Core University Program

**Research Report**

# Establishment of Wastewater Treatment System using Aquatic Plant

Visiting Scientist: Nguyen Thi Thuy Duong

Host Scientist: Prof. Masanori Fujita

Research period: 16 August, 1999 to 31st March, 2000

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Signature

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## 1. Introduction

In Vietnam, water pollution is a particular problem not only in cities but also in rural areas. A large proportion of urine and household wastewater is discharged untreated, resulting in water pollution in rivers, canals, and lakes. Household wastewater treatment facilities are rare, and those that do exist often do not function properly, so that the open sewage channels and underground pipes in Hanoi, Ho Chi Minh city, and other rural areas often discharged directly into water channels or rivers. Generally, soils and river water are no longer the last fate for the discharged effluent [15].

The use of constructed wetlands for wastewater treatment is emerging as a viable alternative, especially for small sized communities and isolated areas. These systems are attractive because of the low cost in terms of capital investment, operation, and maintenance. Constructed wetlands are widely researched and applied for treatment of domestic wastewater and storm run-offs in Europe, United States, and Australia, and in other many countries [44]. On the other hand, in tropical zones, such as in Vietnam where the technology may be most cost effective, little research has been done and use of the technology is still very limited. The tropical or equatorial environments have a conducive climate all year round for plant growth and enhanced microbiological activities.

The outline of this report is as follows: In the first section, the general overview of constructed wetland systems for wastewater treatment is presented. The next section is a study of using Water Lettuce (*Pistia Stratiotes)* for wastewater treatment. In the third section, Tsukuba visiting report is shown. Some thinking about the present state of science of Japan is presented next, and lastly some future research note in Vietnam is discussed.

## 2. Constructed wetland for wastewater treatment : a Review

Wetlands have been used for water purification in different parts of the world since 1950s [25]. Environment concerns over insufficiently performing individual septic systems, as well as high costs involved in the construction of sewer systems with centralized water purification have spurred investigations into the suitability of wetland ecosystems for this purpose [17]. Generally, constructed wetlands have been loaded with several types of wastewater.

Constructed wetlands are used for the treatment of municipal wastewater can be divided into three systems, according to the life of the dominating macrophytes [19]:

- Free floating system
- Submergent system
- Rooted emergent system

Free floating system such as duckweed and water hyacinth systems have been used for a long time [4]. Ducweed have a low biomass but a very high growth rate, and therefore require frequent harvesting. Their major role is through anaerobic conditions because they can remove nutrients from a thin layer (1—2cm) of water only. Water hyacinth has also to be harvested frequently but has greater potential for nutrient removal and reducing suspended particulates. Difficulties in harvesting and using water hyacinth have checked its place in constructed wetland only in pilot plants. Similarly, submerged macrophytes have a lesser role than the perennial and emergent plants. So the majority of the constructed wetlands is now based on the rooted system, in which different designs can be used: free water surface and subsurface flow system.

Free water surface constructed wetland typically consist of trenches or basins with emergent macrophytes and free water on the surface [5].

Subsurface flow system includes either horizontal or vertical flow system [5].

*Horizontal flow systems* are rectangular beds planted with emergent macrophytes and, ideally, have no water on the surface. The medium which the wastewater has to pass through horizontally may be soil or gravel.

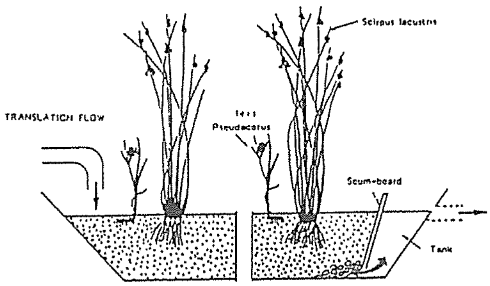


Figure 2. 1 Horizontal flow system

*Vertical flow system* is system in which the water is led onto the surface of a planted bed from where it percolates through the medium (usually fine sand) to a drainage system located in the bottom of the bed .

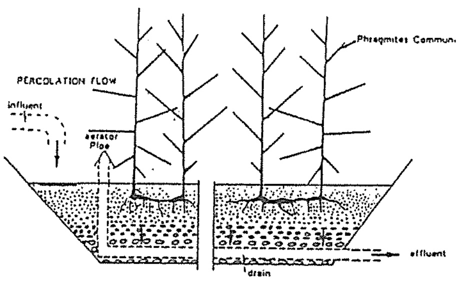


Figure 2.2 Vertical flow system

**Wastewater handling options**

Usually, constructed wetlands are applied as biological stages for mechanically pretreated wastewater, but pretreatment is not obligatory in every case. Constructed wetlands can also be used as a polishing stage after a conventional treatment plant.

