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12

Land Flooding Irridation Treatment System for Water Purification in Taiwan

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1. Introduction

The primarily focus of the agricultural development is to create an appropriate and suitable environment for growing plants. To do so, supplying plants sufficient growing factors would be necessary, including water, nutrition, sunlight, adequate temperature and air. For water, a construction of irrigation system is one of the vital methods of supplying sufficient water.

Trace back to Taiwan's history, irrigating system began really early. However, due to the features of the natural geology and people migration, the accumulation and application of water resource is not average. From the era of Japanese occupation (1895-1945), Irrigation Waterway Popularization was being promoted (Taiwan Governor-General Office, 1901), which started by integrating private irrigation waterways to public ones. Afterwards, here comes the establishment of farmland cultivating and water conservation system, first began in the north Taiwan and then to the middle, south, finally from west to east.

In 1949, while the R.O.C. government retreated to Taiwan, the managing organization still remained as it was during Japanese occupation, that is, the Irrigation Association as to keep the public legal entity. Therefore, the agricultural irrigation system could keep operating appropriately.

However, with Taiwan's miraculous economy took-off, needs from various kinds of livelihood, industry, and infrastructures gradually occupied the farmland. Furthermore, because of inferior drainage facilities that utilized original irrigation waterways as sewage drainages, polluted crops incidents emerged in endlessly.

Due to the 21st century global changes issue, Taiwan's water resource now faces a more devastating situation caused by climate abnormality. According to the data resourced from Taiwan Water Resource Bureau (2011); currently, there are 69 dams among all now have severely siltation problem that leads to the deficiency of water retention capacity. Under the circumstance, reducing water expenditure becomes one of the solutions to the future water usage; moreover, sewage recycling and reuse also can be other conditions which we should take into consideration.

Facing the dilemma, the application of Land Treatment System (LTS) plays an important role inside; especially the offspring from the trend that can cope with it, flood irrigation. It allows the sewage which is about to flow into the irrigation waterway to be purified by the interaction of earth, plants, and microorganism. For countries or regions with limited water resource, the design, construction, and maintenance of LTS are quit cost-efficient and its degree of technique is low. Therefore, in Taiwan, it is a possible method to deal with the

sewage recycling issue for future climate changes. Later on, this chapter would take the last sections of LTS as examples and also; from a long-term observation, it would analyze and explain its improvements to the water quality.

2. History of irrigation system in Taiwan

2.1 Features of topography and environment in Taiwan

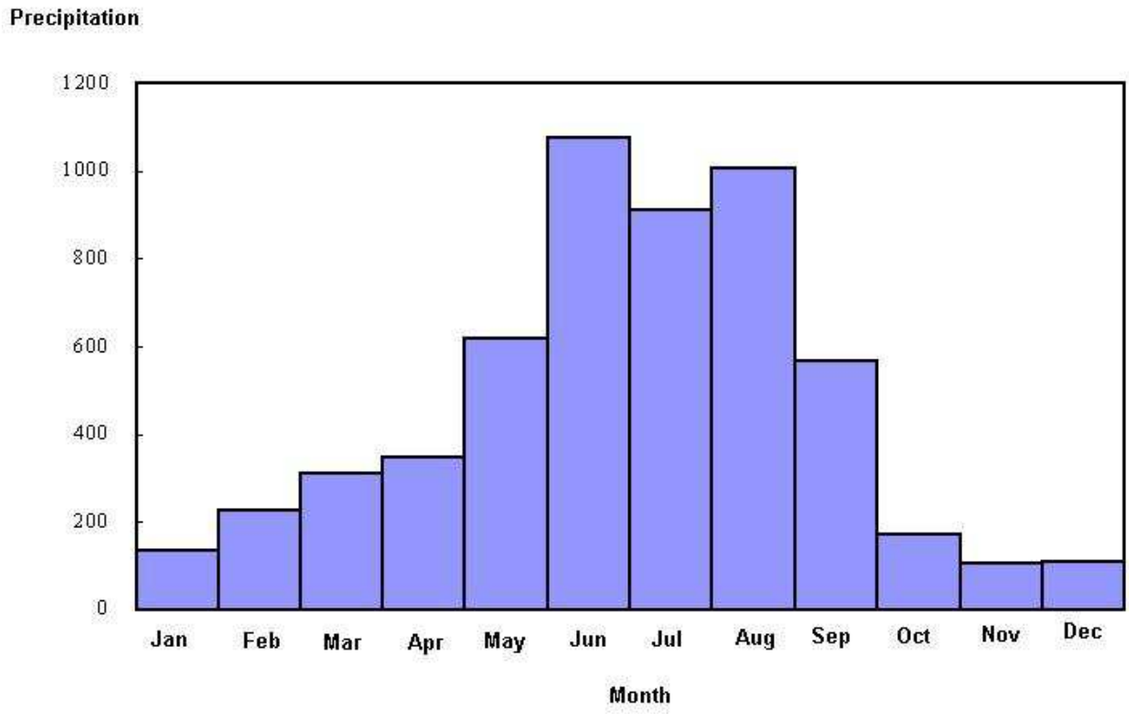
Two-thirds of the total area in Taiwan is covered by forested mountains and the remaining area consists of hilly country, platforms and highlands, coastal plains and basins. The longest main river is 186 km, and the shortest one is merely 41 km; also, most of the river basins are among precipitous mountains and most of this rainfall rushes directly to the sea, is hard to keep. (Picture 1)



Picture 1. Satellite image of Taiwan

In terms of rainfall, since Taiwan is located in the sub-tropical area, at typhoon path, most rainfall concentrates in this abundant rainy season. (April to October, about 78%) (Picture 2) (Northern Region Water Resources Office, Water Resources Agency, Ministry of Economic Affairs, 2009). Therefore, the amount of runoff is rich with sufficient water resource; on the contrast, during the dry season from October to next May, the amount of runoff occupies only one tenth of the abundant rainy season resulted by the dificiency of rainfall. As the consequence, the problems of extremely and seasonal lack of water resource have been quite a challenge to Taiwan.

