leachates, mine drainage, and industrial wastewater. Since constructed wetlands offer cost-effective treatment potential, use of this type of natural systems replacing traditional mechanical ones for wastewater treatments become more and more prevailing in Europe, America, Australia, and Mainland China. Due to lack of suitable lands for constructed wetlands, in Taiwan, there are no authorities, including government and private companies, considering to use constructed wetlands to treat their wastewater. However, owning to the same reasons, more and more industrial parks will be developed through land reclaim by dredging in the coastal areas of Taiwan. Hence, the problems of lack of lands will be solved. Therefore, we can consider using constructed wetlands as advanced treatment systems for the wastewater produced from those coastal industries. Due to the lack of fresh water resources in coastal zones, the effluents from wetlands might be recycled and reused in the water supply systems of coastal industries to sustain the water resources. Thus, the feasibility of using the effluents from constructed wetlands treating partially treated industrial wastewater as recirculated and reused water for those industries located in coastal zones was studied (Yang, 2000). In the meanwhile, the complement between constructed wetlands and ecological conservation will also be studied.

In Yang's study (2000), based on the results achieved in the first year's study that used lab-scale constructed wetlands to test, we discussed the treatment efficiencies of oil-refinery industry wastewater by pilot-scale constructed wetland. The purpose this study is to decrease certain pollutants in the effluents investigate the feasibility of water reuse and recovering. The constructed wetland was a free water surface system (FWS) filled with the sandy media, while was planted with *Phragmites communis*. The flow rate of inflow for the treatment wetland was controlled at 330 mL / min. As a result, orthophosphate (PO_4^--P) and TSS were reduced over 80% . Also, TP, COD, NH_3 and TKN were reduced above 60 % .Oil and grease were reduced about 20% . However, the removal efficiencies of nitrite (NO_2^-) and nitrate (NO_3^-) were poor.

Constructed Wetlands Applied in Sewage Treatment

In the study by Kuo (2000), constructed wetland was built next to a secondary wastewater treatment plant in the National Pingtung University of Science and Technology to polish the effluent intended for water reclamation. Three units of the same dimension (L×W×H) 10m×3m×1.2m were built, with three different media: air-cooled blast furnace slag, rocks, and artificial fiber media. The Hydraulic Retention Times (HRTs) tested were 1/6 day, 1 day, 3 days, and 5 days. The Organic Loading Rates (OLRs) tested dependent on the influent concentrations of BOD_5 or COD, was found to between.

In the overall performances in slag filter bed and rock filter bed, removal efficiencies of the Suspended Solids (SS) were 64%±17(n=24) and 53%±26(n=24); Total-COD were 31%±20(n=24) and 31%±12(n=24); Soluble-COD were 34%±16(n=15) and 36%±17(n=15); TKN were 19%±11(n=14) and 21%±15(n=14); NH_3-N were 22%±13(n=18) and 28%±29(n=18); NO_3-N were 50%±12(n=19) and 60%±34(n=17); Total Phosphorous (TP) were 39%±20(n=19) and 17%±16(n=19); and the removal efficiencies of PO_4-P were 36%±25(n=19) and 21%±21(n=19), respectively.

In Kuo's study (2000), slag filter bed showed better performance than rock filter bed in SS and BOD removal. This could be attributed to the reasons that slag can provide more surface area due to the small holes on the surface, microorganisms could attach on the surface area, and SS could settle better. The plants grown in slag filter bed were not as good as the plants grown in the rock filter bed. It is possible that some unidentified elements in the slag could inhibit the growth of plants. It's important to find out the reason before the slag is to be applied in constructed wetland.

