LITERATURE REVIEW

Wetland

Wetlands are among the most important ecosystems on Earth. They spread out through most climatic parts of the world, from tropics to tundra. About 1970s It was estimated that wetlands occupied about 6 million km^2 (Neushul, 1974), but at the present time, with more precise method it was estimated to be more than 6 percent of the land surface of the world, or about to 8.6 million km^2. (Mitsch and Gosselink, 1993)

Since early civilization many cultures have learned to live in harmony with wetlands and have benefited economically from surrounding wetlands, whereas other cultures quickly drained the landscape. There are many well-known places which is, in fact, the site of wetlands or lakes that disappeared as a result of human influence, for example, Mexico City, Chicago, Washington D.C. (Mitsch and Gosselink, 1993)

There are many different attitudes of people in general toward natural wetlands. To some people, wetlands are just places of unpleasant waterlogged areas providing shelters for diseases and their vectors. To others, wetlands can be places providing different benefits, such as, food source, flooding barriers and water supplies, as well as their esthetic values can also be quite impressive. Table 1 shows list of natural functions of wetlands.

Table 1. Natural function of wetlands. (Denny, 1997)

Climatic effects	*Habitat functions*
Global warming amelioration	Water supply
Carbon fixation and CO_2 balance	Wildlife habitats and refugee
Rainfall and humidity improvement	Ecotone habitat diversity
Micro-climate influences	Biodiversity conservation
Biodiversity functions	*Hydrological and hydraulic functions*
Landscape and ecosystem diversity	Erosion protection and flood defenses
Ecosystems transition zones	Catchment dynamics
Centers of endemism	sponge effects, stream flow,
Population and genetic diversity	groundwater recharge, etc.
Diverse microbiological activities	Floodplain hydrodynamics
Water quality functions - water quality improvements	
Particulate filtration	
Nutrient stripping	
Biodegradation of toxic compounds	
Human pathogen reductions	
Heavy metal stripping and accumulation	
Wastewater treatment	

Wetland ecology

Wetland ecosystems are rarely drought and often receive supplementary nutrient in'puts. It is not surprising that the world's most productive wild vegetation is reedswamp. (Etherington, 1983) Wetland soil are hostile to roots and the plants which are able to survive in them are herbaceous, mostly monocotyledons lacking secondary thickening. This lack is significant as it prevents the plants from accumulating non-photosynthesizing, respiring tissue, thus a given biomass of leaf canopy in the wetland environment is likely to have a higher net productivity than the same canopy in a terrestrial habitat where large volumes of secondary tissue have usually occurred. (Etherington, 1983)

Wetlands also have considerable ability to 'sink' pollutants of all kinds including nitrogen and phosphorus from sewage and agricultural drainage, heavy metals and artificial products such as chlorinated hydrocarbons. (Etherington, 1983)

Wetland identification and characteristics

There is a need to recognize a variety of wetlands to ensure correct management and to comply with federal statues and regulations. However, posing characteristics of both upland and aquatic environments and exhibit a mix of soil, plant, and hydrological conditions, makes wetlands to be quite difficult for their identification. Definition of wetlands is then varied with different purposes and different fields of work. There are a variety of formal wetland definitions worldwide. (Lyon, 1993)

There are also some confusion about terminology of wetlands. The term " wetland" is relatively new describing the landscape that many people knew before under different names. In general, wetlands are lands where saturation with the water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. (Vymazal, 1995) However, being used widely for wastewater treatment purpose, the term "wetland" assimilated more types of landscapes, especially constructed wetlands.

Wetland function in wastewater treatment

Many wetlands are open systems that receive inputs of organic matter, nutrients, metals, and toxic organic compounds from adjacent agricultural watersheds, industrial and urban areas. While many wetlands are sensitive to these contaminants, others are capable of attenuating pollutants. Differences between wetland systems are largely due to differences in physical, chemical, and biological conditions that affect transformations and transport processes and treatment efficiency in the soil-water-plant system. While individual fate processes are known, little is known about how processes are influenced by diverse conditions in wetlands, and conversely, how pollutants influence the functioning of wetlands. Evaluation for pollutant removal efficiency has considerable merit when wetland are intentionally used for pollutant abatement. (Reddy and Angelo, 1997) However, pollutant impacts on wetlands are a serious concern because of associated eutrophication problems and resulting adverse effects on the overall value and functioning of wetlands.