In Taiwan, the annual average rainfall is 2,510 millimeters, the volume of it is 90.5 billion cubic meters. Most of rainfall comes from typhoon season, which is 2.6 times the globally averaged annual precipitation. However, bacause of the spatial and rainfall period limitation, only 15% of the amount of rainfall is available to use; moreover, since the population density in Taiwan is quite high, the per capita rainfall is 4,250 cubic meters (in the context of 21 million population), which is one sixed of globally average. As a result, Taiwan ranked as the 18th water shortage country worldwide. (Li, 2003) Therefore, in the constraint of the topography, rainfall issue, and under the circumstance as an isolated sea island, water resource is precious to Taiwan.



Picture 2. Taiwan's Monthly average rainfall bar chart, 2009

In addition, according to the research done by The Asian Development Bank, in Asia, the yearly per capita rainfall is around 26,007 tons, but the volume in Taiwan is only 4,250 tons, which is far behind Asia's average value. In terms of the volume of water, the yearly per capita rainfall in Taiwan is merely higher than Pakistan (1,800 tons), China (2,000 tons), India (2,200 tons), Sri Lanka (2,400 tons), Afhanistan (2,500 tons), Thailand (3,400 tons), and other six countries. It can be seen from that, though there is plenty of rainfall in Taiwan, resulting by the factors of geology and population, Taiwan still is a "water in shortage" country.

According to the statistic from Water Resource Agency, Minister of Economy, the annual amount of water usage is about 18 billion tons, occupies 20% of the amount of annual rainfall, the rest of it returns to the nature either by evaporation or flow into the sea. As for the 18 billion water supply, only 15.7 billion of them fits into safe water supply capacity. Among them, 11.7 billion tons is from surface water, 4 billion tons from groundwater, and the rest insufficient part would be made up by over pumping groundwater; which means at least 2.3 billion tons of groundwater ever year. As a result, it leads to the problems such like groundwater drawdown, land subsidence, salt water intrusion, and water deterioration.

Besides, the amount of annual rainfall is not the only difference, but also regional divergence (north, middle, south, and east) in terms of the runoff during dry and wet seasons. As for the rigional ratial comtrast, it's 1:3.5 at north, 1:7 at middle, 1:10 at south, and 1:4 at east.The tremendous difference of runoff ratial during dry and wet seasons is one of the main causes which lead to the seasonal water shortage. Among them, the contrast and water shortage possibility during dry season is much higher in the south of Taiwan; furthermore, affected by regional water resource issue and the deficiency of pipeline construction, water distribution remains a hard task and can easily influence the industry

producing capability and livelihood water supply. (Water Resource Agency, Ministry of Economy, 2001). To this day, if there is any other severe dry season coming or globally climate changes that cause the abnormal to the rainfall, water shortage can happen even during wet season that bring the sufficient water resource, let along dry season with limited water supply, it will only getting worse.

2.2 Water conservation constructions in Japanese occupation

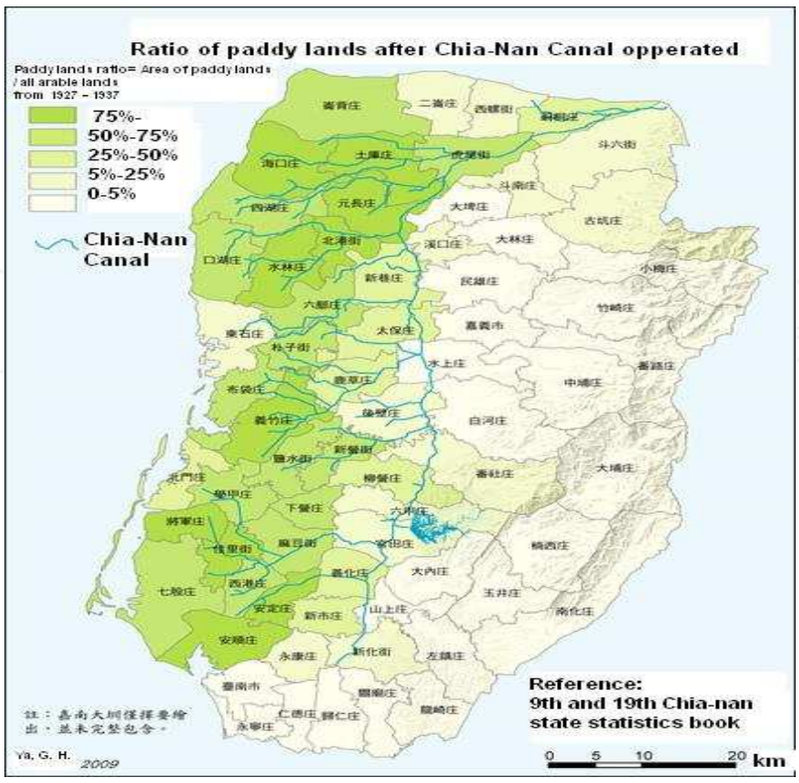
During Japanese occupation, the Taiwan Governor-General Office published "The Rules of Public Irrigation Waterway", which integrated all private owned ditches or waterways to a public irrigation system; meanwhile, various kinds of water conservation planning and facilities were being promoted to the expectation of the land settlement policy, as to make Taiwan an agriculture base.

The hydraulic engineering carried out by Taiwan Governor-General Office included irrigation project, land improvement project, drainage engieering, old waterways renovaing project and brought in the new water conservation techniques; among them, Tao-Yuan Canal and Chiayi-Tainan Canal are the biggest irrigation waterway projects. Because of these water conservation facilities and engineering projects, they efficiently increase the available irrigation ground area and rise up the productivity of rice and sugar. Since then, Taiwan's agricultural development foundation had been setted up, the influence was profound even now.

In Febuary, 1908, Taiwan Governor-General Office issued new law and began to operate the construction of official irrigation waterway. Afterwards, in 1910, water conservation combination rules of public irrigation waterways was published as to organize the management organization. During this period, because the water conservation environment in Tao-Yuan tableland accorded with official irrigation water subsidy conditions, this region was listed as one of the official irrigation system planning area. In 1913, a severe drought damage occurred in Taiwan and alerted Taiwan Governor-General Office; thus, the engineering in Tao-Yuan irrigation canal was accelerated. In terms of the canal project, it contains two part, one is the official irrigation waterway, which started construction in 1922 and finished in 1924 and began irrigating that year; another is the combination project of water conservation, which consisted of constructing, renovating reservoirs and separated channels, starting from 1916 and finished in 1928.