In another study of sewage treatment by constructed wetland systems in Taiwan (Yang *et al.*, 2001), four lab-scale microcosm constructed wetlands, including gravel-beds with plant (A1) and without plant (A2), and soil-beds with plant (A3) and without plant (A4), were used to conduct the nutrient removal tests. The influent used in the tests is primarily treated sewage, while the plant selected is Napier grass (*Pennisetum purpureum*). The purpose of this study is to compare the removal efficiencies of nitrogenous and phosphorus nutrients among these four microcosm wetland systems based on statistical analyses. Three factors, namely, with/without vegetation (F_1), medium types of gravel/soil (F_2), and time period for the test run of first/second stage (F_3), and four combined effects of factors, F_1 by F_2 ($F_{1,2}$), F_1 by F_3 ($F_{1,3}$), F_2 by F_3 ($F_{2,3}$), and F_1 by F_2 by F_3 ($F_{1,2,3}$), were run by an ANOVA model to analyze the relationships between the amounts of nutrient removed from the wetland systems and these seven factors. According to the analytical result, we found that the removals of ammonia (NH_3-N), nitrate (NO_3^--N), and soluble reactive phosphorus (SRP) were related to these factors and combined effects of the factors. It was found that the main removal mechanism for NH_3–N was nitrification, which could be enhanced by the root zone effect (RZE) in the vegetated gravel-bed wetland systems, while NO_3^--N were removed mainly by denitrification and plant uptake in vegetated systems. However, the main removal mechanism for SRP was chemical adsorption in the unsaturated soil-bed systems. The effect of plant litter was also a significant mechanism affecting nutrient removal in the surface flow pattern soil-bed wetland systems without harvest.

In the study conducted by Yang (2001), two lab-scale, two-stage constructed wetland systems, including gravel-soil beds with or without plants were used to study the nutrient removal effects of primarily treated sewage. According to his experimental results, in both of the systems, the gravel beds (the first stage) removed most of the N and P nutrients (above 70% of removal efficiencies) during the three-month running time after the systems had reached a steady state. However, the soil bed (the second stage) in the vegetated wetland system showed little increase in N nutrient, while further removal of P nutrient was found in the bed. In the system without vegetation, we found that both N and P nutrients were removed further in the soil bed. The reason might be that the plant litter was accumulated on the soil surface of the vegetated bed with a free water surface flow regime, in which the plant uptake effect might be less than plant litter release effect on N nutrient. However, the accumulation of plant litter did not affect the nutrient levels in the effluent of the vegetated gravel bed due to its subsurface flow pattern. The average first-order rate constants for nitrogen removal in the systems with and without vegetation were measured to be equal to 0.067 and 0.073 day^{-1}, respectively, while the numbers were equal to 0.045 and 0.107 day^{-1}, respectively for phosphor removal. The conclusion is that the biological processes, including microflora processing and macrophyte uptake, were dominant in the vegetated gravel bed to remove N nutrient, while P nutrient was removed mainly by chemical adsorption in the soil bed with or without plant. It might be that (due to) the higher porosity and significant root zone effects exist in the vegetated gravel bed system and that (to) the mineral clay soil type has low porosity in the soil bed.

