Benthic Macroinvertebrates as a Biological Index of Water Quality in the Lower Thachin River

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Abstract

Thachin River is an important river in the central area of Thailand. Pollution sources along the river cause its water quality becomes worse, especially in the lower section. This study collected water samples and benthic faunas for 1 year from June 1999 to May 2000 at 4 stations along the lower Thachin River. Physical and chemical water quality parameters were analyzed every month and the matrices, i.e. total species abundance, taxa richness, percent dominant taxon, Shannon Weaver diversity index (H), modified Hilsenhoff species - level biotic index (HBI), family biotic index (FBI), biological monitoring working party (BMWP), and average score per taxon (ASPT), were calculated. Generally, water in the lower Thachin River during the study period was in poor quality. Most of the values of DO, BOD and ammonia content were higher than these values of surface water quality standard class 4. Benthic macroinvertebrate samples found in this area belonged to 6 phyla (Annelida, Arthropoda, Mollusca, Nematoda, Platyhelminthes, and Sipuncula), 11 classes, 29 orders, 50 families, 66 genera, 79 species and 4 unidentified species. The most abundant species was oligochaete *Ophidonais* sp. According to matrices' results, water condition in the lower Thachin River was impaired status every month during study period and at every sampling station. H values of benthic faunas, as well as pH, DO, and temperature values of water samples at the same stations or nearby stations in this study were significantly different from those of Sittilert's study (1985). Benthic macroinvertebrates can be used as a biological index of water quality in the lower Thachin River.

Some relationships between matrices and water quality parameters are significant, such as relationships between FBI values and these water quality parameters (pH, salinity, COD content, and suspended solid content). However, tolerant values of some benthic faunas are not available as well as variability in natural habitat can affect taxa richness. Nevertheless, these relationships can be improved by taking sample at more stations and continual study for longer period in order to obtain more informations about the related natural variation in the study area. Furthermore, biomass measurement of benthic macroinvertebrates and important parameters for their distribution and abundance (such as the content of organic matter and hydrogen sulfide in sediment) should be also analyzed in order to get better results.

Key words : Thachin river, water quality parameter, benthic fauna, biological index

Introduction

Thachin River is one of the main river in Thailand which is important for economics and society development of the central area as well as important for the living of organisms. It is situated on the west of the Chao Phraya River and runs pass through 4 provinces, i.e. Chainad, Supunburee, Nakorn Pathom and Samutsakorn. The upstream section of the Thachin River is separated from the Chao Phraya River at the mouth of Klong Ma Kham Taw, Amphoe Wat Shing, Chainad Province. Thachin River passes Supunburee and Nakorn Pathom, then flow to the Gulf of Thailand at Amphoe Muang, Samutsakorn Province. The River is about 325 km. long and covers approximately 12,076 km^2. Water in Thachin River is used for households, industries, agriculture, fisheries, transportation and relaxation (Soato 2000).

Thachin River is divided into 3 sections (Harbour Department, 2002) and its water quality standard was classified basing on standard water quality (Pollution Control Department. 2004) as follows:

Upstream area: begins from river mouth, Amphoe Muang, Samutsakorn Province at 0 km. up to the north to Amphoe Nakorn Chaisri Office, Nakorn Pathom Province at 82 km. from river mouth. It was classified as class 4.

Middle section: begins from Amphoe Nakorn Chaisri Office, Nakorn Pathom Province at 82 km. from river mouth to the north up to Pho Phraya drainage gate, Amphoe Muang, Supunburee Province at 202 km. from river mouth. It was classified as class 3.

Downstream area: begins from Pho Phraya drainage gate, Amphoe Muang, Supunburee Province at 202 km. from river mouth to the north up to the beginning of the river at Ban Pak Klong Ma Kham Taw, Amphoe Wat Shing, Chainad Province at 325 km. from river mouth. It was classified as class 2.

Important sources of water pollution in Thachin River such as industries (33%), sewage from domestic sources (30%), pig farms (23%), fish and shrimp farms (12%) and duck farms (2%) cause water quality situation in Thachin River trends to be worse quickly, especially the lower Thachin River (Harbour Department 2002, Pollution Control Department 1995 and Simachaya 1999).

Benthic macrofaunas were studied in the Thachin Estuary from November 1979 to June 1980 by Sanguansin (1981) and in the Thachin River from June to December 1980 by Sittilert (1985). The dominant species found in these studies were relatively close to each other. They were bivalve *Tellina opalina*, and two species of polychaetes *Nephtys capensis* and *Sternaspis scutata* as reported by the Sanguansin (1981) while bivalves *Tellina* sp., *Corbicula* sp., polychaetes *Perinereis* sp., *Nephtys capensis*, and gastropod *Pachdrobia* sp. were dominant species found by Sittilert (1985). Annelids was reported as the dominant group found in the Thachin River in 1996 by Soato (2000). He also found that the highest species diversity index of benthic fauna was 2.36 from Thachin Estuary. Furthermore, species diversity index was proposed as the aid in the interpretation of water quality (Sanguansin 1981, Sittilert 1985, and Soato 2000). In addition, it has been reported that benthic invertebrates can be used as a method to indicate good or poor quality of water. (Yandora 1998 and Chiasson 2000). Then, it is interesting to study relationships between benthic macroinvertebrates and water quality parameters in the lower Thachin River.

Materials and Methods

Materials and Equipment

Equipment used in this study were a zoom stereo microscope model SZ4045TR, a compound microscope model CHT, and an inverted microscope model CKX41 with 1 set of photography equipment (Olympus Optical Co., Ltd., Japan), a zoom digital camera DC 3400 (Eastman Kodak Company, USA.), a salinometer model 33 (Yellow Springs Instrument Co., Inc., USA.), a pH meter (Ciba Corning Diagnostics Ltd., UK.), sieves number 35, 18 and 10 with 500 µm., 1.0 mm. and 2.00 mm. mesh sizes, respectively (Tamis d’ analyse F. Kurt Retsch GmbH & Co., Germany), 15 x 15 cm^2 Ekman grab (Num Ta Lay Co., Ltd., Thailand), van Dorn water sampler (Num Ta Lay Co., Ltd., Thailand), and a secchi disc (Num Ta Lay Co., Ltd., Thailand). In addition, these chemicals were consumed, e.g. standard solutions for pH 4, 7 and 10 (Horiba, Ltd., Japan), AR grade chemicals for water quality analysis, and commercial grade 40% formalin solution. BOD bottles, sampling bottles, forcepts, needles, and glass apparatus for laboratory analysis such as beakers, erlenmeyer flasks, pipettes, burettes, droppers, etc. were also used in this study.

