Assessment of Water Pollution in Khun Thale Swamp

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Abstract

The Khun Thale swamp is an integral part of the Tapi River's catchment area and its geographical location is a small lake. The swamp is located in the lower part of the Tapi river. The average depth of the swamp is 2.2 meters and it covers an area of about 2.03 km^2. The local authorities and the provincial government have planned to develop this swamp as a site for tourism in Surat Thani province. Since the environmental scientific information of this swamp has not been updated, this study was carried out in order to assess water quality, identify the pollution sources as well as to determine the biodiversity of this ecosystem. This information brings understanding of the existing ecosystem of the Khun Thale swamp and its water pollution condition. The study implies that the Khun Thale swamp has been polluted from many sources. It was found that around 30 factories contribute to the swamp's pollution. Domestic wastewater and potential sources of agricultural pollution discharge were identified and described. From the biodiversity information, 47 genera within 3 divisions of phytoplankton and 21 genera of zooplankton were found in this swamp. It also found that 60, 44 and 41 genera of aquatic animals, plants, and birds were determined in this area, respectively. These reflected the Khun Thale swamp as a place of environmental richness in Surat Thani province, and it should be protected. In addition, suggestions and alternative approaches for sustainable water pollution management of the Khun Thale swamp were also addressed.

Keywords: Khun Thale swamp, ecosystem, Surat Thani, water pollution, Tapi river.

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Introduction

In Thailand, as all over the world, anthropological pollution of water is a real concern. As the demand on natural resources by a growing population, as well as industrialization, continues to increase, freshwater will be the first resource to run short and be damaged. In the upper South of Thailand, Surat Thani province has been industrially and demographically developed, and these have lead to a growing deterioration of water quality in the province. The Khun Thale swamp is an integral part of the Tapi River's catchment area and it's geographical location is a small lake. The swamp is located in the lower part of the Tapi river and is about seven kilometers

from the center of Surat Thani city. The government planned to develop this swamp area as a tourist destination. Concern about the sustainability of this water resource is a strong motivation to better understand the driving forces and the consequences of water utilization. This paper is written as an overview version to introduce the current status of water pollution and water quality management of the Khun Thale swamp in Surat Thani Province. In the following sections the current status of water ecosystem, water pollution, and water quality management in the Khun Thale swamp are described from the sources to the target of an environmental conservation site and along with sustainable development.

Methodology

This study was conducted by using primary data and secondary data as follows.

Water quality determination.

30 water samples were taken from the main part of the swamp and its two southern branch expansions, also the two canals connected to the Tapi river. The water samples were taken during high and low tide. The water samples were analyzed for pH, temperature, salinity, conductivity, turbidity, DO, BOD_5, COD, NH_3-N, TKN, TDS, SS, TP, coliform bacteria, as well as pesticides in terms of Dichlorvos, Methamidophos, Mevinfos, Dimethoate, Malathion Methylparathion, and Fenthion. The analysis was conducted following the procedures described by APHA, AWWA & WEF in 1992 (APHA et al.,1992).

Aquatic animals, plants, birds, phytoplankton and zooplankton determination.

The biodiversity, in terms of aquatic animals, plants, birds, phytoplankton and zooplankton in the swamp was also investigated during field surveys in the Khun Thale swamp. The determination of the Khun Thale ecosystem was made in order to provide more details that can be used as background information in the management plan of the area. This part is very important to understand in order to know more about the ecosystem and the lives which have developed on, in and around the swamp. By plant sampling and observation in the field, the swamp's area and the hydrologic connections had been described, and the characteristic vegetable species and birds have been quoted with several references (Sanitsok,1983; Lekagul and Round, 1991).

For phytoplankton and zooplankton determination, sampling was undertaken at 12 sampling points from the main part of the swamp and its two southern branch expansions, also the two canals connected to the Tapi river. The sample collection and analysis were conducted following the procedures described by APHA, AWWA & WEF in 1992 (APHA et al.,1992). All the collected samples were

preserved in bottles, labeled with site name, date and replicate numbers. The identification was made by using stereo-microscope and several references (APHA et al.,1992; Biswas,1949; Shirota, 1966;Wongrat,1998; Wongrat,2001; Zheng-Zhong, 1787).