Constructed Wetland Applied in Aquaculturing Wastewater Treatment

In Taiwan, Lin and Jin (2000) have studied the effects of using constructed wetland systems to treat aquaculturing wastewater for the purpose of recirculation. In their study, a pilot-scale constructed wetlands system consisting of a free water surface (FWS) wetland and a subsurface flow (SSF) wetland run in series was set up for treating aquaculture farm wastewater in this study. The FWS wetland was planted with water spinach (*Ipomoea aquatica*) in the front half and with a native weed (*Paspalum vaginatum*) in the second half, and the SSF was planted with common reed (*Phragmites communis*). The first part of this study was conducted to examine the system performance in removing suspended solids (SS), algae, chemical oxygen demand (COD), inorganic nitrogen and phosphate under various hydraulic loading rates (1.8 to13.5 cm d^{-1}). Several significant findings were obtained in this study, which included: (1) the start-up periods for achieving stable performance of pollutants removal and macrophyte establishment; (2) regression equations for correlating the effluent qualities and the loading rates; (3) the relationship between pollutants removal rate and loading rate; (4) first-order removal rate constants for various pollutants. These results could be provided as basic information for process design and operation in constructed wetlands system for aquaculture wastewater treatment. In the second part of this study, we set up a recirculating aquaculture system (RAS) that consisted of a tank for fish rearing and a SSF wetland for recirculated water treatment. A control aquaculture system (CAS) containing the same size of the rearing tank as the RAS, but without water recycling, was also run for comparison. A culture density of 7 fish m^{-2} of milkfish and 61 prawn m^{-2} of Thailand shrimp was employed in the rearing tanks of both systems. The performance of the SSF wetland and the water qualities and the culture species growth in the two rearing tanks were investigated. The recirculated water was performed at a rate of around 15 % of the water volume of the rearing tank per day. During the 12 weeks experimental duration, SSF wetland showed efficient removal for BOD_5, nitrite, and microorganisms (algae, total coliform, *Vibrio*) from the recirculated water (> 70%), while maitaining substantial removal for SS, ammonium, nitrate, and phosphate (30-60 %). The water qualities of SS, nitrate, algae, turbidity, total coliform, and *Vibrio* in the RAS rearing tank were significantly lower ($p < 0.33$) than those in the CAS rearing tank, whereas the levels of BOD_5, ammonium, and nitrite in the rearing tanks between the two systems were not significantly different ($p > 0.7$). The body length of the culture species increased 272 for milkfish and 1510 % for Thailand shrimp in the RAS system, which was 26 and 250 % higher than those in the CAS ($p = 0.08$ and < 0.005).

Application of Constructed Wetlands in Polluted River Water

The Erh-Ren River is one the most polluted rivers in Taiwan. Although its flow rate is relatively low, the rate is still beyond the capacity of any traditional water treatment facility. A pilot-scale constructed wetland (CW) was the attempt used to purify the highly polluted river water and to collect data for the construction and operation of a full-scale system in the future (Jing[a] *et al.*, 2001). During the study, the most efficient nutrient removal occurred between April and October. The monthly average removal rates for chemical oxygen demand (COD), ammona-N (AN) and orthophosphate (OP) were ranged from 13-51%, 78-100%, 52-85%, respectively. After November, imput COD levels increased, and the monthly average removal rates of AN dropped to 26%, while OP was decrease to 13%. The dramatic changes in removal efficiency suggest that the macrophytes in the CW had a direct influence on the water treatment and that the change of seasons and the quality of the river water inhibited the growth of the macrophytes.

In another study on Erh-Ren River (Jing[b] *et al.*, 2001), a pilot-scale constructed wetland (ERRCW) system containing a free surface flow wetland (FSF) followed by a subsurface flow wetland (SSF) was set up to treat the polluted Erh-Ren River water. The system was designed to include solids removal. A removal efficiency of suspended solids (SS) in the ERRCW system that was greater than in a control system indicated that the existence of macrophytes in wetlands cold enhance solids removal. The results of this study also showed that SS were removed mainly through the SSF in the ERRCW system. The poor removal of SS, or even an increase in SS, that occurred in the FSF was found to be caused by the growth of algae. Although the macrophytes reduced the penetration of sunlight into the water in FSF portion of the ERRCW system, the residue of nutrients in water and a low flushing rate still induced the growth of algae on some open water surface. From this study, it may be concluded that the roles played by macrophytes in solids removal include providing barriers for filtration, reducing sunlight penetration, supplying oxygen to enhance biodegradation of organic solids, and absorbing nutrients to limit the growth of algae.

Wetland Systems Applied in Non-point Source Pollution Control

In Taiwan, non-point source (NPS) pollution is one of the major causes of impairment of surface waters. The non-point source pollution controlled by wetland systems has been studied by Kao (2000). In his study, the constructed wetland systems were built inside the campus of National Sun Yat-Sen University to remove (1) NPS pollutants due to the stormwater runoff, and (2) part of the untreated wastewater from school drains. The plants grown on the wetland included floating (*Pistia stratiotes* L.) and emergent (*Phragmites communis* L.) species. Analytical results indicated that the constructed wetland removed significant amount of NPS pollutants and wastewater constituents. Results from this study would be very useful in the design of constructed wetlands for NPS pollutin control and water quality improvement.