Methods

Study Duration and Sampling Frequency

Duration of Study

The study was undertaken in the lower Thachin River from June 1999 to May 2000.

Frequency of Sampling

Field samples were collected once a month during the study period.

Sampling Stations

Four suitable sampling stations were selected along the lower Thachin River (Fig. 1).

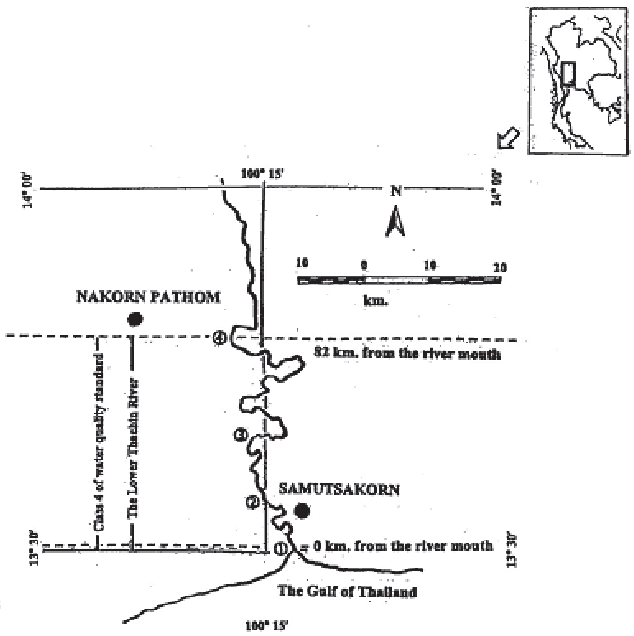
Samples Collection

Water

Water samples were collected by van Dorn water sampler at approximately the middle width of the river and the middle of river depth.

Benthic Macroinvertebrate

Benthic macroinvertebrate samples were collected by Ekman grab and kept in big plastic bags. For each sampling station, three subsampling sites (i.e. riverside, the middle of river width and subsampling site between these two subsampling sites) were determined with two replications per subsampling site.



sampling station	distance from river mouth (km.)
① the mouth of Thachin River	0
② the bridge across Thachin River	8.5
③ the port at the end of Rungsuwan Road, Moo 12, Tambol Bangyang, Amphoe Kratumban, Samutsakorn Province	23
④ the front of Amphoe Nakorn Chaisri Office	82

Fig. 1 Map of sampling stations along the lower Thachin River (modified from Pollution Control Department 2004)

For each replication of each subsampling site, benthic macroinvertebrate samples were throughly rinsed in a set of sieves, i.e. mesh size 2.00 mm., 1.00 mm. and 500 µm., respectively. Visually inspected, discarded unwanted material, placed samples in glass bottle and then preserved with 5% formalin solution. Then, the samples were brought back to the laboratory and identified to the lowest possible taxonomic level according to APHA, AWWA and WPCF (1998), Brandt (1974), Dance (1974), Edmondson, W.T. (1966), Needham and Needham (1962), and Pianthipmanus and Charoenruay (1982). The number of each type of benthic macroinvertebrate samples were counted.

Analysis of Physical and Chemical Parameters of Water Samples

Water samples were collected, preserved and analyzed according to methods suggested by APHA AWWA and WPCF (1998) and Pollution Control Department (2004). Three replications were performed for each parameter. Physical and chemical properties of water quality were both in situ and ex situ determined. The in situ determined were temperature, pH, Secchi depth and salinity and the laboratory analysis parameters were DO, BOD, COD, phosphate, ammonia and suspended solid.

Matrices

The data of macroinvertebrate for each sample site a month were used to calculate the following analytical metrices, i.e. total species abundance, taxa richness, percent dominant taxon, Shannon Weaver diversity index (H), modified Hilsenhoff species - level biotic index (HBI), family biotic index (FBI), biological monitoring working party (BMWP) and average score per taxon (ASPT) as in Table 1.

Table 1 Matrices used in this study.

Matric	Formula/Description	Comment	Reference
Total Species Abundance	is the density or number of aquatic macroinvertebrates per unit area	Normally abundance decreases when flow is high, an increase in fine sediment or the presence of toxic substances	Barbour et al.1999, and Vinson 2000
Taxa Richness	is the total number of taxa persent	Taxa richness increases with increasing habitat diversity, suitability, and water quality. >26 non - impacted 19 - 26 slightly impacted 11 - 18 moderately impacted 0 - 10 severely impacted	Plafkin et al. 1989, and Department of Civil and Environmental Engineering 1999
Percent Dominant Taxon	is the ratio of the number of individuals in the most abundant taxon/taxa to the total number of organisms collected, then multiplied by 100.	This value increases with increasing pertubation >45 inpaired 40 - 45 possibly impaired <40 unimpaired	Barbour et al. 1999, and Citizens' Environmental Watch 2002
Shannon Weaver Diversity Index (H)	$H = -\sum_{i=1}^{S} (\frac{n_i}{N})(\log_2 \frac{n_i}{N})$	>4 clean water 3 - 4 slightly pollution 2 - 3 moderately pollution <2 very polluted	Shannon and Weaver 1963, and Trivedi 1979
Modified Hilsenhoff Species - level Biotic Index (HBI)	$HBI = \frac{\sum_{i=1}^{S} x_i t_i}{N}$	0.00 - 3.50 excellent 3.51 - 4.50 very good 4.51 - 5.50 good 5.51 - 6.50 fair 6.51 - 7.50 fairly poor 7.51 - 8.50 poor 8.51 - 10.00very poor	Hilsenhoff 1987, Barbour et al. 1999, Llansó 2002, Madaville 2002, and Soil & Water Conservation Society of Metro Halifax 2004
Family Biotic Index (FBI)	$FBI = \frac{\sum_{i=1}^{S} x_i t_i}{N}$	0.00 - 3.75 excellent 3.76 - 4.25 very good 4.26 - 5.00 good 5.01 - 5.75 fair 5.76 - 6.50 fairly poor 6.51 - 7.25 poor 7.26 - 10.00very poor	Hilsenhoff 1988, Barbour et al. 1999, Llansó 2002, Madaville 2002, and Soil & Water Conservation Society of Metro Halifax 2004
Biological Monitoring Working Party(BMWP)	is calculated by adding the individual scores of all families in the sample.	The lower the BMWP score, the greater their tolerance towards pollution.	Mackie 2001
Average Score per Taxon (ASPT)	is calculated by dividing the BMWP by the number of all families found in the sample	>6 clean water 5 - 6 doubtful quality 4 - 5 probable moderate pollution <4 probable severe pollution	Mandaville 2002

Analysis of the Relationship between Benthic Macroinvertebrate Matrices and Water Quality Parameters

Each pair of matric and water quality parameter was analyzed by linear regression analysis. Then, significance of its relationship was tested by using t - test analysis at á = 0.05.