The secondary data collection.

The secondary data of pollution sources and related information of the Khun Thale swamp were reviewed and collected from the Thambon Local Authority, Provincial Industrial Office, and several research reports discussing the pollution status of the swamp.

Data analysis and discussion.

In this paper, the present perspective of water environment and water quality in the Khun Thale are discussed by reviewing the secondary information and primary data study obtained from field survey and laboratory analysis. The information focusing on pollution sources, water quality, and industrialization/ urbanization was discussed. Finally, comments, suggestions and alternative approaches for water pollution management of the Khun Thale swamp are centered round sustainable solutions for water quality management.

Results and discussion

Khun Thale watershed characteristics: locations and geography.

Surat Thani Province is located in the upper south of Southern Thailand. The population of Surat Thani is about 950 thousand. It is a high economic growth rate city. It is also a major city for transportation, communication, education, tourism and commerce in the upper South of Thailand. Muang district is the center of development in Surat Thani. Agriculture and industry in Surat Thani have expanded rapidly over the last ten years. Tourism also shares an important part in the province's economy (Sanitsok, 1983).

The Tapi river is a major river in Surat Thani, and 80% of it's the catchment area is in Surat Thani province. The river flows through the fertile north-east plains of the province and joins the Gulf of Thailand at Ban Don Bay. The length of the Tapi river is 232 kilometers. An average runoff per year of the Tapi river basin is about 12,977 million cubic meters. The Khun Thale swamp is located at the lower part of the Tapi river. The swamp is an integral part of the Tapi river catchment area and it is connected with two canals namely Tha Kub and Makham Tia. These two canals are located 12 kilometers from the Gulf of Thailand, and so are affected by its high tide. The swamp covers an area of approximately 2.03 km^2, and its watershed area is 152 km^2 in the 3 Tambons of Makhamtea, Khun Thale and Watpradu. It is 7 kilometers from Surat Thani municipality to the south. It is mostly fresh water and is largely covered by aquatic weeds. Figure 1 illustrates the Khun Thale swamp area. The swamp is shallow. The depth across the swamp is approximated 2-3 meters and the average depth is 2.2 meters (Surat Thani Provincial Office, 2003).

Figure 1. Location and characteristics of Khun Thale swamp.

Khun Thale watershed-specific developments.

The Khun Thale watershed is a heavily developed suburban area of Muang district in Surat Thani, mostly residential, but containing areas of governmental, commercial, agricultural and industrial development. Much of the residential development has taken place within the last 3-5 years. Industrial activity, in particularly rubber and the rubber wood industry, is important in this watershed area.

The Khun Thale watershed is the home of more than 6,500 inhabitants with about 700 households (Prince of Songkla University,2005). The Khun Thale swamp is an important place for ecological, economic and social concerns, among others, in Surat Thani Province. The Khun Thale swamp water resources are very valuable, both socially and economically, to the surrounding population. They rely upon the swamp for fishing, agriculture, water supply and transportation. Agriculture and industries were shown to had expanded rapidly. There are 16 factories around the Khun Thale swamp. Fruit, rubber and oil palm plantations are the major agriculture around the swamp. Such expansions will no doubt have an impact on the quantity of pollution and pressure out on the Khun Thale water environment.

The present trend of population growth, industrial and agriculture development near the swamp may create greater problems in terms of water quantity demands and water quality concerns. It was determined that around 30 factories contribute to the swamp's pollution, directly or via the rivers connected to the swamp (Industrial Office- Surat Thani Province, 2004). It is certain that there are some wastewater discharges into the two canals connected to the swamp. The swamp is also polluted by the Tapi river, and the pollution is is then diluted into these canals. The organic load of treated industrial wastewater directly discharged into the swamp was estimated to be 35-40 kg BOD_5/day, with a volume of 6,000-6,500 m^3/day.