The following configurations are feasible:

| | | |
|---|---|---|
| - | Constructed wetlands | - |
| - | Constructed wetlands | - |
| Mechanical pretreatment | Constructed wetlands | - |
| Mechanical pretreatment | Constructed wetlands | Polishing stage (constructed wetlands) |
| Mechanical pretreatment | Conventional biol. Treatment | Polishing stage (constructed wetlands) |

Table 2.1 shows some constructed wetlands applied in some places loaded with different wastewater.

Table 2.1. Location and sizes of constructed wetlands used to treat municipal wastewater

| Location | Design type | Wastewater type | Observation Period | Reference |
|---|---|---|---|---|
| Strengberg, Aus. | VF | Secondary | 4/95 – 5/96 | 41 |
| Montromant, France | VF | | 15 months | 4 |
| South Affrica | HF | | 1987 -1995 | 15 |
| Dhulikhel, Nepal | Hybrid | Hospital | | 23 |
| Fundacion, Colombia | HF | Secondary | 1997 (March – July) | 19 |
| Analandia, Brazil | Floating + HF | River water | 1997 (Feb. – Aug.) | 10 |
| Dar es Salaam, USA | Frre water surface +HF | Stabilization pond | 4 weeks | 7 |
| Pachuca, Mexico | Anaerobic+HF | Abattoir waste | 1 year | 13 |
| | FW | Water supply | | |
| Maryland, USA | HF | Dairy wastewater | | 26 |
| Grobbeeren, Germany | HF | Domestic | | 31 |
| Mariellhole, Germany | VF | Agriculture+ domestic | | 31 |
| Gradisce, Slovenia | HF | Industrial | 2 years | 9 |
| Czech Reb. | HF | Secondary | | 25 |
| Pima county, France | Floating | Primary, secondary | Jul- Dec 1994 | 32 |

Many constructed wetlands have been tested for their ability to retain or transform nutrient inputs from municipal wastewater, and the results showed that the removal efficiency vary with the design of the constructed wetlands.

On the basis of experience in the USA, it has been established that the purification efficiency of free water surface system loaded with less than 500 pe/ha of domestic wastewater is high for COD and BOD (90%), and for bacterial pollution (99%), but substantially lower for N and P (10-15%) [25]. The low removal of nutrients is due to the fact that the most important processes involved occur within the sediment, whereas the wastewater flows over the sediment, so that the dissolved nutrients have to penetrate through diffusion, which is a slow process. If the water levels in wetland are manipulated so that it has alternating wet and dry periods, the efficiency of N and P removal can be doubled. Moreover, there are disadvantages such as odor, and the possibility for people to come in direct contact with the waste. For these reasons, as well as an increased efficiency, the free water surface is preferred for small application such as for a single residence.

The use subsurface system has gradually developed over the past 20 years. Initially the main interest was in horizontal flow (HF) systems, because they were simple and promised low construction and operation costs.

There are many fine examples of HF systems for secondary treatment [15], and they are proved very satisfactory where the standard required only $BOD_5$ and TSS. These horizontal systems turned out to be a very appropriate technology providing stability in their efficiency with a low level operation and maintenance demand. The elimination of COD and $BOD_5$ produced no problems with the removal efficiency of 65-90%, and the effluent values do not usually exceed the limiting standards, even in cold seasons. Nutrient removal only amount to average values of 40-60% [2, 44]. Higher rates are usually prevented by a low hydraulic conductivity resulting in reduced contact time within the system on the one hand, and by an oxygenation deficiency in the root zone on the other hand [18]. Very high elimination efficiencies far better than 90% for BOD, COD and P are possible; similarly for elimination of N, when loading rates are below 20mm/d, or the area is larger than 10m$^2$/pe [29, 44]. The denitrification is complete generally, whereas nitrification seems to be limiting.

There has been a growing interest in achieving fully-nitrified effluents. As a result of this, there has been a growing interest over the past 10 years in vertical flow (VF) system.