Results and Discussion

General Description and Observation of Sampling Stations

Four suitable sampling stations were selected along the lower Thachin River, which is an estuary (Fig.1).

Station 1 : The mouth of Thachin River is at 0 km. from river mouth, in Amphoe Muang, Samutsakorn Province. The current was strong, especially in the middle of river. One side of the shore was a mudflat area with some residences along the shore. During sampling period, some areas of water surface near the shore were covered by leaked oil (in January 2000) and water hyacinths (in January and May 2000).

Station 2 : The bridge across Thachin River is at 8.5 km. from river mouth. The current was strong. There was dispersion of water hyacinths on the water surface from January to May 2000 during sampling period. Slightly leaked oil was also observed on the surface of water in February 2000. Furthermore, leaked oil was observed in collected sediment samples during sampling period from October to December 1999.

Station 3 : The port at the end of Rungsuwan Road is at approximately 23 km. from river mouth in Moo 12, Tambol Bangyang, Amphoe Kratumban, Samutsakorn Province.The current was strong. Both sides of the shores were muddy, residences and a small port for each side were observed along the shores. Water hyacinths were observed near the shore during sampling period.

Station 4 : The front of Amphoe Nakorn Chaisri Office is at 82 km. from river mouth. Both sides of the shore were muddy. There were some food shops, a market, and an area for giving food to fish near Amphoe Nakorn Chaisri Office. On the opposite site consisted of residences, a school, food shops and some aquatic vegetable growing areas. The current was strong. There were dispersion of water hyacinths on the water surface and dense water hyacinth mats near the shores during sampling period.

Macroinvertebrate Animals

Benthic macroinvertebrate samples found in the lower Thachin River belonged to 6 phyla, 11 classes , 29 orders, 50 families, 66 genera, 79 species and 4 unidentified species (Table 2).

Table 2 Benthic macroinvertebrates of the lower Thachin River from June 1999 to May 2000.

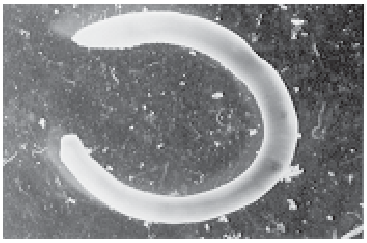
Benthos					Station			
Phylum	**Class**	**Order**	**Family**	**Genus species/ unidentified**	**1**	**2**	**3**	**4**
Annelida	Hirudinea	Rhynchobdellida	Piscicolidae	*Piscicola* sp.			■	■
Annelida	Oligochaeta	Branchiobdellida	Branchiobdellidae	*Cirrodrilus thysanosomus*				■
Annelida	Oligochaeta	Tubificida	Naididae	*Ophidonais* sp.	■	■	■	■
Annelida	Oligochaeta	Tubificida	Tubificidae	*Branchiura* sp.	■	■	■	■
Annelida	Oligochaeta	Tubificida	Tubificidae	*Tubifex* sp.	■	■	■	■
Annelida	Polychaeta	Amphinomida	Amphinomidae	*Chloeia* sp.	■			
Annelida	Polychaeta	Capitellida	Arenicolidae	*Arenicola* sp.			■	
Annelida	Polychaeta	Capitellida	Capitellidae	*Notomastus* sp.			■	
Annelida	Polychaeta	Eunicida	Eunicidae	*Marphysa* sp.	■			■
Annelida	Polychaeta	Eunicida	Onuphidae	*Diopatra* sp.	■	■	■	
Annelida	Polychaeta	Orbiniida	Orbiniidae	unidentified species	■			
Annelida	Polychaeta	Phyllodocida	Nephtyidae	*Nephtys* sp.	■			
Annelida	Polychaeta	Phyllodocida	Nereidae	*Neanthes limnicola*		■	■	■
Annelida	Polychaeta	Phyllodocida	Nereidae	*Nereis* sp.	■	■	■	■
Annelida	Polychaeta	Sabellida	Sabellidae	*Manayunkia* sp.	■			
Annelida	Polychaeta	Sabellida	Sabellidae	*Sabellaria* sp.	■			
Annelida	Polychaeta	Spionida	Spionidae	*Aquilaspio* sp.	■		■	■
Annelida	Polychaeta			Polychaete larvae (unidentified)	■			■
Arthropoda	Custacea	Amphipoda	Gammaridae	*Gammarus* sp.		■		
Arthropoda	Malacostraca	Decapoda	Grapsidae	*Sesarma* sp.	■	■		■
Arthropoda	Insecta	Diptera	Ceratopogonidae	*Bezzia* sp.			■	
Arthropoda	Insecta	Diptera	Chironomidae	*Chironomus* sp.		■	■	■
Arthropoda	Insecta	Diptera	Tabanidae	*Tabanus* sp.		■		
Mollusca	Bivalvia	Arcoida	Arcidae	*Anadara multicostata* (Sowerby)	■			
Mollusca	Bivalvia	Arcoida	Arcidae	*Barbatia* sp.	■			
Mollusca	Bivalvia	Arcoida	Arcidae	*Arca (Anadara) inaequivalvis* (Bruguiere)	■			
Mollusca	Bivalvia	Arcoida	Arcidae	*Arca granulosa*	■	■		
Mollusca	Bivalvia	Myoida	Pholadidae	*Barnea candida*	■	■		■
Mollusca	Bivalvia	Myoida	Pholadidae	*Pholas dactylus*	■	■	■	
Mollusca	Bivalvia	Mytiloida	Mytilidae	*Musculus senhousia* (Benson)	■	■	■	■
Mollusca	Bivalvia	Mytiloida	Mytilidae	*Perna viridis*	■			
Mollusca	Bivalvia	Pterioida	Ostreidae	*Crassostrea* sp.	■	■		
Mollusca	Bivalvia	Unionoida	Amblemidae	*Ensiden ingallsianus ingallsianus* (Lea)	■			■
Mollusca	Bivalvia	Unionoida	Amblemidae	*Pilsbryoconcha exilis exilis* (Lea)	■		■	■
Mollusca	Bivalvia	Unionoida	Amblemidae	*Scabies crispata* (Gould)	■			■
Mollusca	Bivalvia	Unionoida	Amblemidae	*Uniandra contradens rustica* (Lea)				■
Mollusca	Bivalvia	Unionoida	Amblemidae	*Uniandra contradens rusticoides n. subsp.*				■
Mollusca	Bivalvia	Unionoida	Amblemidae	*Uniandra contradens tumidula* (Lea)	■			
Mollusca	Bivalvia	Unionoida	Unionidae	*Hemistena lata*	■			■
Mollusca	Bivalvia	Veneroida	Cardiiae	*Corculum* sp.	■			
Mollusca	Bivalvia	Veneroida	Carditidae	*Venericardia purpurata* Deshayes	■	■	■	
Mollusca	Bivalvia	Veneroida	Corbiculidae	*Corbicula baudoni* (Morlet)	■	■	■	■