A lot of small domestic pipes either for discharging wastewater into the swamp and the canals, or for pumping water to the houses were observed during field surveys. It could be dangerous if these pipes are directly next to bathing and fishing zones. However, the new housing estates at the north shore of the swamp were fitted with septic tanks to treat wastewater before discharging into the canals and swamp. Domestic garbage is in general burned next to the roads but with the winds and rains, they can fly everywhere on the swamp and the canals and thus contribute to visual pollution more than a real destruction of the ecosystem, and which see can see around the shelters on the swamp shore.

Knowing the agricultural and fishing practices, (with strong concentrated pesticides to drug the fish and catch them easily) the discharge of pesticides into the swamp and canals is certain. More than the direct pollution of the ground and visible part of ecosystem, excessive use of pesticides can pollute water bodies and also arrive at the canals and swamp which is a geographical basin (Durand, 2005).

Water quality.

The water quality of the Khun Thale swamp is shown in Table 1. The average water pH was in the range of 7.4-7.5. It was observed that water was influenced by the sea water as the salinity detected in the concentration was 1.67-3.17 g/l. The DO concentration in the canals connected to the swamp was determined to be lower than 5 mg/l and

was higher than in the swamp. This was because of the discharge of wastewater into the canals as well as re-oxygenation from plant photosynthesis in the swamp.

The BOD_5 and COD concentrations of the water reflected that the water quality of this swamp was much polluted with organic matter. However, the total coliform bacteria was not in excess of the standard limits for class 2 and class 3 levels of fresh water quality standard of Thailand (5,000 MPN/100 ml and 20,000 MPN/100 ml, respectively). The coliform bacteria concentration in the swamp was found not to be higher than the aquaculture water standard (coliform bacteria should not be more than 1,000 MPN/100ml). This result indicates that there is not much domestic wastewater contamination in the swamp water, but the industries located around the swamp were the major source of pollution.

In addition, organophosphorus pesticide residues in terms of Dichlorvos, Methamidophos, Mevinfos, Dimethoate, Methylparathion, Malathion, and Fenthion in the canals and swamp water were also detected (Table 1).

The pesticide concentrations observed in this study were consistent with the previous report (Danteravanich, 2001). It reported that organophosphorus pesticide residues in the Tapi river were also detected. Monocrotophos, dimethoate, diazinon, methyl-parathion, fenitrothion, malathion, quinalphos, profenofos and trizophos in the rivers were also detected with ranges of 0.088-0.146 mg/l, undetected to 0.085 mg/l, 0.003-0.059 mg/l, undetected to 0.007 mg/l, undetected to 0.046 mg/l, undetected to 0.061 mg/l, undetected to 0.007 mg/l, undetected to 0.019 mg/l., and undetected to 0.037 mg/l, respectively. In general, the pesticide concentrations detected in the swamp water samples are alarming. Actually, it is important to note that even if the concentrations found are not so high, knowing the agricultural and fishing practices (using pesticides to catch fish easily) and because of the influence of tides which carry the pesticides fixed in the sediments, it is sure that swamp and canal waters are polluted by pesticide accumulation. This finding is alarming and implies in toxic chemicals from agricultural activity around the swamp.

Table 1. Water quality in average in Khun Thale swamp.