VF systems are good for nitrification because of their high oxygen transfer capability which also leads to good removal of BOD and COD, and they are considerably smaller (1-2 m$^2$/pe) than the HF systems (which need 5-10 m$^2$/pe for secondary treatment). However they are not effective in suspended solid removal and can become clogged if the sand selection is not correct [32].

Even more recently over the past 5 years, there has been a growing interest in hybrid systems (also called combined systems). In these systems, the advantages, and disadvantages of the HF systems and VF systems can be combined to complement each other. It is possible to produce an effluent low in BOD, which is fully nitrified and partly denitrified and hence has a much lower total nitrogen concentration.

There are basically two main types of hybrid systems depending on whether the HF stages or VF stages are placed at the front of the system.

The first system is that placed HF systems before VF systems [17]. The system is showed in Figure 2.3.

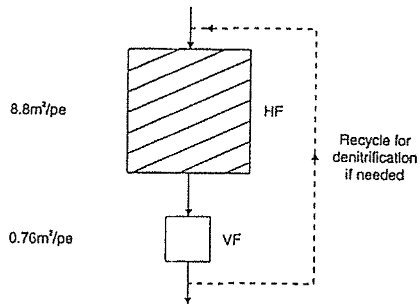


Figure 2.3. System used by Johansen and Brix (1996) and Ciupa (1995, 1996)

The paper presents the design for 55 pe with a 485m$^2$ HF bed followed by a 42m$^2$ VF bed. The idea behind the system is that BOD is removed in the HF system to prevent interference with nitrification in the VF bed. The results show that the system is achieving satisfactory $BOD_5$ (85-95%) and TSS removal (67-85%), but that the nitrification is not complete. Significant total N reduction (57-66% T-N) is taking place presumably by denitrification.

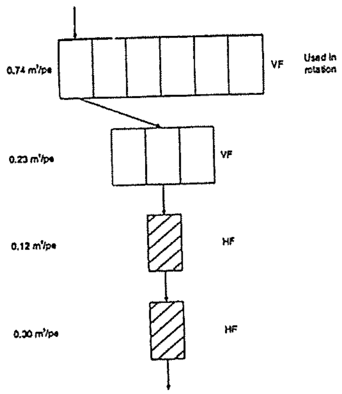


Figure 2.4. System used by Burka (1990)

The alternative arrangement with the VF stage placed first has been used in France at St Bohaire and in UK at Oakland Park [17]. The system for 65 pe contains two intermittently-loaded VF stages (63 $m^2$) in series followed by two HF stages (28 $m^2$) as shown in Figure 2.4.

The BOD and TSS removal was satisfactory in the VF stages, and significant nitrification took place in the 1st VF stage. Significant denitrification took place in HF stage despite the relative low BOD.

An alternative to the combination of VF and HF stages has been used in Austria [19]. They have used the intermittent-loaded VF stages but have incorporated a recycle to improve the nitrification and denitrification achieved. Two systems were used, one with recirculation of the effluent to settling tank at the influent. In the settling tank, the raw wastewater mixes with the nitrified effluent water, and the raw wastewater contains the necessary carbon compounds for the denitrification bacteria and the anoxic conditions exist in the settling tank. The other is two stage VF systems, in which the external carbon source (methanol) was added into the second VF with respect to the optimal C/N ratio for denirification. The system achieved 72% removal of T-N in the recirculation system and 78% for the methanol dosed system.

**Nutrient removal processes in wastewater wetlands**

As is clear from the previous section, wastewater wetlands generally perform well for COD, BOD and bacterial pollution, but show limited capacity for nutrient removal. The high removal rates for COD and BOD are caused by sedimentation of suspended solids and by rapid decomposition processes in the water and upper soil layers. As nutrient removal is often also an important objective, optimization of the nutrient removal processes should always be attempted. Knowledge of various nutrient removing processes and the conditions in which they operate optimally is a prerequisite for enhancement of the nutrient removal function [25].

Table 2.2 lists a number of important nutrient removal processes and the soil redox and soil acidity conditions in which they occur optimally. The processes leading to N removal are mostly bacterial transformations [20, 21]. Nitrification is the oxidation of ammonium to nitrate by nitrifying bacteria. This process is only operational under aerobic conditions. Denitrification is an anaerobic decomposition process in which organic matter is broken down by bacteria by using nitrate instead of oxygen as an electron acceptor [22]. The process occurs in two steps: first nitrate is reduced to nitrous oxide, which is substantially further reduced to atmospheric N. Both end products are emitted into the atmosphere. Nitrous oxide is a greenhouse gas and excessive emissions may contribute to the global warming problem. At low pH, the second step of denitrification is inhibited, so that all N is released in the form of nitrous oxide. So, the pH of wastewater wetland should remain above 6.0, so that a large percentage of the N denitrified will leave the wetland as atmospheric N.