Table 2 (contiuned)

Benthos					Station			
Phylum	**Class**	**Order**	**Family**	**Genus species/ unidentified**	**1**	**2**	**3**	**4**
Mollusca	Bivalvia	Veneroida	Corbiculidae	*Corbicula solidula* Prime				
Mollusca	Bivalvia	Veneroida	Corbiculidae	*Corbicula virescens n. sp.*				
Mollusca	Bivalvia	Veneroida	Pharidae	*Siliqua (sp.) patula*				
Mollusca	Bivalvia	Veneroida	Solenidae	*Solen* sp.				
Mollusca	Bivalvia	Veneroida	Tellinidae	*Tellina* sp.				
Mollusca	Bivalvia	Veneroida	Veneridae	*Paphia undulata* (Born)				
Mollusca	Gastropoda	Basommatophora	Ellobiidae	*Melampus (Micromelampus) siamensis* Martens				
Mollusca	Gastropoda	Caenogastropoda	Naticidae	*Tanea hilaris* (Sowbery)				
Mollusca	Gastropoda	Entomotaeniata	Pyramidellidae	*Chrysallida (Salasiella) eppersoni* (Brandt)				
Mollusca	Gastropoda	Heterostropha	Architectonicidae	*Architectonica perdix*				
Mollusca	Gastropoda	Limnophila	Planorbidae	*Gyraulus convexiusculus* (Hutton)				
Mollusca	Gastropoda	Limnophila	Planorbidae	*Gyraulus* sp.				
Mollusca	Gastropoda	Mesogastropoda	Ampullariidae (Pilidae)	*Pila ampullacea* (Linnaeus)				
Mollusca	Gastropoda	Mesogastropoda	Ampullariidae	*Pila pesmei* (Morlet)				
Mollusca	Gastropoda	Mesogastropoda	Aporrhaiidae	*Aporrhais* sp.				
Mollusca	Gastropoda	Mesogastropoda	Bithyniidae	*Bithynia (Digoniostoma) s. siamensis* (Lea)				
Mollusca	Gastropoda	Mesogastropoda	Bithyniidae	*Bithynia* sp.				
Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae	*Manningiella polita* (Brandt)				
Mollusca	Gastropoda	Mesogastropoda	Littorinidae	*Littorinopsis* sp.				
Mollusca	Gastropoda	Mesogastropoda	Potamididae	*Cerithidea (Cerithideopsilla) cingulata* (Gmelin)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Adamietta housei* (Lea)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Brotia (Brotia) c. peninsularis n. subsp.*				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Brotia (Brotia) c. varicosa* (Troschel)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Brotia (Brotia) citrina* (Brot)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Brotia (Brotia) pseudoasperata* (Brandt)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Brotia (Senckeenbergia) wykoffi n. sp.*				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Melanoides tuberculata* (Müller)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Neoradina prasongi m. sp.*				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Taerebia granifera* (Lamarck)				
Mollusca	Gastropoda	Mesogastropoda	Thiaridae	*Thiara scabra* (Müller)				
Mollusca	Gastropoda	Mesogastropoda	Viviparidae	*Filopaludina (Filopaludina) sumatrensis speciosa* (Deshayes)				
Mollusca	Gastropoda	Mesogastropoda	Viviparidae	*Filopaludina (Siamopaludina) j. continentalis n. subsp.*				
Mollusca	Gastropoda	Mesogastropoda	Viviparidae	*Filipaludina (Siamopaludina) m. munensis n.subsp.*				
Mollusca	Gastropoda	Mesogastropoda	Viviparidae	*Mekongia* sp.				
Mollusca	Gastropoda	Neogastropoda	Buccinidae	*Clea (Anentome) helena* (Philippi)				
Mollusca	Gastropoda	Neogastropoda	Harpidae	*Harpa articularis* (Lamarck)				
Mollusca	Maxillopoda	Sessilia	Balanidae	*Balanus* sp.				
Mollusca	Cephalopoda	Sepiida	Sepiidae	*Sepia* sp.				
Nematoda				unidentified species				
Platyhel minthes				unidentified species				
Sipuncula	Sipunculidea	Sipunculiformes	Sipunculidae	*Sipunculus* sp.				

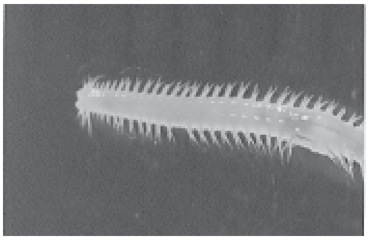
Note : Grey colour in the block means benthos found in that station

Examples of benthic macroinvertebrates of the lower Thachin River are shown in Fig. 2.

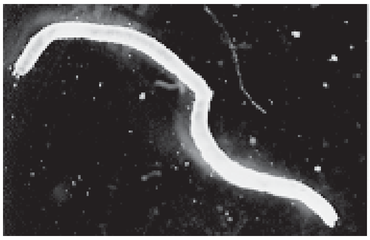


Ophidonais **sp (3x)**

Branchiura **sp. (3x)**

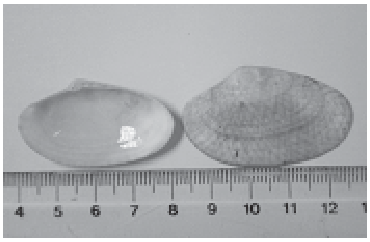


Nereis **sp. (head) (3x)**

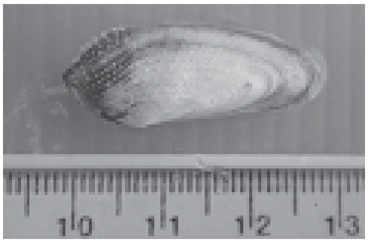


Tubifex **sp. (4x)**

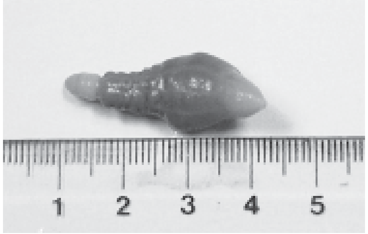
Diopatra **sp. (head) (3x)**



Paphia **sp.**



Pholas dactylus



Sipunculus **sp.**

Fig. 2 Examples of benthic macroinvertebrates found in the lower Thachin River.