parameters	river	swamp
pH	7.4-7.5	7.4-7.5
Temperature (°C)	31-32	31-32
Salinity,(g/l)	1.67-3.17	1.89-2.11
Conductivity(mS/cm)	2.46-3.2	2.4-2.65
Turbidity(NTU)	4.29-5.14	3.61-6.01
DO (mg/l)	3.3-4.9	5.1-5.8
BOD5 (mg/l)	3.2-3.5	3.7-3.8
COD (mg/l)	79-80	44-89
NH3-N (mg/l)	0.2-0.4	0.2
TKN (mg/l)	0.5-0.7	0.4-0.6
TDS (mg/l)	2086-3080	2109-2151
SS (mg/l)	7.2-14.5	7.4-20.8
TP (mg/l)	0.09-0.13	0.08-0.12
Coliform (MPN/100 ml)	129-280	103-209
Dichlorvos (μg/l)	<0.066	<0.066
Methamidophos(μg/l)	<0.498	<0.498
Mevinfos (μg/l)	<0.066	<0.066
Dimethoate(μg/l)	<0.132	<0.132
Methylparathion (μg/l)	<0.132	<0.132
Malathion (μg/l)	<0.066	<0.066
Fenthion (μg/l)	<0.066-0.23	<0.066-0.48

Although relatively little is known about the diffused discharged to these freshwater bodies from agricultural activities. Chemicals associated with agro-chemicals and fertilizer use were found to be the main pollutants from the agricultural sector in Southern Thailand. These chemicals are absorbed by living organisms and by plants and are accumulated over time (Danteravanich et al.,2003).

Based on the water quality of Khun Thale swamp determination in this investigation, it indicates a decreasing trend in water quality problems in the Khun Thale swamp, especially area affected by the agricultural sector and industrialization. In assessing the water quality status of the Khun Thale swamp, the fourth level of water quality targets was classified, in accordance with the National Environmental Board Standards.

Ecology of Khun Thale swamp.

It is noted that Khun Thale Swamp is a very special watershed. The land surrounding the swamp is a natural green area with fruit, oil palm and rubber plantations. It is a small swamp but ecologically most complex. The swamp is a habitat for various species of water fowls. In analyzing the biodiversity, 47 genera within 3 divisions of phytoplankton and 21 genera of zooplankton were found in this swamp. 60, 44 and 41 genera of aquatic animals, plants, and birds respectively were also determined in this area.

Table 2 illustrates phytoplankton, zooplankton and benthos found in the Khun Thale swamp. It illustrates that the highest density of benthos in the Khun Thale swamp is Arthropoda Phylum, such as Amphipod, Tanaidacea and Isopod. The average density of benthos was determined to be 1,421 per square meter. The highest density was observed to be 3,177 per square meter. This diversity and abundance of benthos in the Khun Thale swamp was reflected to be higher than in other fresh water areas.

For phytoplankton, it was observed that the highest density was 356×10^6 and the average density was 159×10^6 cells per m^3. The dominant phytoplankton was found with *Chlorella* spp., *Chaetoceros* spp., *Oscillatoria* spp., *Raphidiopsis* sp., *Euglena* spp., *Rhizasolenia* spp., *Minidiscus* spp., and *Diatom* spp. The zooplankton was determined with the density ranging of 1.22×10^6 - $47.89 \times 10^6/m^3$. The dominant species were *Amphistaurus* sp., *Tricocerca* sp., and *Pompholyx* sp.

Khun Thale swamp includes 44 species of plants. Table 3 shown the plant species found in the Khun Thale swamp. It was determined to be 4, 5 and 35 species of submerged type, floating type, and emergent type, respectively. One of the most typical plants in the swamp is the water hyacinth (*Eichornia crassipes*, classified in Pontederiaceae family, from South America and brought to Asia around 1888). (Danteravanich et al.,2003). The International Union for the Conservation of Nature (IUCN) considers this plant as being dangerously invasive.

The water hyacinth is particularly formidable because it is not fixed to the land, and all parts of it are floating. The roots are dense and long (sometime more than 30 cm) and form a perfect spawning place for fish. It multiplies by stolons in general, but can also have seeds scattered by birds and can be viable for 15-20 years (Osei-Agyemang, 2002).

In the swamp, the water hyacinth is on stains everywhere. In general, it is gathered along the shores, particularly the south-west branch expansion where it is impossible to circulate by boat.