Careful management of natural wetlands can often improve their water purification: simple hydraulic and biological manipulation may be sufficient. But first, the functions and values of wetland need to be assessed and prioritized. The most valuable wetlands in term of their biodiversity require the strictest protection and are inappropriate for the receipt of wastewater, but others can be used in such a way that the functions of water purification are managed; input loads regulated and multi-purpose sustainable utilization (e.g. for swamp fisheries, biomass production, seasonal agriculture, water supply and nature conservation) is optimized. (Denny, 1997)

Aquatic plant

Aquatic plants can be divided into three main types : emergent, floating and submerged (Le Thi Van Ann, 1997.) Emergent aquatic plants produce root system in submerged substrate and project aerial parts above water surface. Their dominant life-form are in wetlands and marshes with water depth ranging from 50 cm to 150 cm. The typical species are common reed, cat-tail, and bulrush. Floating aquatic plants are free floating with well-developed submerged root system hang in water. This type is highly diverse in form and habit. The typical species are water hyacinth, duckweed, pennyworth, and water ferns. The last one, submergent aquatic plants grow entirely below water surface and require good condition of light intensity. Many of emergent species have been selected as being potentially suitable for wastewater treatment due to their hard stem and being well- resistant to both pests and diseases (Gray, 1989.)

Aquatic vascular plants (hydrophytes) are of limited economic value in the modern world. Their benefit to man now resides mainly in wildlife conservation practices, where they provide food for water fowl and other animals and protection for spawning fish, and in horticulture, as purely ornamental plants. Their aesthetic and material significance to the people of the Orient, the Near East and the early European civilizations is vividly revealed in Sanskrit, Chinese, Greek and Roman literature and in the appearance of numerous species as motifs in ancient architecture, painting, pottery and metalwork. (Sculthorpe, 1967) Although the nutritional and medicinal importance of most hydrophytes has subsequently declined, their aesthetic value has achieved renewed recognition in the last hundred years.

Aquatic plant biology in wetland

Plants can suffer from too much water in the soil, as well as too little, owing to the lack of air in the soil pores. However, despite the lack of oxygen and the often low nutritional status of waterlogged soils of wetland, many species of aquatic plants are adapted to such an environment. Most of wetland plants have large intercellular air spaces which enable them to transport oxygen from the shoots to the roots. Some of this oxygen diffuses into the soil, so that an aerobic layer is formed around the roots. Aerobic organisms living in this rhizosphere oxidize ferrous ions to ferric and manganous ions to manganic, thus removing potential toxins fromthe vicinity of the root. This association reveals the example of the biological symbiosis in wetland. (Vickery, 1984)

Vegetation in wetlands distributes and reduces the current velocities of the water creating better conditions for sedimentation of suspended solids. This can also reduces the risk of erosion and resuspension, and increases the contact time between water and the plant surface areas. The macrophytes (larger hydrophytes) are also important for stabilizing the soil surface in treatment wetlands, as their dense root systems impede the formation of erosion channels. Movements of the plants as a consequence of wind, and other factors, keep the surface open, while the growth of roots within the filter medium helps decompose organic matter and prevent clogging. (Brix, 1997)

With the standing of dense wetland's vegetation, velocities are reduced near water surface reducing resuspension of settled material and thereby improves the removal of suspended solids by sedimentation. However, this factor has a drawback where such wind velocity reduction can also reduce aeration of the water column. In wetlands that have dense mat of some floating macrophytes such as water hyacinth and duckweed , light is attenuated, hindering the proportion of algae in the water below the vegetation cover. The stems and leaves of macrophytes that are submerged in the water column provide a huge surface area for biofilms. The plant tissues are colonized by dense communities of photosynthetic algae as well as by bacteria and protozoa. These biofilms are responsible for the majority of the microbial processing that occurs in wetlands. (Brix, 1997)

Table 2 is the summary of the major roles of macrophytes in treatment wetlands listed by Brix (1997.)