Annelida, Mollusca, and Arthropoda were the most abundant reported by Sittilert (1985), and Soato (2000) while Annelida and Mollusca were the most abundant phyla in this study (Table 3). The number of identified benthic genera/species were higher in the later studies. One possibility might be because there were less available keys for identification in the past than nowadays.

Table 3 Average abundance and richness values of each phylum in the lower Thachin River from June 1999 to May 2000.

Phylum	Average # of Organism/sq. m.	# of sp. Found (Richness)
Annelida	355.86	18
Arthropoda	2.31	5
Mollusca	325.62	57
Nematoda	1.23	1
Platyhelminthes	0.77	1
Sipuncula	9.88	1

Sittilert (1985) found that the most abundant species in the lower part of the river were bivalves (*Tellina* sp., *Corbicular* sp.), polychaetes (*Perinereis* sp., *Nephtys capensis*) and gastropod (*Pachydrobia* sp.) while oligochaete (*Dero* sp.) was reported by Soato (2000). But the most abundant species in this study was oligochaete (*Ophidonais* sp.).(Table 4)

Table 4 Average abundance of the most four abundant species in the lower Thachin River from June 1999 to May 2000.

Species	Average # of Organism/sq. m. of Species
Ophidonais sp.	161.57
Branchiura sp.	83.33
Paphia undulata (Born)	79.78
Pholas dactylus	77.16

In 1980 the highest density found in May while in 1996 was November (Sittilert 1985 and Soato 2000). But it was August in this study (Table 5). It was found that the most abundant station was the port at the end of Rungsuwan Road, Samutsakorn Province but the highest number of species was found at the mouth of Thachin River (Table 6).

Table 5 Monthly average abundance and richness values of benthic animals in the lower Thachin River from June 1999 to May 2000.

Year/Month	Average # of Organism/sq. m.	# of sp. (Richness)
1999/6	337.04	25
1999/7	768.52	21
1999/8	1,379.63	32
1999/9	611.11	23
1999/10	468.52	24
1999/11	683.33	21
1999/12	587.04	34
2000/1	837.04	24
2000/2	675.93	18
2000/3	692.59	24
2000/4	950.00	17
2000/5	357.41	19

Table 6 Average abundance and richness values of benthic animals in the lower Thachin River from June 1999 to May 2000.

Parameter	Station 1	Station 2	Station 3	Station 4
Average Abundance (# of Organism/sq.m.)	14.45	539.51	770.37	680.25
Richness (# of sp.)	57	31	35	44

Water Quality

Average values of water quality in the lower Thachin River every month during study period and at every station are shown in Table 7 and 8, respectively.

Table 7 Monthly average values of water quality in the lower Thachin River from June 1999 to May 2000.

Parameter	Average Value in the Year 1999							Average Value in the Year 2000				
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Depth (m)	7.0	7.1	5.8	8.5	13.3	9.7	8.9	8.6	8.2	7.7	6.4	6.1
Secchi depth (cm.)	68*	65*	63*	46	40	65*	70*	78*	80*	80*	40	50
pH	6.76	7.13	6.87	6.28	6.87	6.77	6.75	7.65	7.53	7.20	6.97	6.80
DO (mg/L)	0.8^	1.8^	0.9^	0.6^	1.2^	1.3^	1.8^	2.6	2.3	2.3	0.9^	1.9^
Temp (ºC)	30.2	32.5*	31.4	30.5	28.6	28.2	24.5	28.8	28.7	30.7	30.0	31.4
Salinity (ppt)	0.7	20.9	2.6	1.3	1.6	0.8	3.5	10.1	14.0	6.8	0.4	1.7
BOD (mg/L)	5.3^	3.3	4.1^	4.6^	3.5	9.5^	3.2	3.2	6.5^	6.7^	4.6^	3.8
COD (mg/L)	59	209	76	163	270	163	125	155	218	137	30	76
Phosphate (mg/L)	1.12	3.10	1.47	2.30	1.34	0.80	0.66	0.88	2.10	1.32	1.40	1.58
Ammonia (mg/L)	1.2^	0.9^	1.2^	0.9^	0.6^	0.7^	0.4	0.8^	0.9^	0.7^	0.7^	0.6^
SS (mg/L)	15.7	34.1*	35.7*	74.2*	79.3*	38.7*	26.8*	23.5	27.8*	18.4	60.1*	35.5*

Note : ^ out of the reported value of surface water quality standard class 4 (Pollution Control Department 2004)
* out of the suitable range for aquatic faunas (Pollution Control Department 2004)

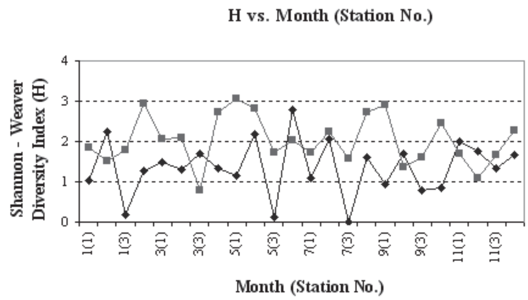
Table 8 Average values of water quality in the lower Thachin River at each station from June 1999 to May 2000.

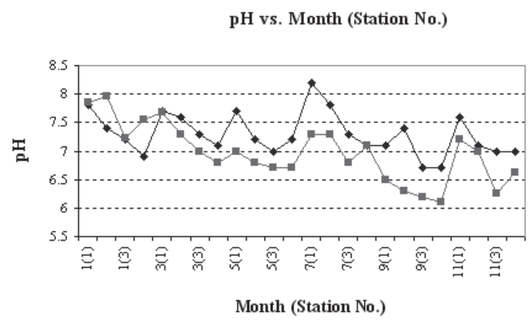
Parameter	Station 1	Station 2	Station 3	Station 4
Depth (m.)	5.8	10.1	8.5	8.1
Secchi Depth (cm.)	55	62*	71*	60
pH	7.20	7.09	6.80	6.77
DO (mg/L)	2.4	1.4^	1.1^	1.2^
Temp (ºC)	29.7	29.8	29.5	29.4
Salinity (ppt.)	13.2	6.8	0.9	0.6
BOD (mg/L)	4.2^	4.6^	5.8^	4.8^
COD (mg/L)	381	110	36	32
Phosphate (mg/L)	1.46	1.49	1.27	1.81
Ammonia (mg/L)	0.8^	0.7^	0.9^	0.6^
SS (mg/L)	65.9*	48.2*	17.9	24.6