Table 2.2 Some important nutrient removal processes operational in wastewater wetlands with the redox and pH conditions under which they occur

| | Soil redox status | | Soil base status |
|---|---|---|---|
| | Aerobic | Anaerobic | pH |
| $NO_3$ production (nitrification) | + | - | |
| $N_2O$ production (denitrification) | - | + | 6-8 |
| $N_2$ production (denitrification) | - | + | 6-8[a] |
| P adsorption to iron | + | - | <6.5 |
| P adsorption to aluminium | + | + | <6.5 |
| P adsorption to calcium | + | + | >6.5 |
| Storage in organic matter | + | ++ | |

[a] At pH<4, $N_2$ production is inhibited and $N_2O$ is the end product of the denitrification.

As the N in wastewater is mostly in a reduced state, for a removal into gaseous compounds, nitrification as well as denitrification have to occur. In many wetlands, nitrification rates are much slower than denitrification rates, so that the first process determines the actual rates of the second process as well. This means that aerobic as well as anaerobic conditions are needed for optimization of the denitrification process. This can be achieved by using large emergent plants which aerate the soil through leakage of oxygen from their root, such as *Phragmites australis* [3,22]. Another possibility is to install a water regime of alternating flooded and dry conditions, e.g. a cycle of 2-3 days of flooding followed by 4-6 days of dry conditions. Both water temperature and organic carbon availability affected denitrification rates whereas surface water dissolved oxygen and nitrogen concentration did not. Plant physical structure, waterfowl grazing pressures affected the rate litter enter the water column. Plant decomposition rates depend upon the plant $C{:}N_{litter}$ ratio and the plant fiber content. All these factors likely affected the rate bioavailable organic carbon was made available to microbial denitrifiers [21].

With the deposition of solids comes a decrease in contaminants which are associated with solids, such as phosphorus. Phosphorus removal in a wetland occurs through three parallel paths, with reaction rates of: sorption to substratum > biofilm assimilation >> macrophytes [23,24]. Adsorption of phosphates to soil particles is an important removal process. The adsorption capacity is dependent on the presense of iron, aluminium or calcium in clay minerals or bound to organic matter. Under aerobic, neutral to acidic circumstances, Fe (III) binds phosphates in stable complexes. If the soil turns anaerobic as a result of flooding, Fe (III) will be reduced to Fe (II), which will lead to less strong adsorption and release of phosphate [2]. Adsorption of phosphates to calcium only occurs under basic to neutral conditions. Apart from the reversible nature of the adsorption as soon as the soil redox or base status change, adsorption is also subject to saturation. Each soil has only a certain adsorption capacity and as soon as all adsorption sites will be occupied, no further adsorption will occur.

Apart from these fast adsorption – desorption processes, phosphates can also be precipitated with iron, aluminium and soil compounds. These processes, which include fixation of phosphate in the matrix of clay minerals and complexation of phosphates with metals, have a much slower rate but are not so easily subject to saturation. If previously adsorbed P is precipitated, the adsorption sites become available again for adsorption of new P.

Storage in accumulating organic matter is another sustainable mechanism removing N as well as P from the through-flowing wastewater. Plant-derived litter is low in N and P just after death, as the plants retranslocate part of the nutrients during senescence. The microbes decaying the litter may take up large amounts of nutrients from the aqueous environment, which will be released several months to years later. In most wetlands, part of the organic matter is broken down as such a slow rate that it accumulates along with it and this forms a significant 'removal' process in many wastewater wetlands.

The vegetation itself functions as a temporary storage of nutrients. Particularly at the start of the growing season, large quantities of nutrients are taken up by the root system. If the vegetation is not harvested, most of these nutrients will be gradually released again through leaching and organic matter mineralization. Only a small part of the nutrients taken up stays in the vegetation as additional long-term storage in aggrading wood or rhizome material [3,4].