Table 2. Phytoplankton, zooplankton and benthos found in the Khun Thale swamp

Type	Species
Benthos	Phylum Annelida : Nereidae, Sabellidae, Spionidae, Nephtyidae Phylum Arthropoda : Tanaidacae, Amphipod, Isopoda, Decapoda, Insect Phylum Mollusca: Bivalve, Gastropod Phylum Chordata: Pisces
Phytoplankton	Division Cyanophyta: *Anabaena* sp., *Oscillatoria* spp., *Spirulina* sp., *Lyngbya* sp., *Anabaenopsis* sp., *Merismopedia* sp., *Raphidiopsis* sp., *Microcystis* sp., *Pleurotaenium* sp. Division Chlorophyta : *Chlorella* sp., *Scenedesmus* spp., *Geminella* sp., *Ulothrix* spp., *Euglen*a spp., *Elakatothrix* sp., *Pleodorina* sp., *Netrium* sp., *Treubaria* sp., *Closterium* sp., *Geminella* sp., *Phacus* sp., *Peranema* sp., *Pediastrum* sp., *Hyalotheca* spp., *Cosmarium* sp., *Tryblionella* sp., *Xanthidium* sp., *Rhizosdenia* spp., *Coscinodiscus* spp., *Cocconesis* sp. Division Chromophyta : *Haslea* sp., *Nitzschia* spp., *Achinanthidium* sp., *Minidiscus* spp., *Wolozynskai* sp., *Pleurosigma* spp., *Navicula* spp., *Diatom* spp., *Thalassionema* sp., *Chaetoceros* sp., *Crucigenia* sp., *Soenedesmus* spp., *Cyclotella* sp., *Pseudoguinarda* sp., *Synedar* sp., *Asteromphalus* sp., *Diayasphaerium* sp.
Zooplankton	Phylum Protozoa: *Undella* spp., *Bract* sp., *Tintinidum* spp., *Tintinnopsis* sp., *Cymatocylis* sp., *Amphistaurus* sp., *Xystonella* sp., *Globigenrinita* sp., *Ascomonoha* sp., *Trichocerca* sp., *Codonella* spp., *Rhabdonella* sp. Phylum Rotifera : *Pompholyx* sp., *Monommata* sp. Phylum Arthropoda : *Alonella* sp., *Oithona* spp., *Copepods* sp., *Paracalanus* sp., *Simocephalus* sp., *Nauplius* sp., *Tigriopus* sp.

Table 3. Plants and birds found in Khun Thale swamp.

Type	Species
Plants	*Cyperros difformis, Hangvana malayana, Elaeocarpus rugosus, Eulipta prostatal, Pistea stratiote, Salvinia cucullata, Nipa Fruticans, Baringtonia acugangula, Caryota mitis, Ficus benjamina, Erythrina fusca, Aesculus assamica, Colocasia spp., Nymphaea lotus, Acrostichum aureum, Guettarda speciosa, Ceratopteris thalictroides, Eichornia crassipes, Enydra fluctuans, Altermanthera philoxeroides, Horsfieldia irya, Thespesia populnea, Vernonia willichii, Dendrolobium triangulars, Shorea siamensis, Neonaclea sessilifolia, Sonneratia caseolaris, Stenochlaena palustris, Llygodium polystachyum, Maranta arundinacea, Utricularia aurea, Chara zeylanica, Hydilla verticillata, Melaleue leucadendra, Sesbania javaica, Brachiaria mutica, Leersia hexandra, Areca catechu, Daemonorops angustifolia, Flagellaria indica, Acanthus ebracteatus, Oncosperma tigillaria, Lemna trisulca, Ocoix aquatica*
Birds	*Nettapus coromandelianus, Dendrocygna javanica, Passer flaveolus, Orthotomus atrogularis, Orthotomus sutorius, Prinia flaviventris, Vanellus indicus, Centropus bengalensis, Centropus scinensis, Amauromis phoenicurus, Halcyon capensis, Haicyon smymensis, Upupa epops, Copsychus malabaricus, Copsychus saularis, Phalacrocorax niger, Phalacrocorax maculates, Anthreptes malacensis, Stachyris rufifrons, Streptoppelia chinensis, Chloropsis cyanopogon, Calyptomena viridis, Strix leptogrammica, Merops viridis, Nyctyornis amictus, Dicrurus aeneus, Dicrurus remifer, Caprimulgus macrurus, Ketupa zeylonensis, Metopidius indicus, Ardeola bacchus, Bubulcus ibis, Egretta alba, Lxobrychus cinnamomeus, Loriculus vermalis, Meiglyptes tristis, Cceleus brachyurus, Chrysocolaptes lucidus, Rallus striatus, Prophyrio prophyrio, Hydrophasianus chirusgus*