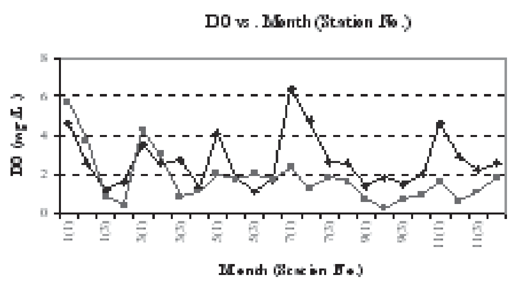
Note : ^ and * the same as in Table 7

General, it can be seen that water quality in the lower Thachin River was in poor quality. Most of the values of DO, BOD and ammonia content were higher than these values of surface water quality standard class 4. In addition, some parameters were out of the suitable range for aquatic faunas.

Water quality parameters at the same stations or nearby stations were compared between the study of Sittilert (1985) and this study by using paired sample t - test analysis. Among these parameters, H values, pH, DO, and temperature were significantly different as shown in Fig. 3.







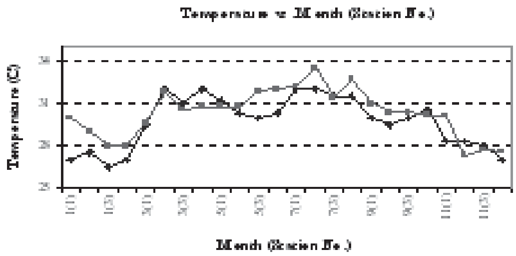


Fig. 3 Comparison among H values, pH, DO, temperature and month (station number) in the year 1980 (Sittilert 1985) and 1999 - 2000 in this study.

Note : ——— the year 1980
——— the year 1999 - 2000

Temperature and pH values in Fig. 3 were in the accepted range of surface water quality standard class 4 (Pollution Control Department. 2004). However, the tendency of pH values was lower in this study than that reported by Sittilert (1985) while the tendency of temperature values was slightly higher in this study than that reported by Sittilert (1985). Generally, DO values in this study were lower than those reported by Sittilert (1985). This is in accordance with water pollution crisis in Thachin River in the year 2000 which was reported by Pollution Control Department (2000). Based on the results of DO values, H values in this study should be lower than those reported by Sittilert (1985). However, they were in the opposite way which might be because there were more available keys for identification in this study than in previous study.

Benthos - Water Quality Relationship

In the Environmental Protection Agency's Rapid Bioassessment Protocol, eight matrices were proposed for macroinvertebrate community analysis (Plafkin et al. 1989). Therefore, eight matrices were calculated in this study. Average values of matrices in the lower Thachin River every month during study period and at every station are shown in Table 9 and 10, respectively.

Table 9 Monthly average values of water quality in the lower Thachin River from June 1999 to May 2000.

Parameter	Average Value in the Year 1999							Average Value in the Year 2000				
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Abundance (no./sq.m.)	337.04	768.52	1,379.63	611.11	468.52	683.33	587.04	837.04	675.93	692.59	950.00	357.41
Log_{10} Abundance (no./sq.m)	2.45	2.67	3.09	2.53	2.62	2.78	2.76	2.75	2.82	2.80	2.89	2.52
H	2.50 mod. poll.	2.07 mod. poll.	1.85 very poll.	2.09 mod. poll.	2.42 mod. poll.	1.68 very poll.	2.52 mod. poll.	2.02 mod. poll.	1.31 very poll.	1.93 very poll.	1.45 very poll.	2.41 mod. poll.
Taxa Rich.	9 sev. impac.	9 sev. impac.	11 mod. impac.	9 sev. impac.	10 sev. impac.	8 sev. impac.	12 mod. impac.	10 sev. impac.	6 sev. impac.	8 sev. impac.	8 sev. impac.	9 sev. impac
% Domina	40.46 poss. impa.	61.70 impa.	56.82 impa.	54.60 impa.	43.67 poss. impa.	65.68 impa.	41.50 poss. impa.	63.15 impa.	70.13 impa.	50.57 impa.	69.93 impa.	40.35 poss. impa.
HBI	8.42 poor	8.82 very poll.	6.06 fair	6.02 fair	6.11 fair	6.04 fair	6.01 fair	6.00 fair	6.09 fair	6.10 fair	6.00 fair	6.14 fair
FBI	7.91 very poor	7.71 very poor	7.71 very poor	7.13 poor	8.08 very poor	7.54 very poor	7.58 very poor	7.11 poor	6.75 poor	7.05 poor	7.46 very poor	8.49 very poor
BMWP	10.00	13.67	23.00	11.00	11.00	7.75	12.00	8.25	7.33	16.00	13.00	13.00
ASPT	2.75 prob. severe. poll.	3.13 prob. severe poll.	4.20 prob. mod. poll.	3.67 prob. severe poll.	3.60 prob. severe poll.	3.88 prob. severe poll.	3.94 prob. severe poll.	3.54 prob. severe poll.	4.17 prob. mod. poll.	4.00 prob. mod. poll.	4.33 prob. mod. poll.	4.00 prob. mod. poll.

Note :

mod. poll.	moderately polluted
very poll.	very polluted
mod. impa.	moderately impacted
sev. impac.	severely impacted
poss. impa.	possibly impaired
impa.	impaired
prob. mod. poll.	probable moderate pollution
prob. severe poll.	probable severe pollution

Table 10 Average values of matrices in the lower Thachin River at every station from June 1999 to May 2000.

Parameter	Station 1	Station 2	Station 3	Station 4
Abundance (# of Organism./sq.m.)	792.59	539.51	770.37	680.25
Log_{10} Abundance	2.78	2.49	2.84	2.78
H	2.19 mod. poll.	1.65 very poll.	1.69 very poll.	2.55 mod. poll.
Taxa Richness	11 mod. impacted	6 severely impacted	8 severely impacted	10 severely impacted
% Dominance	54.63 impaired	61.08 impaired	64.62 impaired	39.19 unimpaired
HBI	6.53 fairly poor	6.37 fair	6.64 fairly poor	6.40 fair
FBI	6.44 fairly poor	7.34 very poor	8.35 very poor	8.04 very poor
BMWP	5.60	8.63	12.17	15.17
ASPT	3.13 prob. severe poll.	3.58 prob. severe poll.	3.71 prob. severe poll.	4.02 prob. mod. poll.