Fate of the Pollute in the Wetland System

The fate of pollute in wetland systems has also been studied in Taiwan (Wang and Lee, 2000). The main goal of this research was to study the relation between various metal (Pb, Cr, Zn) removal efficiencies and macrophyte growth in constructed wetlands (CW) using fixed influent concentration (20 mg/l). The artificial wastewater also contained 5 mg P/l orthophosphate and 25 mg N/l ammonia. The CW's were free water surface systems and four systems were operated in parallel. Each system planted with different macrophytes (*Phragmites communis L., Pistia stratiotes L., Commelina communis L.,* and vetiver) with hydraulic retention time 4 days (flow rate = 2.2ml/min). In these systems, removal efficiencies of Pb were higher than 94% of Cr ranged from 75 to 87% and of Zn were lower than 40%. The Pb contains in plant tissues were all increased after treatment indicating plant accumulation; Cr contains in plant tissue were decreased probably due to dilution because of plant growth; however, Zn contains were remained low before and after treatment. Although metal concentrations in roots of each system were the highest amount various tissues, the total accumulation of metal was found in the leaves. In the whole plant, the accumulation of Pb ranged from 22 to 95 mg; Cr ranged from 64 and 352 mg; and Zn ranged from 3 to 12 mg. The Pb accumulations in soil ranged from 1172 to 1660 mg; Cr ranged from 118 to 4425 mg;

and Zn ranged from 137 to 1277 mg. Therefore, soil sorption was the major sink for metal removal in a CW system.

Development of Database of Designing Constructed Wetland in Taiwan

Li (2000) has localized the design criteria of constructed wetland systems for wastewater treatments. His study presented the performance of constructed wetland for improving water quality by using pilot scale constructed wetlands, consisting of two cells of subsurface wetland and two cells of free surface wetland. There are two types of influent sources to the constructed wetland – the discharged wastewater from a secondary wastewater treatment plant and the lake water. Based on the result, the treatment performance is good for removing nutrients from the secondary effluent. But the suspended solid, volatilized suspended solid, and the total organic carbon, are somewhat poor. Similarly, the treatment performance for lake water is good in the nitrate removal, but poor in volatilized suspended solid, biological oxygen demand, and the total organic carbon. The subsurface flow constructed wetland can remove phosphorus, total phosphorus, in contrast, the free constructed wetland is incapable of removing total phosphorus.

The obtained experiment data were modeled using the first order kinetic theory. In comparison with the reported results, the kinetic coefficients(k)of suspended solid is low, but the value of k for the other pollutants is close to that reported. We also used visual basic for application (VBA) to develop a computer program for designing constructed wetland. Through the input of the flow rate, the influent concentration, and the expected effluent concentration as well as kinetic coefficient k, the constructed wetland area can be determined. Though the applicability of the program has been demonstrated in personal computer, its reliability needs further test.

Conclusions

Since Taiwan is located in subtropical areas, it is very suitable to use constructed wetland systems to treat the contaminated water in Taiwan. However, according to the experimental results of those studied conducted in Taiwan, even though constructed wetlands have been proved performing well for water pollution control, there is still no any field-scale constructed wetlands built or under construction in Taiwan to treat the polluted water bodies. The reasons may be summarized as followed:

1. The EPA officials of Taiwan think that there is no enough land provided for building constructed wetlands in Taiwan.
2. Wetlands may be the sites to raise mosquito, which are the media causing some disease.
3. Wastewater is still needed pretreatment before it is discharged into constructed wetland systems, which still cost more in treating wastewater.
4. There is no legislation on the issue of wetland systems in Taiwan.