Because of the permission of building Tao-Yuan Canal, it simulated the engineering project of Chiayi-Tainan Canal, which started constructing in September, 1920 and finished in May, 1930. The predicting irrigating area was 145,500 hectares, but after operating for one year, the actual irrigating area was about 131,920 hectares. Nevertheless, contrasting to Tao-Yuan Canal, with only 22,310 hectares irrigating area, the benefit brought by Chiayi-Tainan Canal was hard to count.

Resulted by irrigating system, dry lands gradually tranformed to paddy fields. In 1928, after full operating of Tao-Yuan Canal, area of paddy lands rocketed up obviously; especially for coastal regions, some even increased over 40% (picture 3). By using the the altitude gap and interceptive return flow from rivers, it enabled low-lying coastal areas with underdeveloped agriculture resulted by factors such as barren grounds, sea wind, salt spray and irrigation shortage areas to transform from low productivity dry lands to high productivity paddy lands.



Picture 3. Paddy lands ratio after Chiayi-Tainan Canal operated. (Reference: 9th and 19th Chia-nan state statistics book)

Although Chiayi-Tainan Canal was the biggest water conservation construction during Japanese occupation, the irrigating region was still far bigger than it could supply. Therefore, the water supply couldn't satisfy all farm reservoirs. Under the circumstance, the organization supplyed water by taking turns; meanwhile, farmers were forced to practice rotation of planting crops which are rice, sugarcane and others, and that is the so-called the "Three-year rotation". Though farmers couldn't choose which crop to grow by themselves, after the canal started supplying sufficient irrigation water, dry farmlands around Chiayi-Tainan Canal soon transformed into paddy lands; hence, crop productivity, land value rose up and farmers' lives also improved.

2.3 Development of water conservation after R.O.C. government retreated to Taiwan

During World War II, because of centrol supervision, goods and materials deficiency, the mainteinance of water conservation facilities was difficult. With series of disasters and bombing at that period of time, mutiple water conservation utilities were damaged or couldn't operate appropriately. For instance, the Tseng-wen Stream intake in Chiayi-Tainan Canal was the water abstraction utility that was piled up by water conservation wire barriers; however, later on it collapsed because of rusty iron. At that time, iron and wires are under supervision; therefore, they couldn't but renovate it with concrete. In 1941, a flood crashed it again; thus, renovation of water conservation facilities became one of the post-war tasks.

In addition to the renovation of water conservation facilities, the taking over and recovering of water conservation managing organization were also vital issues during post-war period.

Moreover, after WW II, Taiwan's political and ecnomical status transformaiton were extreme; as a result, the water conservation managing organizaiton had to keep adjusting its structure as to fit environmental changes and development needs.

At the initial stage when the R.O.C. government took over Taiwan, all water conservation combinational orgainizations were adopting systems in Japanese occupation. The only difference was to replace regions to districts. Since a huge amount of Japanese left their job, Taiwanese had the opportunity to fill in the vacant position and then recovered the water conservation's operation.

Since there was no similar organizations like water conservation combinations in Mainland China, the R.O.C. government followed Japanese water conservation system for about a year; afterwards, to in line with the spirit of democracy and autonomy, central officials then revised the rules of electing president, that is, replacing officially appointment with popular vote. On December 26th, 1946, Taiwan Chief Executive Office comanded all districts to elect the first water conservation combination president while the articles of orgainization remained the same.

From 1953, the R.O.C. government successively implemented a five-terms four-year economical construction, aiming to "cultivate industry with agriculture, and develop agriculture with industry." Within this mission, the foundation of industry development was founded but, on the other hand, contrainted agriculture, transferring plenty of resources to industry.

In November, 1956, in order to advocate the "land to the tiller act" policy, the R.O.C. government issued "The Articles of Irrigation Association of Taiwan Province" which consolidated the original 40 water conservation boards to 26 farm irrigation associations. However, from 1960, the value of industry product first surpassed agriculture; therefore, more and more villege labors moved to either cities or industries. As a consequence, labor shortage gradually became common situaion; thus, wages and commodities then got higher and higher. While industry development expanded generously, population and arable lands; however, became smaller and resulted in impoverished finacial problem of farm irrigation association. In order to keep operating, quarrels and disputes occurred between water conservation associations. In 1982, the volatile political situation in Taiwan became stablized and the water conservation orgainizations operated regularly, the R.O.C. government then revised the "Organic Statute of Farm Irrigation Association", which enabled all water conservation associations to operate autonomously and gave all assocaitons public legal entities. The R.O.C. government would select 2 to 3 people as appointment of candidates of the organization president , then members could elect one of them. In June, 2001, "Organic Statute of Farm Irrigation Association" was revised again, which enabled members to elect the boards and the president of the association.

All in all, before 1970, the agricultural irrigation system constructions mainly focused on renovating damaged water conservation facilities; afterwards, in order to increase the crop productivity, "water conservation engineering" then concentrated on improving the original utilities' efficiency. Moreover, the exploitation of water resource then transformed to power generation and supply potable water or other multiple purposes from agricultural irrigation.

Resulted by the shift of national policy, areas of farm lands became much smaller in order to meet the needs of industry and livelihood development. In January, 2000, after the third-reading of "Agricultural Development Act" in the legislative Yuan, the R.O.C. government lifted the embargo on farm lands, arable lands free on trade, relaxing the restrictions of farm

segmentation, no limitations of farm segmentation inheritage, and allowed farmers with farmhouse non-ownership status to build farmhouses, officially broke the "farmlands will be used as agricultural purposes" policy. As a result, it withered Taiwan's agriculture; what's more, environmental impacts such as sewage pervading problems are currently grand challenges to Taiwan.

3. Coping strategy to water shortage

People have right to use water resource, and government has to guarantee this right. Due to causes like climate, geological environment and other factors, though Taiwan remains a sea island with the amount of rainfall that is 2.6 times global average volume, the per capita rainfall is only one fifth of global average volume. Therefore, Taiwan is a rainly country but remains a water shortage region; in that case, in terms of coping this problem, there is no shirking the responsibility to the government.