Table 2. Major roles of macrophytes in treatment wetlands (Brix, 1997)

Macrophyte property	Role of macrophyte in treatment process
Aerial plant tissue	• Light attenuation - reduce growth of phytoplankton • Influence on microclimate - insulation during winter • Reduced wind velocity - reduced risk of resuspension • Aesthetic pleasing appearance of system • Storage of nutrients
Plant tissue in water	• Filtering effect - filter out large debris • Reduce current velocity-increase rate of sedimentation, reduces risk of resuspension • Provide surface area for attached biolfilms • Excretion of photosynthetic oxygen - increases aerobic degradation • Uptake of nutrients

Roots and rhizomes in the sediment	• Stabilizing the sediment surface - less erosion • Prevents the medium from clogging in vertical flow system • Release of oxygen, increase degradation (and nitrification) • Uptake of nutrients • Release of antibiotics

Adaptation of aquatic plant in wastewater treatment

There are many papers about using aquatic plants for water treatment both in Europe and America. Lots of researches and studies were carried out in order to develop the efficiency of this water treatment.

In the mechanism of pollutants removal by aquatic plants, the pollutants are removed by a complex variety of physical, chemical, and biological processes (Moshiri, 1993.) Settleable and suspended solids are removed primarily in the mechanical pretreatment unit, sedimentation pond, which is usually installed in front of the actual wetland. The macrophytes remove pollutants by (1) directly assimilating and storage them into their tissue, and (2) providing surface and suitable environment for microorganisms to transform pollutants and reduce their concentrations. Oxygen transfer by aquatic plants from their leaves into the rhizosphere is also a requisite for certain microbial pollutant-removing processes to function effectively. For the aspect of physical parameter in wastewater treatment, suspended solids in the water is counted as a potential one and is related to its sedimentation in the wetland system. The principal factor affecting a wetland's ability to trap sediments is the change in the velocity or energy level of incoming water, the influent (Marble, 1992.) Decreased water velocity results in sediment deposition. The ability of a wetland to retain water is determined by: the presence of constricted outlet, gentle gradient of the basin, density of vegetation (aquatic plant community), seasonal flooding, and the depth of the actual wetland.

In 1994, Qiuheng Lou, from Chiang Mai University, studied about treatment of the piggery waste water from this Mae Hia site using a set-up three step aquatic plant system including water hyacinth being first step. Some physicco-chemical parameters used were the same to the present study and the results (only for similar parameters) were summarized here as in table 3.

Table 3. Data of former study of the same wastewater source (Lou, 1994)

Parameter	influent (mg/l)	effluent (mg/l)	% Removal
BOD_5	128-384	5-14	94
COD	201-612	63-76	76
NH_3-N	10.4-19.1	2.1-4.8	75
pH range	6.64 - 6.89		

A more recent study about this wastewater source, also using water hyacinth from this studied wetland, was carried out in 1997-1998 by ชลธี (Cholatee) from Chiang Mai University. This set up batch-experiment had put out some resulted data as summarized in table 4.

Table 4. Data of former study of the same wastewater source (ชลธี, 2541)

Parameter	influent (mg/l)	effluent (mg/l)	% Removal
NH_3-N	1261.9	160.32	87.30
NO_3-N	0.79	0.38	44.59
PO_4-P	145.71	62.86	56.86
pH range	7.0 - 9.1		

Note : These data were summarized from only the result of experiment 1, using older water hyacinth in treatment of wastewater from pig manure biogas digester.