Therefore, first of all we should make more efforts on pushing the legislation work on protection, conservation and creation of wetlands in Taiwan. Then, building field-scale constructed wetland systems for water pollution control in Taiwan may become possible. In the future, the sustainability of water resources will thus be achieved in Taiwan.

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Apply Neural Networks to Watershed Management

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Abstract

This paper demonstrates neural network model can be used as a powerful tool in watershed management. Two applications were presented: (1) development and evaluation of several hydrological interpolation schemes for correcting missing or noisy data inflow data in Seattle Public Utility's Tolt River watershed and (2) forecasting short-term water demand in summer months. Neural network model was compared with traditional method such as linear regression. It was found that neural network model performed better than the traditional statistical models, especially when relationship among parameters is not linear.

Introduction

Water supply, demand and quality are major concerns of Seattle Public Utilities. Since the beginning of late 80's the population in metropolitan of Seattle has grew significantly and the growth is projected to continue at the rate of 1.0% annually for the next 20 years (Skeel, et al., 1998). Without developing new water resources the management of existing water supply and quality to meet the regional growth become critical task to Seattle Public Utilities, especially during the summer months when the demand increasing significantly while precipitation is very low. Three issues related to the watershed management are

(1) Yield prediction, which is dependent on the in-stream flow in Seattle Public Utility's Cedar River and Tolt River watershed
(2) daily consumption, which may affect the reservoir operations during the summer months; and
(3) the water quality in the distribution reservoirs.

In issue (1) the key question is how to estimate the data gaps in the in-stream flow? In issue (2) the key question is whether or not we can forecast water consumption in a short-term period, say a week ahead; and the key question issue (3) is that can we adequately model the dynamics of water quality parameters. In this paper I will only answer the first two questions by applying neural networks. The third question will be addressed in a separate paper.

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The Architecture, Train, Validation and Test of Neural Network

Neural network has been applied to water treatment, water quality and waste water management in recent years (Garrett, et al., 1997; Yabunaka et al., 1997; Baxter, et al., 2001 and Brion et al., 2001). In this paper a neural network with feed-forward architecture and backpropagation learning algorithm was chosen for the tasks. The feed-forward neural network is simple and counts for more than 90% applications in civil and environmental engineering fields. Figure 1 shows a layout for a typical three-layered feed-forward neural network, which contains an input layer made up L input nodes (variables), a hidden layer, made up m hidden nodes, and an output layer, made up n output nodes (variables). The architecture is denoted as a L-m-n neural network. In general, a feed-forward neural network contains an input layer, an output layer, and one or more hidden layers between the input and the output layer. Each node at current layer is connected with nodes in the previous layer by a linear combination of weights and bias (see Figure 1) except for input nodes. An activation function, usually in form of $1/(1+e^{-x})$ or tanh(x), then is invoked to process the combination before sending its output directly to nodes in the next layer except for output nodes.

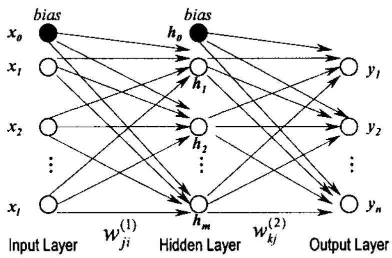

Figure 1. A three-layered feed-forward neural network

After the setup of a feed-forward network the backpropagation algorithm is used to train the network. The backpropagation algorithm uses a gradient descent method to minimize errors. The training process can be viewed as updating network architecture and connection weights and bias so that a network can learn complex systems. That is given a set of input variables and corresponding output variables, the network organizes itself internally so it predicts the desire output. The training process (backpropagation) is an iterative process that has three steps:

(1) starting with a randomized weights and bias, the input variables are forward propagated through the network to yield an output
(2) the output then backpropagates the errors back to the sensitivity according to generalized delta rule (GDR) or other learning rules
(3) the weights and bias are updated using this backpropagated error and learning rules. The process is repeated until the error is within a tolerable limit or range