Traditionally, whenever there is a water problem, after traceing it to its causes, there are always two possible reasons, water shortage and deterioration. However, ever since the climate abnormality intensified, there is a significant difference of water resource problem comparing to the past. Which can be indicated from a simple localized problem, slowly expanding to a regional one, even a whole area's evironmental issues; worst of all, becomes a significant restriction to economical development.

In Taiwan, because of government's negligence and inappropriate policy, we will need a new concept while dealing with water resource problems, especially for climate abnormality changes in 21st century.

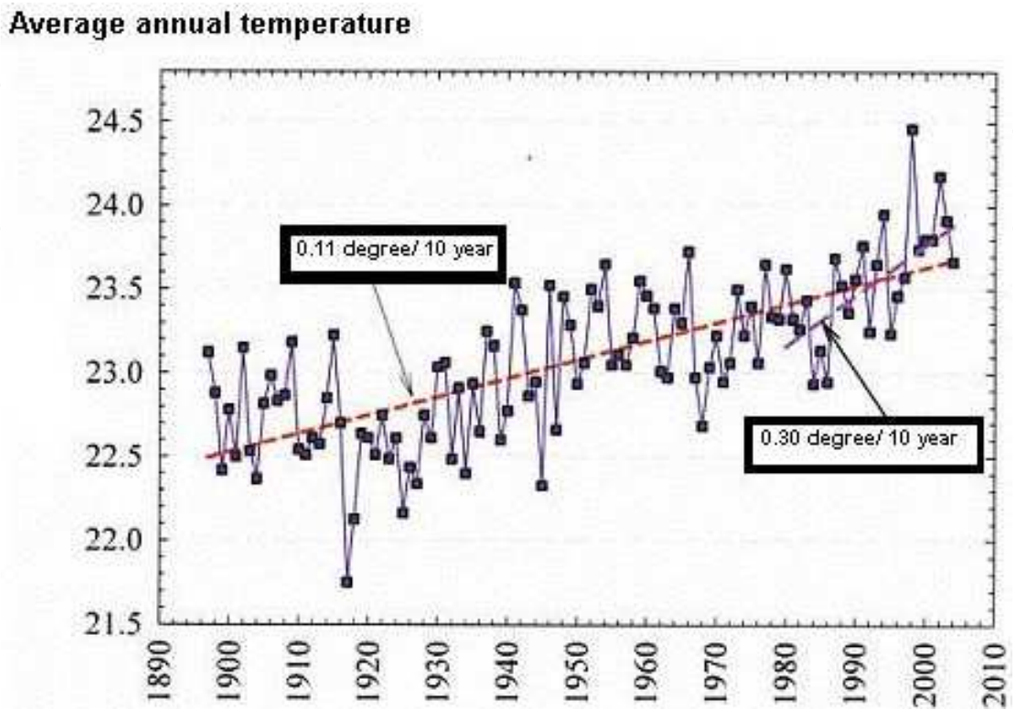
3.1 Impacts of global warming

During the past one hundred years, the annual mean temperature rose more than one celcius (picture 4), global warming effect is obvious. The main reasons are the global warming effect and regional human exploitation. (Chang, 2011) Generally speaking, in the half of 20th century (before global warming), the temperature rose slowly and the changes of rainfall was rather stable with timely wind and rain. However, in 1950, after the annual mean temperature first exceeded the average value for a century period of time, water conservation and precipitation evolved to a completely different type of problem, included increased level of scale, dry season period became longer, and the rainfall intensity rose up significantly after 1980. Basically, they all had something to do with global warming in some measure. It shows the operation of nature was transforming swiftly, extremely and interactively, which could be as a reaction to the increasing temperature; meanwhile, it affected Taiwan's water resource problems profoundly.

After global warming tendency effect in evidence since 1950, there were some features of the rainfall: (1) Precipitation tended to bipolar distributed; divergence of south and north region gradually expanded; (2) the whold island's rainfall periods decreased; (3) all districts' intensity of rainfall strengthened; worst of all, due to global warming, it decreased the temperature difference which also leaded low humidity to atmosphere, causing frosting and fogging time reduced; finally, shortering rainfall days annually.

On the contrary, the average intensity of rainfall had an opposite effect comparing to the change of rainfall days. Since 1950, the long-term intensity of rainfall indicated an increasing value. (Wang, 2004; Lin, 2007). Especially in wet seasons, as a result of the increasing of

precipitation in the north of Taiwan, the increasing ratio of intensity of rainfall was twice times east. In southern west, the record was broke almost every year and became a vital precaution movement in Taiwan.



Picture 4. Temperature Increasing in the Past Century (Wang, 2005)

3.2 A predicament of lacking enough sewage pipes

In 2000, total livelihood water consumption was 3,633 megatons (MT), industry water consumption was 1,870 megatons, and agricultural water consumption was 12,318 megatons; which occupied total water consumption of 20.4%, 10.5%, and 69.1%, repectively. In Taiwan, the dominant source of sewage came from household sewages (about 40%-50%). Therefore, in order to improve the household environmental sanitary, constructing public sewage pipes system has become an urgent environmental protection infrastructure. (Environmental Quality Protection Fundation, 2000)

In Taiwan, the popularization rates of the sewage pipe intallation were 0.45% – 46.30% in 2000 and the country's average value was 6.92%, which was quite a divergence between rural and urban areas. (See chart 1) (Construction and Planning Agency Ministry of the Interior, 2000) Untill in April, 2011, the country's popularization rate had risen up to 26.92 %, which was still lower than the presetted 35.8% (Environmental Protection Administration Executive Yuan, 1998). In order to figure out on how to solve the serious sewage pollution, it's the government, academic fields and civil orgainization's joint responsibility.