**Pretreatment and post-treatment**

Wetlands for wastewater treatment should always be coupled with additional waste management. Several pretreatment strategies are in use and their effectiveness is of importance to the constructed wetland's performance. The accumulation of solids shortens the effective life of a constructed wetland, making solid removal a necessary pretreatment step. Upstream settling basins, lagoons, or septic tanks can remove solids and ideally release only liquid effluent for treatment within the wetlands.

**Soils**

The site of wastewater treatment wetland may be predetermined by the topography of the farm, existing structures, and land availability. Soils in the chosen area should be tested and deemed suitable to retain water before a wetland is constructed. Soil profiles can show soil type, particle size distribution, and allow classification of the soil. Hydraulic conductivity should be measured. A clay or plastic liner may be necessary in order to retain standing water and prevent contamination of ground water. In some instances, compacting the clay layer may provide sufficient water retention that the wetland's substrate will be sealed as hydric condition develop. If plastic or geo-textile are used to line the basin, a soil layer must be added to provide a plant substrate. The thicker the liner, the more expensive it is, so the addition of soil rich in bentonite may be a more practical solution.

**Plant selection**

Aquatic plants are an essential component of a wetland, and contribute to the nutrient transformation by abbeting in the physical, chemical and microbial processes besides removing nutrients for their own growth [4]. They offer mechanical resistance to the flow, and facilitate settling of suspended particulates. They improve conductance of the water through the soil as the roots grow and create spaces after their death. The plants add organic matter into water as well providing a large surface area for microbial growth. Many aquatic plants actively transport oxygen to the anaerobic layers of the soil [3], and thus help in oxidation and precipitation of heavy metals on the root surfaces [41]. The submerged macrophytes directly oxygenate the water column. The emergents and free floating shade out the water surface and prevent the algae. The algae contribute much to the wastewater purification process as the oxidation pond. The adsorption of nutrients by macrophytes varies with the species and is related to the growth under different conditions.

In constructed wetlands, plants provide a substrate and a carbon source for microbes. Wetland plants oxygenate the substrate immediately adjacent to their roots and increase the aerobic portion of an otherwiswe anaerobic zone. In addition, plants remove nutrients from the incoming wastewater during growing season. While plant nutrient uptake is usually not the major pathway of nitrogen and phosphorus removal, it has been credited with 16-75% of total N removal and 12-73% removal of total P in wastewater treatment wetlands [38].

A variety of plant species have been recommended for use in wastewater treatment wetlands. Desirable species are native, and therefore best suited to local conditions. They should have high productivity for rapid nutrient uptake, rhizome production, and colonization, and they should be easily and inexpensively obtained. Finally, in order to survive, they should be able to tolerate high nutrient inputs.

Plants may survive best if they are planted before waste enters the wetlands and then allowed to establish under wet conditions. Surrency [38] recommends planting when the wetlands are dry and adding 2.5 cm of clean water per week until the desired depth is reached. At the end of 6 or 7 weeks, the wastewater can be added. If the plants are well established, they can withstand high ammonia concentration.

Table 2.3. Some plant species to be used in wetland for the treatment of wastewater

| Common name | Latin binomial |
|---|---|
| ***Emergents*** | |
| Arrow head | *Sagittaria* spp. |
| Bulrush | *Scirpus* spp. |
| Canna lily | *Canna flacida* |
| Cattail | *Typha* spp. |
| Elephant ear | *Colocasia esculenta* |
| Giant bulrush | *Scirpus californicus* |
| Giant cutgrass | *Zizanopsis milacea* |
| Iris | *Iris versicolor, I. Pseudacorus* |
| Maidencane | *Panicum hemitomom* |
| Pickrelweed | *Pontederia cordata* |
| Plaintain | *Alisma* spp. |
| Giant reed | *Phragmites australis* |
| Rush | *Juncus* spp., *Cyperus* spp., *Eleocharis* spp. |
| Water chesnut | *Eleocharis dulcis* |
| ***Submergent*** | |
| Coontail | *Ceratophyllum demersum* |
| Naaid | *Najas* spp. |
| Pondweed | *Potamogeton* spp. |
| Water weed | *Elodea canadensis* |
| Wild celery | *Valisneria americana* |
| ***Floating*** | |
| Big duckweed | *Spirodellla punctata* |
| Duckweed | *Lemna* spp. |
| Rooted floating leaves | |
| American water lily | *Nelumbo lutea* |
| Gentian | *Nymphoid* spp. |
| Water lily | *Nymphea* spp. |

There have been some studies to compare the removal efficiency of plants for treating wastewater [30, 3, 5]

**Conclusion and recommendation**

Properly designed, constructed, and maintained, constructed wetlands can effectively reduce or eliminate contaminants loads to downstream waters. Constructed wetlands are relatively inexpensive and easy to construct and maintain.