Water quality assessment

In the routine analyses used to analyze sewage, processes to determine temperature, pH, settleable substances, chemical oxygen demand and biochemical oxygen demand are usual (Fresenius, 1988.) More comprehensive analyses of sewage also record organic substances such as oil and grease-type substances, organic solvents, phenols, detergents, cyanides, heavy metals, pesticides or other pollutants which can in particularly also inhibit chemical degradability. In water analyses, any secondary, physico-chemical or biological change to the water sample should be prevented. If such a change cannot be prevented, the changeable substances should be determined analytically on site, or fixed so that they can be recorded in the laboratory. Information should accompany the sample for the analyst conducting investigations. While carrying out water sampling for sewage, it is important to preserve samples of wastewater, particularly for determining cyanide, phenol, organic compounds and nitrogen compounds, etc.

Physicco-chemical parameter

Water Temperature (นันท์ชลี, 2541)

Water temperature can be varied by different factors: light intensity, season, air temperature, wind, latitude, geographical pattern, water depth, time, turbidity and also surrounding environment. In addition, heat resulted from biochemical reactions from microbes, animals and human can also effect the water temperature. Temperature can effect some properties of water such as the amount of oxygen dissolved in water and cycle of nutrients.

pH (นันท์ชลี, 2541)

The pH value in water or solution indicates the concentration of hydrogen ions at the measuring time which characterize the acidic or alkali state of that water or solution. In natural water source, pH of water varies between 5.0 to 9.0. There are some factors responsible for the difference of pH values in natural water sources, such as soil and rock type. For the survival of most hydrophytes, pH value should be between 7.0 to 9.2 .

BOD (biochemical oxygen demand) (นันท์ชลี, 2541)

BOD (biochemical oxygen demand) is the amount of oxygen used by bacteria in degrading organic matter under aerobic condition. In aquatic systems, the BOD associated with settleable solids in wastewater can be removed by sedimentation and anaerobic decay at the bottom of water sources. The colloidal/soluble BOD remaining in solution can be removed as a result of metabolic activity by microorganisms that are: (i) suspended in the water column, (ii) attached to the sediments, and (iii) attached to the roots and stems of aquatic plants. The microbial activity at the roots and stems of aquatic plants is the most significant for BOD removal.

COD (chemical oxygen demand)

COD (chemical oxygen demand) is used as a measure of the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. For sample from a specific source, COD can related empirically to BOD, organic carbon, or organic matter. COD in wastewater can also be removed by chemical reactions occurred under anaerobic condition.

Nitrogen

Nitrogen is one of the nutrients which can be drained into water courses and can cause some problem as eutrophication of the water. Nitrogen can be removed from wastewater by a number of mechanisms: (I) uptake by plants and subsequent harvesting of them, (ii) volatilization of ammonia, (iii) bacterial nitrification and denitrification. Among these mechanisms, bacterial nitrification and denitrification have the greatest nitrogen removal potential.

Phosphorus

Phosphorus is also one of the vital nutrients for plants which possible for being drained into watercourses. The main removal mechanisms for phosphorus in aquatic systems are plant uptake and several chemical adsorption and precipitation reactions. In general, chemical adsorption and precipitation are more significant mechanisms of removal

Surface water quality (table 5) released by the Environmental Quality Standards Division Office of the National Environment Board, Thailand, in 1989, gives some ideas about these physicco-chemical parameters as indicators for water quality.

Table 5. Surface water quality : classification and objectives

Parameter	Units	Statistic	Standard values for class				
			1	2	3	4	5
Temperature	°C	-	n	n	n	n	-
pH value	-	-	n	5-9	5-9	5-9	-
BOD (5 days, 20 °C)	mg/l	P80	n	1.5	2.0	4.0	-
NO_3-N	mg/l	Max. allowance	n	5.0	5.0	5.0	-
NH_3-N	mg/l	Max. allowance	n	0.5	0.5	0.5	-

Note - n = naturally

- These data were summarized concerning only similar parameters to the present study.

Wastewater from biogas unit

Eventhough, The effluent from biogas-digester still has even far more benefits than the biogas by being used as food source for algae and fish, and different forms of fertilizer, it is sometimes expressed regarding (a) the heavy metal content (b) disease-carrying organisms in the effluent (United Nations, 1980.) Therefore, this wastewater needs to be treated before releasing into natural waterways, and using aquatic plants is one of the economy and possibly desirable method for the developing -country.