Area	Taipei	Kaosiung	Taiwan
Pupularization rate（%）	46.30	11.25	0.45

Table 1. Popularization Rate of Sewage Pipes, April, 2000

The tendency of water environmental deterioration makes us concern, especially water pollution.The aggravation of water pollution resulted in multiple contradictions between regions, urban and rural areas such as, how to transfer and release the original agricultural irrigation water in order to put down the disputes among agriculture, residents, and industry.
Also, the severe water pollution demolished the ecological environment profoundly. The emerging of Lifestyles of Health and Sustainability (LOHAS) made the middle class reconsider their health and living environment; for example, purchasing farmlands and builds farmhouses, liberating themselves from busy city lives, but resultes in a more serious pullution. Besides, the farmland segmentation makes ensuing water conservation planning hard to practice.
During the past, building constructions didn't include separating the allocation of rainfall and sewage. Moreover, illegal buildings also unabled the processing of constructing sewage pipes as to centralize the sewages. Illegal farmhouses on farmlands often directely drains the wated water into irrigation waterways. (see picture 5) Thus, solving illegal buildings would be the first stop in order to construct sewage pipelines. Moreover, it's difficult to install the sewage pipelines for legal users even the distribution of pipelines were already setteled because of factors like to conduct construction across private lands.



Picture 5. Community sewage directely drains to irrigation waterways

Eventually, the sewage would flow into dams, streams, rivers, and to the sea. There are 21 principle rivers, 29 secondary rivers and 79 ordinary rivers in Taiwan; in 2001, the total lenth of all rivers is 2,934 kilometers, among all, unpolluted lenth of rivers is 1808.88 kilometers, light polluted rivers for 287.62 kilometers, meduim polluted rivers for 451.3 kilometers, and heavy polluted rivers for 386.2 kilometers; which occupies 61.65%, 9.08%, 15.38% and 13.16%, respectively. During the past decades, the statistic has shown that fewer and fewer unpolluted rivers exised, which means water pollution is getting worse. As a result, the amount of available water keep diminishing.

3.3 Approaches to broaden water resources of income and reduce expenses

We can never put too much emphasis on the importance of water resource since it plays an important role to civilizations on earth. Though water covers 70.9% of the Earth's surface, oceans hold 97% of surface water, plain water holds 3%; in terms of plain water, glaciers and polar ice caps 75%, rivers, dirt, atmosphere, lakes and biological organisms occupy 3%; the rest available water for humankinds is less then 1%. The human civilizations and developments heavily rely on water resource.

Since a long time ago, living near the river makes people easy to utilize water; thus, most human civilizations originated from banks of significant rivers. With the development of civilization, humankinds grow plants, fertilize, clean objects, accumulate garbages and so on, the wastedwater and sewage that penetrates from the wastes often flows into rivers or streams. Furthermore, fertilizing and cleaner chemicals such as phosphor, nitrogen, bisphenol A (BPA), nonylphenol (NP), plasticizer and other heavy metals all causes sever water pollution, diminishing available water resources.

Due to the high density of phosphor and nitrogen under water which can intrique eutrophication easily, plenty of algen grow and cover the water surface, even sunshines. As a consequence, it results in the death of fish, shrimp and other underwater plants. Besides, the decomposition of either animals or plants needs oxygen in the water and form into the anoxic vicious cycle. “Eutrophication” indicates the excessiveness of nutrition materials in the water, which leads to a situation of algae bloom. In terms of its nutrients, there are roughly two main sources: (1) Natural eutrophication: It refers to the sedimentaion and accumulation of nutrients in a lake of natural ecosystem, which causes eutrophication step by step. In other words, it means the lake is getting old and it a normal but must successsion in natrual ecosystem. (2) Artificial eutrophication: artificial eutrophication occurs when human activity introduces increased amounts of these nutrients, which speed up plant growth and eventually choke the lake of all of its animal life. For instance, growing and fertilizing plants and lake recreation activities, pouring amounts of nutrients into ponds, rivers, lakes or dams, which often lead to the propagation of plankton underwater. Finally, the ecosystem underwater changes swiftly and water quality will become deteriorated. Usually the phenomenon can be form up in just a few years. (Wen, 1995)

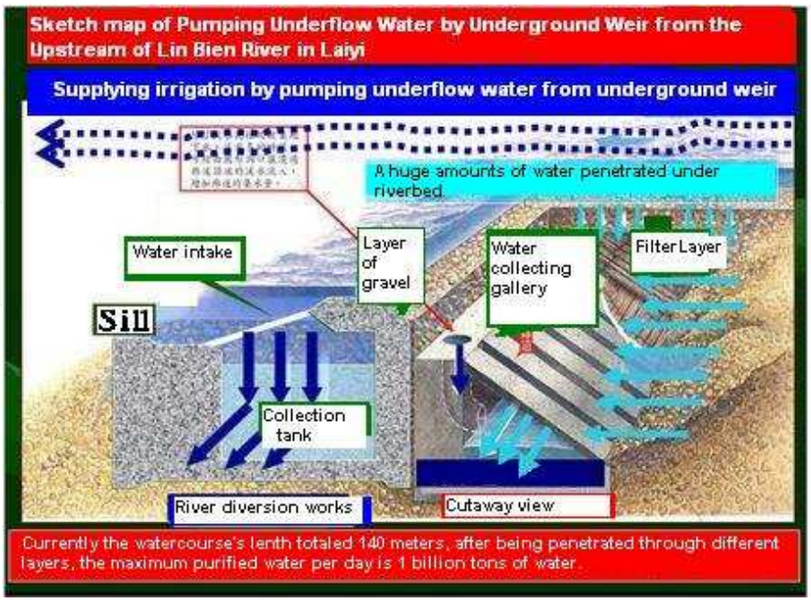
In Taiwan, the water resources supply mainly come from dams, rivers, and groundwater; to this day, there are 109 dams and dikes. In terms of the functions, it included power generating, irrigation, water supply, travelling and flood protection. Due to natrual causes and over-manmade exploitation, dam siltation has been a serious problem. In the past, there was a misconception, that is to consider Taiwan as a island with rush rivers, centralized rainy seasons, water shortage problem in winter, and the only way to solve it was to construct dams. However, the truth is, because of steep mountains, a huge amounts of dirt, rubbles, and R.O.C.ks would be flooded into dams and caused siltation after rainfall. Take

the Kaopinghsi weir which is located in Kaoping River as an example, whenever there is a heavy rain, the weir would act more like a silt arrester rather than a weir. Also, resulted by the high turbidity of dirt and R.O.C.ks that affects the height of water, intaking water gradually becomes a challenge.