However, constructed wetlands may not be an ideal best management practice on every place. A definitive design does not exist, so wetlands may have to be altered after construction.

Adjustments may have to be made to correct construction problems or to compensate for management changes. Constructed wetlands may not effectively remove pollution immediately after construction. A period of time in which the plant and microbial communities become established may be necessary before removal rates reach acceptable levels.

### 3. Water lettuce for wastewater treatment

Oxidation ponds are widely used wastewater treatment method, particularly for small communities and in hot climate. A serious draw back associated with oxidation ponds, however, is the growth of algae induced by intense solar radiation. In hot climates, the solar radiation is sufficiently intense all year around to induce high algae concentrations in the effluent. This reduces treatment efficiently, particularly with respect to the suspended solids concentration. Implanting macrophytes appears to be an attractive alternative option. Water lettuce (*Pistia stratiotes*), a kind of floating aquatic plant with the growth rate slightly higher in dry seasons compared with Water Hiacynth, can improve the effluent quality of ponds at negligible additional cost and without sacrificing the operational simplicity of a pond system, which is one of its main advantages.

The objective of this study is to compare the removal efficiency of oxidation pond and the pond implanted with Water lettuce.

### Experiment Conditions

The experiment was conducted at green house in batch system. The system consists of 2 plastic vessels (30*30*10cm$^3$), with surface area of 0.09m$^2$, one (P vessel) with Water Lettuce, and one (C vessel) without Water Lettuce as oxidation pond. The source of influent is sewage collected from Wastewater Treatment Plant. Light intensity is from 6000 to 8000 Lux, and ambient temperature varies from 16 to 22$^{o}$C.

Wet weight of plant was measured after leaving 5 min to separate water. T-N, $NH_4$-N, T-P were measured according to Japanese Standard method, 1985. TOC was measured by Shumadzu TOC 5000A. Total bacteria was counted on LB medium. DO, pH, and temperature were measured daily.

### Results and Discussions

#### *Plant growth*

The initial water lettuce stocking covered about 20% of the vessel surface. The extension of the canopy increased at an exponential rate until 75% of the pond surface was covered. The extension of the canopy was then increasingly restricted by the vessel boundaries. During this phase plant growth results in the densification of the canopy slows down. The root length of water lettuce at the end of the experiment is longer, it was due to the decreasing nutrient concentration.

#### *Effluent quality*

Comparing the effluent of the oxidation vessel and water lettuce vessel, the difference was visually very significant. The effluent of the oxidation vessel was slightly turbid and green, indicating high algae content. In contrast, the effluent of the water lettuce vessel was fairly clear, distinguishable from tap water only by the presence of some small flocks.

T-N was reduced in both systems (Figure 3.1), but at a considerable higher rate in the water lettuce vessel. The median concentration in the oxidation and in the water lettuce vessels fell from 42 mg/l to 19 mg/l and 10mg/l, respectively. $NH_4$-N showed the same trend (Figure 3.2), from 32 mg/l to 9mg/l in oxidation vessel, and 3 mg/l in water lettuce vessel.

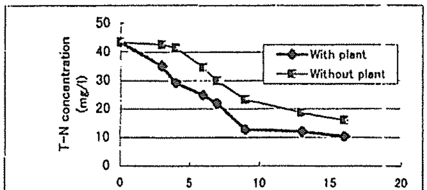

Figure 1. T-N change in ponds

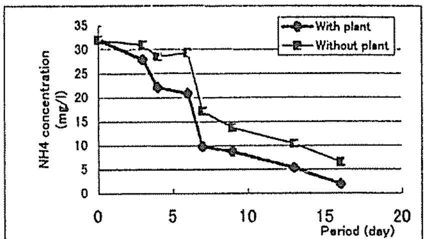

Figure 2 NH4 change in ponds

TOC concentrations decrease from 130 mg/l to 94 mg/l in oxidation vessel, and to 67 mg/l in water lettuce vessel (Figure 3.3). T-P reduction occurred in both vessels (Figure 3.4), but removal efficiency was higher in oxidation vessel.