A floating plant, it invades areas easily, its roots absorbing dissolved mineral in water.

Sunlight is used by plant leaves to produce energy.

It is particularly invasive in the Khun Thale swamp, and according to the people living on the swamp's shores and the local authorities, it has increased a lot during these past five years. The high spread of water hyacinth in the swamp can be easily seen. This can be easily seen from the remote sensing pictures of the swamp taken in 2000 and 2005. This promotes the sedimentation of the swamp. The swamp is the primary producer of the Tapi catchment. It acts as a transition area between the fresh water from the Tapi River and the estuary environment. The significance of the swamp as a bird sanctuary and fishery are also well recognized. The 14 types of bird species are found in the swamp (Table 3).

Table 4 illustrates the aquatic animals found in the swamp. Many commercially important fishes, crabs, prawns and various kinds of mollusks use this swamp as nursery grounds and shelter during their juvenile stages.

Sustainability deficits illustrated.

Sustainable development of the Khun Thale Swamp and its' environmental problems are not much recognized by the provincial officers, local authorities and local people. The swamp is a high potential development place in Surat Thani province. It could be developed as a tourist area, bio-diversity and fresh aqua-culture conservation area. At present, there are many governmental agencies in Surat Thani dealing with the swamp's development, but it lacks the organization directly responsible for the overall environment in parallel with physical development. It can also be noted that there is no specific organi-zation responsible for the environmental manage-ment of the Khun Thale watershed in Surat Thani.

Table 4. Aquatic animals found in Khun Thale swamp.

Type	Species
Aquatic animals	**Fishes :** *Channa striatus, Channa micropeltes, Mystus nemurus, Mustus bocourti, Mustus vittatus, Clarias batrachus, Clarias macrocephalus, Labeo erthrurus, Pangasius sutchi, Pangasinodon gigas, Labeo lohita, Probarbus jullieni, Tilapia nilotica, Barbonemus gonionotus, Barbonemus orphoides, Barbonemus altus, Barbonemus schwanenfeldii Branchydanio kerrii, Rasbolar trilineata, Scatophagus argus, Heterpneustes fossilis, Labiobarbus lineatus, Batrachus grunniens, Kriptopterus apogon, Kriptoterus bicirrhis, Notopterus chitara, Chelonodon spp., Monocanthus sp., Dermogenus pusillus, Xenentodon cancila, Toxotes chatareus, Trichogaster microlepis, Trichogaster trichopterus, Trichogaster pecteralis, Osphronemus goramy, Anabus testudineus, Pristolepis fasciata, Oxyeleotris mamoratus, Mugill spp., Labeo bicolor, Monopterus albus, Parachela sp., Rasbora lateristriata, Esomus metallicus, Puntioplites proctozysron, Macrognathus siamensis, Mastacembelus erythrotacnia, Betta spiendens, Trichopsis vittatus, Osteochilus melanopleurus, Hypoatherina valencierinel* **Crabs and prawns:** *Macrobrachium rosenbergii, Macrobrachium spp., Macrobrachium lanchesteri, Esanthelphusa spp., Scylla serrata* **Molluscs:** *Pomacea canaliculata, Pila ampullaceal, Sinotaia ingallsiana, Radix rubiginosa*