Picture 6. Shihman Reservoir. The picture was took after two weeks of Matsa typhoon, the reservoir water looks pure but the water supply reservoir was muddy. It was because of the dirt which came from the upper reaches of the river silted into the reservoir, and after generating power at the power plant, it became muddy and then flew into the lower reaches of the river. So far, water towers had been constructed on the reservoir in order to intake the pure water on the top. (Li, On 20th Auguest, 2005)

For solutions, first of all, is to broad water resources; constructing sustainable water collection gallery on principle riverbeds. (see picture 7)



Picture 7. Pingtung: Sketch map of Pumping Underflow Water by Underground Weir from Upstream of Lin Bien River in Laiyi (Lin, 2011)

This type of water collection gallery originated from the underflow water that was about 2 meters deep under the riverbed; in other words, while the surface water flew (surface runoff), it would also penetrate down through the layer of gravel to the bottom of riverbed (underground runoff) and formed into underflow water. In July, 1996, typhoon Herb brought a huge amounts of rainfall to Taiwan. According to the statistic, in just one day, there was 0.6 billion tons of water being flushed into the sea (almost equal to the total amounts of water usage in Kaosiung City yearly); meanwhile, the amounts of underwater flow was counted under 10 meters of the riverbed was also about 0.6 billion tons, this indicated the abundance of the underwater flow under riverbeds. In addition, by R.O.C.ks and rubbles' filtration, the water quality was quite superior. In other words, the gravel on riverbeds is the natural water supply and purification plant.

The second approach is to reduce water expenses. Generally speaking, after irrigation water flew through fields and it would become wasted water; finally flushed into irrigation waterways with household sewage. Therefore, the irrigation pollution possibility would go up significantly; after flowing into rivers, it often causes unavailable water in low reaches of rivers. Besides, residents in Taiwan often are lack of proper water usage habbits because of cheap water rates. So, even there is any excellent water conservation construction planning, it still can't satify to make up the load, as a matter of bad water usage habbits. To this day, the cost of broadening new water resources has grown higher and it takes more time to finish a project. What's more, the amounts of safe water supply are currently severely insufficient; thus, it's urgent to publish relevant water reducing policy.

According relevant researches (Li, 2003), here are some available coping strategies as followed: (1) rise up the ratio of recycling industrial wastewater to 65%; (2) promote the system of separating potable and available water in daily lives; (3) advocate the construction of dual water supply system and sewage pipelines in order to rise up the reusing rate of household water; (4) government should build up a precipitation recycle and reuse demonstration; also, issue relevant regulations for residential and industrial areas; (5) for users who tranferred agricultural water to residential water should make efforts to increase the waterways' water delivery efficiency; (6) advocate the installation of water-saving equipments during dry seasons as to decrease the amounts of water supply; (7) regularly examine water supply pipelines in order to drop water leakage rate; (8) enhance water usage management so that the water reducing efficiency will go up.

3.4 Value of wastewater recycle and reuse

According to Water Resources Agency, Ministry of Economy, the definition of "water reclamation", the coverage water refers to wastewater from industries, homes, rainfall storage, seawater and agricultural irrigation water, excluding "before-waterways-water" defined by Water-Conservancy Act. Therefore, the function of water reclamation is to recycle all water in which from rainfall, household, and enterprise wastewater in line with the drainage area regulation and then purify them until to meet all specific water quality standards, so as to achieve the goal. The Water Resources Agency classfied the resources of water to runoff, domestic sewage (meaning same as "livelihood wastewater"), industrial wastwater, agricultural wastwater, aquacultural wastwater, livestock wastwater reuse and so on.

Domestic sewage means all wastewater that originates from humankinds' daily lives, which includes cooking, cleaning, pouring, drinking and so on. According to the statistic shown by the Water Resources Agency; in 2003, the amounts of livelihood water supply reached 3.55

billion tons, which held 20.20% of total amount. The per capita water usage was about 200-250 liters. Since there are various kinds of water using purposes, the deterioration levels are different. In terms of the sewages, excepting wastewater that needs to be purified by septic tanks, others like wastewater from cooking, cleaning, bathing; all were mixed together and then was drained into the sewage pipelines. Speaking of the pollutants in sewage, they are mainly organic materials, suspended solids, nitrogen and phosphorus nutrients, colon bacillus and so on.

In the light of statistics from the Water Resources Agency; in 2003, the amounts of agricultural irrigation water was 12.43 billion tons, occupied 70.70% of tatal agricultural water usage. In Taiwan, the irrigation water primarily comes from Irrigation Association's waterway system. From the survey of the amounts of agricultural water usage shown by the Council of Agriculture, it reported that the irrigation water originated from rivers, pumping surface warter (85.2%), dams and reservoirs (9.1%), and groundwater (4.4%).

So far, the R.O.C. government only started the counseling of the recycling of agricultural irrigation water without practicing the recycle of irrigation water pragmatically. In addition, the amounts of agricultural water usage declined after Taiwan joined the World Trade Organization (WTO); thus, transferring part of the available water would rise the water resource operating efficiency. Furthermore, although overpumping groundwater is the dominant cause of subsidence, still, pumping groundwater within limits is one effective method to make up the lack of water resource.

For irrigation water reuse, livelihood irrigation assocations usually utilize the irrigating water return, espacially for dry type water usage of 1.40/ sec/ ha using mostly by water conservation associations where locates in the west of Taiwan. During the dry season, in order to solve the water shortage problem, the irrigation efficiency can be rose up by utilizing water ruturn as to supply other waterways. In terms of the amounts of water and its quality, measurements and statistical analysis were not practiced but only setted monitors on irrigation waterways in order to test the water conductivity. While reusing the water, in addition to concern the water resource, local terrains and irrigation facilities are also factors which could affect the benefits of reusing water return. Although some water recirculation area had the potetial of water return, the water resource would be deteriorated and unable to use because of sharing irrigation and drainage waterways, let along the pollution caused by community wastewater which also made irrigation water unavailable to use anymore. (Water Industry Information Network, 2011)

If we plus the amounts of agriculture irrigation water from rivers and groundwater which totalled 10.59 billion tons to 3.55 billion tons of domestic sewage, the tatal amounts is 14.14 billion tons. After deducting the number of diminished water effect such as penetration, evaporation and plants absorbing, in the end we'll roughly have 7.07 billion tons of drainage water. According to a report (Irrigation Association, 2003), the amounts of industry water usage was 1.61 billion tons, which held 9.1% of total water usage. If the agriculture water return could be utilized for reusing the water, the industry water needs still could be satisfied even during dry seasons.