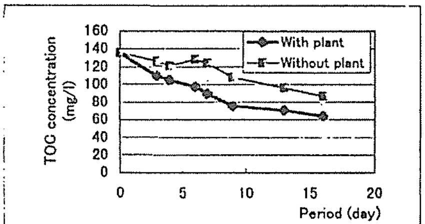

Figure 4. TOC change

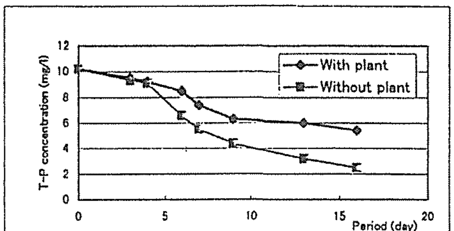

Figure 4. T-P concentration change

Bacteria removal efficiency reached high values in both vessels but a little higher in water lettuce vessel (Figure 3.5).

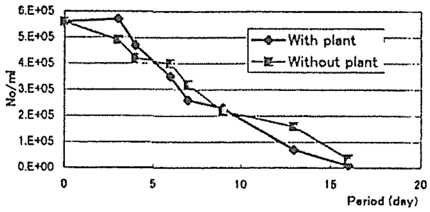

Figure 5. Bacteria change

The pH values for both systems show only moderate fluctuations and remained in the range of 6.6 to 7.4. The pH value increased slightly in the oxidation vessel and decreased in the water hyacinth vessel. The DO concentration increased in both ponds but at much higher rate, of course, in oxidation vessel. A maximum value of 9.7 mg/l was observed in the oxidation vessel, compared with 3.1 mg/l in water lettuce.

It can be concluded that the water lettuce showed in all measured parameters a much higher effluent quality than the oxidation, the exception being DO and T-P concentrations.

## Conclusion

The most critical effluent parameter for oxidation ponds with respect to common effluent standards is the high concentration of algae. The Water Lettuce vessel was considerably more effective in the removal of T-N, $NH_4$-N, TOC. The study, operating a water lettuce vessel and an oxidation vessel in parallel, fully confirmed the efficiency of this approach. Implanting water lettuce will in many cases help to avoid the transition to technical treatment plants when more stringent effluent standards are imposed, particularly in a country like Vietnam.

## 4. National Agricultural Research Center Visiting

Quality Control Laboratory, Department of Soils and Fertilizers

***Recycling System for domestic wastewater treatment using plants***

Subsurface horizontal flow system.

The domestic wastewater was treated in the joint anaerobic/ aerobic treatment plant and then the water was introduced to the adjustment tank. Then, the water was supplied to the bio-geofilter (BGF) ditches (useful plant ditch and flowering plant ditch). The ditches were constructed in a vinyl house without a heater and were arranged as shown in Figure 4.1.

The useful plants were replaced with new ones when they lost most of their nutrient absorbing function after they had flowered and fruited.

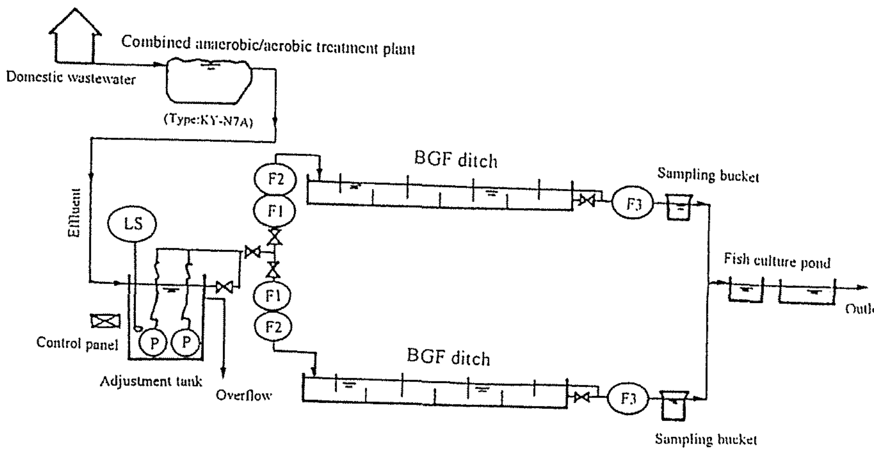


Figure 4.1. Resource-recycling system for wastewater purification combining a treatment plant and BGF ditches

The family in which the verification plant of BGF ditches was established for the system's commercialization has changed their entire lifestyle and has paid much attention to the cycle of resources; for example, they voluntarily stopped the use of chemical pollutants, such as bleach and synthetic detergents. Because of this, the water from their BGF ditches is very clear and has no bad odor. In the fish culture pond to which the water is fed, fishes like killifish, loach and goldfish are breeding and dragonfly larvae and frogs have built their habitat, creating an ecosystem like one of a natural pond. The family eat tomato, taro, water convolvulus, radish... grown in the ditches and enjoy a herb bath using the herbs harvested from the ditches.