Water is vital for the life and health of the people and ecosystems and a basic requirement for the development of the region. However, as evidenced by the Khun Thale example, this principle is jeopardized by various deficits in sustainable

water management. Those are non-point and point sources contamination which 1) are a possible health risk from water used which chemicals contaminated from agriculture and fishery activities in the watershed and in the swamp, 2) cause accelerating eutrophication and sedimentation in the swamp due to discharge of nutrients from industrial, domestic and agricultural sources, as well as erosion from the high hills in the watershed caused by agricultural and urbanization development, 3) cause reduced biodiversity in the swamp and reduced areas of species-rich wetland and marshlands of the swamp caused by the loss of riparian and in-stream ecological habitats due to development and stabilization of waterways and riparian zones. Some of these deficits appear to be becoming more wide-spread. It also reveals that there is no universal agreement on the specific definitions and goals of sustainability. Goals such as safeguarding biodiversity or quality control in swamp water appear to be weighted quite differently, depending on the local interests of the relevant decision-makers in the watershed. This particular local water resource is exploited to its limits because local development has not yet been restricted. Due to urbanization, industrialization and agriculture growth, the number of people affected will increase significantly in the years to come. The discharge of untreated or insufficiently treated wastewater along the canals connected to the swamp and in the swamp itself makes water quality often unsuitable for consumption without proper treatment technology. Where neither alternative water sources from more pristine areas nor the technological and financial possibilities for water treatment are available, the health of people is at risk. It is also to be noted that the lack of enforcement of existing regulations and competing interests between the government and local people around the swamp watershed are further allowing the deterioration of this local water resource. Inappropriate water management, not only impacts current water quality, but also can impede future attempts to restore sustainable use of the local resources (Walter et al.,2002).

It is evident from the Khun Thale swamp that a major loss of riparian and in swamp ecological habitat is still experienced, resulting from structural change in the natural water system. Sustainable watershed management implies the need for the preservation of ecological integrity in riparian and swamp habitats, thus promoting natural biodiversity. This ecological aspect is being increasingly recognized as an important element of sustainable water management and is included in strategies of international water policy (World Water Council, 2000). Therefore, measures to stop or even to reverse the trend of Khun Thale swamp watershed are politically and financially difficult to implement. For example, more urbanization development is still continuous occurring along the shore of the swamp. It damages the area by expanding the inland area into the swamp area. This affects the swamp structure and its ecosystem. The swamp system has suffered loss of quality and quantity due to more sedimentation and potential change of biotic resources. This clearly supports the need for integrated water resource management, taking into account social, economic and environmental factors.

Need and guidelines for the future.

Common problems in the Khun Thale swamp watershed suggest the need of sustainable management of the swamp. Urbanization, industrialization, and agriculture growth and tourism development as experienced in the Khun Thale watershed in the past are clearly accompanied by a decrease in water quality

and its natural structure system. In the watershed, human activities have impacted from the water quality. The primary factors affecting water quality are the use of fertilizers and pesticides for agriculture and domestic and industrial wastewater discharge direct or indirect into the swamp. The lessons learned from many watersheds could help to develop more favorable strategies for the Khun Thale swamp to prevent it from following the same pattern.

A strict preservation of natural water quality is not currently feasible in either industrialized, urbanized, agriculture, or tourism activities in the Khun Thale watershed, since welfare and prosperity are strongly dependent on water use. However, such past development teaches us that neglecting environmental aspects is short-sighted. Sustainability of the watershed is limited by its own environmental effects, and the measures usually taken to overcome such limitations (Walter et al.,2002).

All of us know that socio-economic development —urbanization and industrialization — must go on, and in most cities where poverty alleviation is still the top priority, at ever increasing rates. More pollution will inevitably be produced. Current water quality problems in the Khun Thale swamp are recognized to be of natural as well as anthropogenic origin. Seasonal flooding and erosion threats to water quality are of natural origin. Domestic wastewater; crop residues, fertilizers and pesticides from agricultural lands; runoff and discharge from industries are anthropogenic pollution sources. However, these problems should be resolved to guarantee a secure supply of fresh water for all and should include: preserving water quality, ensuring that there are sufficient quantities of water available, ensuring that water is sustainably used, and ensuring that water resources are managed equitably so that water can be shared fairly between different uses.