4. The combination and application of irrigation system and sewage reclamation

Owing to Taiwan's unique terrains, climate, and history, considering current situation of water shortage issues, processing the planning and application of Land Treatment System

will be a decent choice in terms of its low cost, low tech, envionmental education, and easier maintenance. Comparing to industrial treatment (such as Wastewater Treatment Plant), the Land Treatment System is a more cost-efficient sewage treatment facility in prospect.

4.1 Operation and structure of land treatment system

The Land Treatment System can be classified into four types, which includes: (1) The Slow Rate (SR) method, (2) Rapid Infiltration (RI), (3) Overland Flow (OF) and (4) Wetland System; their operating effects and availabilities are as followed:

Classification	Yearly load (m/a)	Occupancy area (hm2/km3)	Gradient ; soil	Groundwater depth (m)	Water directions	Water quality variation	Purposes
The Slow Rate Method (SR)	0.3~1.53	24.2~119	With crops, less than 20%, if none, less than 40% ; average soil	0.61~2.44	Evaporation, groundwater, few runoff	BOD, SS and Nutrient are eliminated; increasing TDS	Produce as many plant products as possible
Rapid Infiltration (RI)	3.35~153	0.21~10.7	Either ; coarse sand, sandy loam	3.05	Partly by evaporating, groundwater, no runoff	Diminishing BOD、SS ; TDS urinfluenced	Reinjecting or filtrating water; fewer plant products
Overland Flow (OF)	1.53~7.6	4.85~24.2	2%-8 % ; clay, silty soil	Not regulated	Partly by evaporating or groundwater, surface runoff	Diminishing BOD,SS and Nutrient ; increasing TDS	Plant growing
Wetland System	18.25	1.64	1%-8 %; soil at upper layer with gravels at bottom	Not regulated	Partly by evaporating or groundwater, surface runoff	Diminishing BOD,SS and Nutrient ; increasing TDS	Plant growing

(Wang, 1990)

Table 2. Comparison of these four types of Land Treatment Techniques

The system operation includes physical sedimentation and filtration, chemical adsorption, ion exchange, oxidation-reduction reaction, decomposition of biological metabolism and so on. In addition, plant absorption also contributes to the system. Explanations are as followed:

Sedimentation: When sewage flows into the system, in response to flow retardation, suspended pollutants then settles down. As a matter of fact, this process is similar to sediment basins in wastewater treatment plant.

Filtration: Sewage filtration is process in the basement soil by blocking or retarding sewage particles; which is similar to sand filter bed in water treatment plant.

Adsorption: Particles at basement soil or sediment are capable of absorbing organisms or odor materials. Besides, other plants such as Pistia stratiotes L., Eichhornia crassipe, and Commelina communis L. are possessed of absorbing heavy metals.
Ion exchange: Particles in basement soil often possess various charged ions; thus, ion exchanges occur between basement soil particles with ionic contaminants (heavy metals and other salt chemicals) or nutrients (ammonium ion, nitrate, and phosphate), finally eliminate them from sewage.
Oxidation and reduction: Due to the difference of oxygen supply and oxygen consumption rate, aerobic and anaerobic environments are formed on system's surface layer, roots of water plants or wetland surfaces, resulting in the divergence of oxidation reduction potential. In an aerobic environment, high oxidation reduction potential stimulates chemical oxidative reaction to sewage pollutants; on the contrary, oxygen reduction occurs when in anaerobic situations. Oxidation reduction reaction changes pollutants' chemical property, making them either harmless materials or easier treatment processes.
Metabolic degradation: A huge amounts of microorganism exist in the system; thus, metabolic degradation takes place in terms of organisms and nutrients in sewage and then turns them into either harmless chemicals or simple metabolic waste. Speaking of microorganisms, bacteria are the dominant decomposers, followed by fungus. As for protozoan, they balance the number of bacteria as predators. Algae in microorganisms are primary producers in ecological environment; for instance, they conduct photosynthesis and then release oxygen, absorbing inorganic nutrients during metabolism, resulting in water purification.
Plants functions: Generally speaking, there are some aquatic plants and semi-aquatic plants existing in the system, like Water Hyacinth, Commelina Communis L., Pennisetum Purpureum, Cattail, Bulrush and so on; just like algae, plants conduct photosynthesis, in addition to release oxygen and absorb inorganic salt, their roots provide mediums for bacterial growth. (Yang, 1996）
Structurally, the Land Treatment System includes oxidation ponds, water storage ponds, irrigation system, and drainage system; for the types of construction, it is mainly conducted by ecological engineering. Concerning factors are as followed:

1. Stepwise aeration: Taking advantage of the altitude difference, stacking gravels and rocks to form a simple water barrier as to increase the area of water's in tough with the air, finally rise up dissolved oxygen value.
2. Oxidation pond: Also named stabilization ponds. It's an ancient sewage treatment technique; advantages are as followed: using the terrain thoroughly and carries out reclamation of sewage (low energy consumption). Furthermore, there are several creatures living inside, which includes bacteria, fungus, algae, protozoan, metazoan and aquatic plants. Due to green plants' photosynthesis (especially from algae), they supply sufficient oxygen for other organisms under water, and enable them to conduct sewage purifications, including dilution effect, sedimentation, flocculation, aerobic and anaerobic metabolic decomposition, functions from aquatic vascular plants and planktons.（Li, 2002）
3. Water storage pond: After sewage flowing through oxidation pond, the next stop is the water storage pond. In this process, the flow slows down, triggering sedimentation.
4. Land treatment techniques: To this day, developed sewage treatment types can be classified as: (1) The Slow Rate Method (SR): Also named slow rate infiltration. It refers