**River reclamation**

Surface free system

River water was pumped to the settling tank and then introduced to the ditches with the size of 0.4 x 0.4 x 6 $m^3$ (depth x width x length). The ditches were packed with zeolite as substrate for flower plants. This system was operated as surface free system.

The surface free system is simple construction, the nutrient removal was mainly due to plant uptake, however there are some disadvantages that because of the intensive light the algae bloom and this leads to the bad odor and the decreasing of water quality.

**Bio-park**

Bio-park is a purification facility of eutrophic lake water using hydroponic culture of pak-bung and cress, and flowers such as forget-me not and lossestrife. In the facility, approximately 10,000 tons per day of water is pumped up, and pass through the root system of cultivated vegetables and flowers.

The vegetables and flowers are harvested. These aquatic plants absorb nutrients from the mud and roots are taken up from the water and then dried to provide compost having a high fertilizer effect. The water become clean by decrease the phytoplankton and nutrients, and the clean water is discharged into the port.

The removal ratio at the Bio-park is approximately 60% by chlorophyll concentration. The removal ratio of nitrogen and phosphorus is around 20 to 40% and depending on the growth rate of plants. Nine kinds of aquatic plants had been selected from the viewpoints of (1) thin roots and wide spreading for easy catching of planktons, (2) grow faster, and absorb well nitrogen and phosphorus as nutrients, and (3) grow easily in the shallow water flowing parts and are suited to the facility's structure. These nine kinds are for decorative use and can serve as food. These are Pak-Bung (*Convolvulaceae*), Cress (*Cruciferae*), Dropwort (*Umbelliferae*), Water feather (*Haloragaceae*), Lossestrife (*Lythraceae*), Mint (*Labiatae*), Great waterrush (*Cyperaceae*), Lousiana Iris (*Iridaceae*), and Forget-me-not (*Boraginaceae*).

This facility provides people with the places for environmental education and nature observation. Moreover, it can provide aquatic plants for decoration and food, and also compost made from aquatic plants for fertilizer.

**5. Some thinking of Japanese science**

In my mind, Japan is a country of modern industrialized with famous brand name such as Honda, Sony, Kubota... However, in this report I would like to write about my impression of Japanese agriculture science, the impressions when I visited National Agriculture Research Center in Tsukuba.

In this trip, I have visited Quality Control Laboratory, Department of Soils and Fertilizer. Here, studies of using plants for resource recycling have been conducted. This method is very suitable in remote and rural areas for decreasing pollution in water source. The research topics here are not only basic, theoretical, but also practical.

Besides, knowledge needed to solve technical agricultural problems for developing new technology for high income and sustainable farming on paddy field have been studied. In addition, demand of agricultural products of Japanese nation by advancing new pre- and post harvest technologies are expanded. Many modern technologies are studied, thereby contributing to breakthrough a bottleneck for Japanese agriculture and rural communities.

Now the picture of Japan in my mind not only a modern industrialized country, but also a country with a modern agriculture.

## 6. Future research note

Simple construction, large buffering capacity, little excess sludge production, simple operation, and maintenance costs are the advantages of constructed wetlands. On the other hand, it is important to include the function of resource recycling in wastewater treatment systems, for the nitrogen and phosphorus contained in wastewater to promote nutrient cycling in rural areas. With the tropical climate all year round for plant growth and enhanced microbiological activities, study on using aquatic plants for wastewater is a suitable method for solving the pollution in river, lakes, and canals, as well as in rural areas in Vietnam.

Studies on screening the plants, choosing suitable substrate, as well as constructed wetland design, operation, suitable pretreatment method for maximizing pollutant removing efficiency as well as recycling the resource of wastewater in Vietnam condition should be conducted for decreasing the pollution in water source.


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