In order to solve the problem of toxic or chemical pollution of water environment successfully, many alternative are needs, approaches including human resource development, know-how/technology, and participation. All other factors, consistent with integrated implementation by all persons dealing with pollution control and prevention are very important.

Water pollution problems in the Khun Thale swamp are reversible provided that appropriated measures are applied to control pollution sources. The mission is in fact possible provided that the government is willing to protect our water resources and keep them in good shape for future generations. Immediate and long-term measures are proposed for practical implementation. Water recognition should be centered on social-impact-related issues. Integrated management of not only the Khun Thale swamp but also the Tapi river catchment is strongly recommended (Kongnakorn and Danteravanich, 2004).

Future concepts for sustainable water management can therefore not exclusively aim only at protecting the Khun Thale water resource. Such concepts must rather consider all legitimate water uses in the most optimal way. Various vectors can be derived which need to be respected to process towards a more sustainable water management for the Khun Thale watershed. Those are minimization of change in the natural water cycle. The examples of this are to reduce natural system loss, reduce inter-basin water pollution, and minimize water demand in households, industry and agriculture. Increase of the potential to sustain/restore natural biodiversity in the Khun Thale swamp should be included and this can be performed by increased structural diversity, restore natural or close to natural flow dynamics as well as the connectivity of the

water system. Reduction of point and non-point source pollution is strongly conducted by implement cleaner technologies, improved wastewater treatment, a decrease in the use of chemicals and fertilizers in agriculture, improved management of polluted soils and sediments and minimized up stream pollutant inputs of the Tapi River. In addition, an increase in community involvement and social participation in the watershed will be done. This concept also covers the improvement of environmental education and increases the involvement of environmental NGOs, local stakeholders and residents. To lead development on a path along these vectors, a series of preconditions need to be ensured in the watershed. Those are the establishment of precautionary principles in the Khun Thale watershed policy, the establishment of an economic system fostering sustainable water use, the establishment of effective governance on the Khun Thale watershed scale, involving the local stakeholders and integrated into all relevant aspects such as hydrology, ecology, urban and industrial water management, agriculture and waste management. Water can therefore not only be treated as an economic good, but its cultural and social value must also be respected and taken into account. The design and implementation of management measures however are fostered by subsidiary decision-making and democracy (Walter et al., 2002).

The trade-offs in local treatment and disposal appear to be a knowledge gap that, if bridged, would assist the architects of future sustainable water management plans of the watershed. Cooperation among existing agencies is necessary for environmental management and development processes. To upgrade and sustain the environment of the Khun Thale watershed, the initiative will focus on boosting the local agencies' ability to respond to environment in parallel with development. It will strengthen the local agencies' ability to monitor environment and support partnerships with other agencies, municipalities, universities and local groups by financing joint environmental and development projects, for example. Public awareness campaigns will also be undertaken. In addition, public and local authorities should be requested to participate in protecting the Khun Thale's environment. The local governmental agencies, and regional technical environmental offices in Surat Thani should increase cooperation to create and coordinate an action agenda to incorporate the needs of environmental/ resource quality and stability in addition to economic interests of the Khun Thale swamp.

Conclusions

The pollutants discharged in the Khun Thale swamp is the first priority to be considered. The pollution sources of the swamp, mainly agriculture, industries and domestic areas are an important part in the destruction of this swamp. Sustainable development of this swamp can be possible only after a decrease in the pollutants discharged into the canals and swamp. This can be possible with an information campaign about the harmful effects of the pollution on the environment for the population concerned. In addition, the use of sustainable management of the Khun Thale watershed should be strongly applied in the management plan of the area.

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