Note : the same as in Table 9

According to the evaluation of these matrices and modified assessment of Citizens' Environment Watch (2002), water condition in the lower Thachin River was in impaired status every month during the study period and at all stations, especially station 2 (the bridge across Thachin River) and station 3 (the port at the end of Rungsuwan Road, Samutsakorn Province).

Ninety - nine pairs of these matrices and water quality parameters were analyzed by linear regression analysis. However, only these relationships are significance by using t - test at á = 0.05 (Table 11).

Table 11 Relationships between matrices and water quality parameters in this study.

Y = a + bX	r	r^2	df = N - 2	Significance
pH = 7.298 - 0.166 H	- 0.288	0.083	46	0.047
COD = - 8.648 + 16.483 Taxa Richness	0.298	0.089	46	0.040
pH = 6.553 + 7.463×10^{-3} % Dominance	0.338	0.114	46	0.019
Temp. = 25.530 + 0.616 HBI	0.315	0.099	40	0.042
Salinity = - 10.831 + 2.151 HBI	0.344	0.118	40	0.026
pH = 8.460 - 0.199 FBI	- 0.449	0.202	46	0.001
DO = 5.722 - 0.556 FBI	- 0.468	0.219	46	0.001
Salinity = 47.834 - 5.631 FBI	- 0.526	0.276	46	0.000
COD = 1,021.021 - 116.815 FBI	- 0.585	0.343	46	0.000
SS = 134.925 - 12.701 FBI	- 0.361	0.131	46	0.012
Salinity = 11.709 - 0.699 BMWP	- 0.416	0.173	35	0.011
COD = 274.313 - 14.361 BMWP	- 0.422	0.178	35	0.009

Sittilert (1985) reported that there were significantly relationships between the average density of macroinvertebrate fauna in the lower of Thachin River and DO, pH, and salinity. But these were not significant in this study.

Benthic macroinvertebrates can be used as a biological index of water quality in the lower Thachin River for many reasons. Because benthic faunas have limited mobility, they are not able to avoid adverse conditions. In addition, they expose to contaminants accumulated in sediment and reflect local environmental conditions (Gray 1979). Furthermore, a spill of a hazardous substances in waters may disappear after a period of time while the benthic faunas will remain depressed (Chiasson 2000). Actually, these matrices should have good relationships with water quality parameters. However, not all tolerant values of the identified samples are available. Then, it can be a limitation for the matrices calculated by their tolerant values, such as HBI, FBI, BMWP,and ASPT. In additon, variability in natural habitat (stream size, substrate composition, current velocity) also affects taxa richness (Baylor 2000).

Warwick (1986) suggested that the distribution of individual numbers among species behaved differently from the distribution of biomass among species when influenced by pollution - induced disturbance. He also reported that combined k - dominance plots for species biomass and number took three possible forms representing unpolluted, moderately polluted and grossly polluted conditions. Furthermore, only few species can survive and tolerate in the oxygen deficiency condition by increasing their biomass, such as the capitellid and spionid polychaetes (Pearson and Rosenberg 1978). The increasing of organic materials, correlating with high sulfide and low oxygen, in sediment on transitory zone caused the larger species and deeper burrowing forms gradually eliminated and replaced by greater numbers of lamellibranch suspension and surface deposit - feeders, e.g. *Thyasira* and *Corbula*, and holothurian and annelids (Pearson and Rosenberg 1978). Chatananthawej (2001) also reported that the gradients in organic content showed relationship with the polychaete assemblages and opportunistic polychaete species in Kung Krabaen Bay. There were two distinctive polychaete assemblages. *Prionospio (Minuspio) japonica*, *Mediomastus* sp.A and *Glycinde* sp.A were polychaetes associated with high organic content while *Lumbrineris* sp.B, *Mediomastus* sp.A and *Sigambra* cf. *tentaculata* were associated with low organic content sediment in the bay. Chatananthawej (2001) also proposed that a spionid polychaete, *Prionospio (Minuspio) japonica*, could be used as indicator species for moderated organic enrichment area.

Benthos - water quality relationships might be better if more sampling stations were taken. Continual study for longer period will be also helpful for obtaining more informations about the natural variation of both benthos and water quality in the study area. Furthermore, biomass measurement of benthic macroinvertebrates and important parameters for their distribution and abundance (such as the content of organic matter and hydrogen sulfide in sediment) should be also analyzed in order to get better results.

Conclusion

Activities and pollution sources along Thachin River cause the degradation of water quality , especially in the lower section. Water quality and benthic samples were collected for 1 year from June 1999 to May 2000 at 4 stations along the lower Thachin River. Physical and chemical properties of water samples were analyzed and a variety of metrices were calculated. Generally, water in the lower Thachin River during the study period was in poor quality. Most of the values of DO, BOD and ammonia content were higher than these values of surface water quality standard class 4. Annelida, Arthropoda, Mollusca, Nematoda, Platyhelminthes, and Sipuncula were 6 phyla of benthic faunas observed. Oligochaete *Ophisdonais* sp. was the most abundant species. According to matrices' results, the water condition in the lower Thachin River was in impaired status every month during the study period and at every sampling station. Some water quality parameters and H value in this study differed from the study of Sittilert (1985). Some water quality parameters were significantly related to matrices derived from benthic samples's data, such as relationships between FBI values and these water quality parameters (pH, salinity, COD content, and suspended solid content). Taking sample at more stations and continual study for longer period can improve these relationships. In addition, biomass of benthic macrofauna, organic content, and hydrogen sulfide content should be considered in order to get better results.

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References

American Public Health Association, American Water Works Association, and Water Environment Federation. 1998. *Standard Method for the Examination of Water and Wastewater,* 20th. Edition. Edited by Mary Ann H. Franson. (Baltimore, USA.: American Public Health Association).

Auesuk, Wantana. 1998. *Marine Molluscs.* (Bangkok: Marine Science Department, Faculty of Fishery, Kasetsart University) pp. 95-96.

Barbour, M.T., Gerritsen, Jeroen, Synder, Blainde D., and Stribling, James B. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeabele Rivers: Periphyton, Benthic Macroinvertebrates, and Fish,* 2nd. Edition, EPA 841 - B - 99 - 002.(Washington, D.C.: U.S. Environmental Protection Agency).

Baylor, Donald L. 2000. Benthic Macroinvertebrates of Cherry Creek, Monroe County, PA. for Broadhead Watershed Association. Retrieved Jun. 1, 2000 from http://www.cherrywatershed.net/bugs.pdf.

