contamination of Lindane pesticide in Lake of Geneva, Switzerland. That result showed the concentration of Lnidane in Zebra mussels were very high value in agricultural area (Berny *et al.,* 2002). Wagner and Boman (2004) used freshwater mussel to monitor of trace element in Vietnam. Two lakes from difference village were selected to sampling. Twenty elements were analyzed from freshwater mussels. The concentration of element in the mussels were

compared with international standards for metals in mollusks complied by the Food and Agricultural Organization (FAO) of the United Nation. The concentration levels of the metals, Cd, Cr, Cu, Pb, and Zn at both sites were clearly below the FAO limits. The concentration of As was rank within the standard value, but under the highest value. In the oriental area 8 families, 47 genera and 150 species of freshwater bivalves fauna were found (Bogan, 2008). In Southeast asian region, Mekong River is one of the high biodiversity river. One hundred and twenty species of stenothyrid and pomatiopsid snails (gastopods) were found in Mekong River basin. From that number, 111 species were endemic species (MRC, 2003). Some freshwater snails are a vector of disease, serving as the intermediate hosts for the number of infection for which human is definitive host. Snails were transmitted helminthiases caused by trematodes (flukes). At least 40 million people in Africa, Southeast Asia and South America were infected by liver flukes (*Opisthorchis* sp.) and lung flukes (*Paragonimus* sp.) (Strong *et al.,* 2008). Nowadays, the aquatic macroinvertebrates in Mekong River are little known and poorly documented. Therefore, the study on macroinvertebrates and water quality monitoring in the Mekong River should be continued in the future.