Brandt, Rolf A.M. 1974. The Non - marine Aquatic Mollusca of Thailand. *Arch. Moll*. 105: pp. 1-423.

Chatananthawej, B. 2001. *Ecological Studies on Benthic Polychaetes with Respect to Organic Enrichment Condition in Kung Krabaen Bay, Thailand*. Ph.D. Thesis, Chulalongkorn University, Bangkok.

Chiasson, Alyre. 2000. Water Quality and Biodiversity as Assessed by Macroinvertebrate Analysis in the Grand Lake Ecoregion of the Fundy Model Forest. *FUNDY Model Forest Network*. Retrieved Oct. 22, 2002 from http://www.FundyModelForest.net/e/prin_e/prin_fse.html.

Citizens' Environment Watch . 2002. Benthic Macroinvertebrate Data Analysis. Retrieved Apr. 2002 from http://www.utoronto.ca/envstudy/cew/action/BenthDataAnalys.pdf.

Dance, S. Peter (editor). 1974. *The Encyclopedia of Shells.* (London: Blandford Press.).

Department of Civil and Environmental Engineering. 1999. *Otter River Rehabilitation - Virtual Tour of the West Branch.* (Michigan, USA.: Department of Civil and Environmental Engineering, Michigan Technological University).

Edmondson, W.T. (editor). 1966. *Fresh Water Biology: (Oligochaeta & Polychaeta)*. (New York: John Wiley & Sons) pp. 522-541.

Gray, J.S. 1979. Pollution - induced Changes in Populations. *Transactions of the Royal Philosophical Society of London* (B)286: pp. 545 - 561.

Harbour Department. 2002. *Water Quality Analysis Result of Tachin River (from River Mouth to Amphoe Nakorn Chisri Office, during Jan. to Jun. 2002)*. (Bangkok: Harbour Department, Ministry of Communications).

Hilsenhoff, W.L. 1987. An Improved Biotic Index of Organic Stream Pollution. *Great Lakes Entomol*. 20: pp. 31 - 39.

Hilsenhoff, W.L. 1988. Rapid Field Assessment of Organic Pollution with a Family - level Biotic Index. *J. N. Am. Benthol. Soc.* 7: pp. 65 - 68.

Llansó , Robert J. 2002. *Methods for Calculating the Chesapeake Bay Benthic Index of Biotic Integrity.* (Columbia: Versar, Inc.).

Mackie, G.L. 2001. Applied Aquatic Ecosystem Concepts. (Dubuque: Kendall/ Hunt Publishing Company).

Mandaville, S.M. 2002. *Benthic Macroinvertebrates in Freshwater - Taxa Tolerance Values, Metrics, and Protocols, Project H - 1.* (Nova Scotia: Soil & Water Conservation Society of Metro Halifax).

Needham, Jame G., and Needham, Paul R. 1962. *A Guide to the Study of Fresh - water Biology*, 5th Edition. (San Francisco: Holden - day, Inc.).

Pearson, T.H. and Rosenberg, R. 1978. Macrobenthic Succession in Relation to Organic Enrichment and Pollution of the Marine Environment. *Oceanogr. Mar. Biol. Ann. Rev.* 16: pp. 229 - 311.

Pianthipmanus, Neena, and Charoenruay, Manop. 1982. *Note on Polychaete in the Gulf of Thailand, Report No. 10/81.* (Bangkok: Marine Fisheries Division).

Plafkin, JL., Barbour, M.T., Porter, K.D., Gross, S.K., and Hughes, R.M. 1989. *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* U.S. Environmental Protection Agency. EPA 440/4-89.001. (Washington, D.C.: U.S. EPA).

Pollution Control Department. 1995. *Studies of Suitability of Wastewater Management in the Lower Tachin River Area.* (Bangkok: Pollution Control Department, Ministry of Science Technology and Environment).

Pollution Control Department. 2000. *Water Pollution Crisis of Thachin River in 2000*. (Bangkok: Pollution Control Department, Ministry of Science Technology and Environment).

Pollution Control Department. 2004. *Water Quality Standards & Criteria in Thailand*.. (Bangkok: Pollution Control Department, Ministry of Science Technology and Environment).

Sanguansin, J. 1981. *Benthic Macrofauna in the Tha Chin Estuary.* M. Sc. Thesis, Chulalongkorn University, Bangkok.

Shannon, C.E. and Weaver, W. 1963. *The Mathematical Theory of Communication.* (Urbana: University of Illinois Press).

Simachaya, W. 1999. *Integrated Approaches to Water Quality Management using Geographic Information Systems and the WASPA5 Simulation Model: Application to the Tachin River Basin, Thailand*. Ph. D. Thesis, School of Engineering, University of Guelph, Ontatio, Canada.

Soato, Weerasak. 2000. *Abundance and Distribution of Benthic Fauna in the Tha - Chin River.* M. Sc. Thesis, Kasetsart University, Bangkok.

Soil & Water Conservation Society of Metro Halifax. 2004. *Taxa Tolerance Values*. (Nova Scotia: Soil & Water Conservation Society of Metro Halifax).

Sittilert, Supachai. 1985. *Species, Quantities and Distribution of Benthic Fauna in the Tachin River.* M. Sc. Thesis, Kasetsart University, Bangkok.

Trivedi, R.C. 1979. *Pollution Studies of Chambal River and Surrounding due to Nagda Industrial Complex.* Ph.D. Thesis. Vikram University, Ujjain.

Vinson, Mark. 2000. *Aquatic Macroinvertebrate Monitoring Report.* (Logan: National Aquatic Monitoring Center, Department of Fisheries and Wildlife, Utah State University).

Warwick, R.M. 1986. A New Method for Detecting Pollution Effects on Marine Macrobenthic Communities. *Mar. Biol.* 92: pp. 557 - 562.

Wattayakorn, Gullaya. 2000. Tachin River Estuary, Tachin River Budgets. Retrieved Jul. 21, 2000 from http://data.ecology.su.se/mnode/Asia/Thailand/tachinriver/tachinbud.htm.

Wilhm, J.L. and Dorris, T.C. 1968. Biological Parameters for Water Criteria. *Bioscience* 18: pp. 477 - 481.

Yandora, Kimberly. 1998. Rapid Bioassessment of Benthic Macroinvertebrates Illustrates Water Quality in Small Order Urban Streams in a North Carolina Piedmont City. *National Water Quality Monitoring Council (MWQMC) National Monitoring Conference web page.* Retrieved Oct. 25, 2002 from http://www.nwqmc.org/98 proceedings/Papers/40-YAND.html.