to apply wastewater on a land with vegetation at a slow rate to avoid wastewater runoff and it is treated both by plants and microorganisms present in the soil. (2) Rapid Infiltration (RI): The RI process uses the soil matrix for physical, chemical, and biological treatment, which is similar to simulate the soil matrix as a chromatography column carrier (3) Overland Flow (OF): It is applied to the top portion of a sloping land grown over with grass and flows down the terrace to a runoff collection channel at the bottom of the slope. Some wastewater evaporate while others then flow into collection pipes. (4) Wetland System: This method covers part of the Land Treatment System and Aquatic biological treatment. To make short of this matter, filling in standard packages (e.g. gravel) at a settled gradient on a low laying land with settled length breadth ratio and slope at bottom. Then, growing good processing performance, high survival rate, long growth cycle, beautiful, and cost-efficient plants (such as Phragmites communis) in order to form a ecological Wetland System. (Wang, 1990,2000; Yuan et al, 2001）

4.2 Theory and application principles of ecological engineering

In 1938, Germany, Seifert first addressed the concept of near-natural river and stream control; in 1962, H.T. Odum brought the phrase "Ecological Engineering". Trace back the history of humankind's development, it repeatedly revealed that how mankind ignore and disrespect Mother Nature. Therefore, many scholars had addressed their perceptions and researches until the book Ecological Engineering was published , Mitsch, Jorgensn, 1989, the concept of combining ecology and engineer officially spread to people. (Lin and Qiu, 2003; Mitsch, 1998) Moreover, in 1993, as a result of a series of significant activities and campaigns such as holding seminars in Washington, publishing special topics on ecological engineering in important scientific journals like Environmental Science and Technology, and the establishment of International Ecological Engineering Society in Utrecht, Holland, all affected and founded the foundation of ecological engineering.

In 1989, Mitsch and Jorgensen systematically sorted out other scholars' comments, defining the essence and connotation of ecological engineering which included: (1) Self-design; (2) eco-system conservation; (3) based on solar energy; (4) it's a part of, not apart from nature. Thus, based on those principles, while constructing ecological engineering projects, considerations need to be made as followed: (1) Safety issue; (2) biotope conservation near by constructions; (3) reducing impacts on ecology system during constructing; (4) the must follow-up treatments to ecological environment. (Lin & Qui, 2003) In short, following standard principles and rules when starting a ecological engineering, making appropriate designs according to local resources and situations in order not to process it in a mess or being reproached.

In the past, firm, durable, once and for all structures were engineering purposes; therefore, reinforced concrete works became the best choice. From village gutters, irrigation waterways, retaining walls to drainage channels (picture 8), all adopted this method. Meanwhile, in order to maintain headcounts saving, low time-consuming and construction convenience, engineering heavily depended on amounts of machines. As a consequence, finished constructions were always extraordinary huge or became standard template structures, building by one-size-fit-all molds. For instance, common seawalls, riverbank constructions, and wave energy dissipating concrete blocks belong to the category. Those undue size and occasionally impractical reinforced concrete works not only damaged the nature, but also harmed creatures' habitats (Shie, 2001); most importantly, making them the victims when disasters happen.



Picture 8. On the left side: Irrigation and drainage waterways constructed with reinforced concrete; on the right side: Covering slope collapse with cement concrete structure then grew plants on the steep hillside.

Settings of Land Treatment System structurally belong to artificial facilities; however, it could evolve with natural ecology by creature's sustainable self-purification ability. Land Treatment System is capable of various scales; also, it's adjustable in regard of to local terrace or spaces. Therefore, basing on those basic principles, successful results can be achieved.

For rivers and streams, relevant materials can be collected locally in order to build revetments, consolidation works, weirs, fish ladders and so on. Because of this, not only the construction costs can be low down, but also benefits local environments, visual landscape, ecological restoration, green planting and the outcome of engineering. Even the construction was damaged by flood such as being crashed, covered, and submerged of sandy soil, driftwood or trash, the renovation cost would be much cheaper. Most importantly, without those huge steel and concrete wastes that were difficult to clean, the maintenance such as clean away rubbish and weeding would be easier.

Regarding to the water consumption in Taiwan, agriculture water use ranks the highest (more than 70%); nevertheless, if with the industrial transformation and the adjustments of water resource use as well as the reuse of irrigation water resource from these enormous water conservation facilities, the agriculture water consumption would decrease effectively. At the same time, groundwater pumping could also declined; in that way, the problems of Chia-Nan area subsidence would be improved; thus, future water resource can be stored. Furthermore, irrigation quality precautionary system could be installed if we constructed an irrigation area on slopes near by waterway entrance; by doing this, industrial and domestic sewage, relevant agriculture loss could be avoided, safeguarding to farmers and consumers. Moreover, structuring the Land Treatment System at back end of the whole irrigation system (or Aquatic Plant System) will make agricultural drainage more eco-friendly. Since fertilizer and agrochemical utilizations are unavoidable during agricultural activities in Taiwan, preventions of underground water contamination could be made by setting up an artificial treatment system before drainage gets into ordinary rivers or streams. Especially for troublesome chemicals like nitrate-nitrogen can be effectively decreased after this water

treatment system. Also, during fallow durations, the system would prevent nitrate-nitrogen from draining into aquifers in order not to pollute groundwater. (Washington State Department of Ecology, 2004)

5. Application example of land treatment system

5.1 Land treatment system at national yunlin university of science and technology

National Yunlin University of Science and Technology was founded in 1991. Prior to the founding of the school, a huge sugarcane field lied on the region with a principle irrigation waterway across the campus from east to west; after detailed planning and construction, it became a beautiful connection of rivers and lakes. In 2000, in light of achieving the mission of sustainable campus, those widened irrigation waterways construction of present lakes were renovated to a Land Treatment System, as to cope with sewage that flows into the school. This land system of ecological engineering can be divided into the following parts: (1) Step aeration; (2) oxidation pond; (3) water storage pond and (4) irrigated area (picture 9). With the widely distributed system, the principle of natural design for existing plants were adopted; that is, with the changes of seasons and temperatures, plant succession enabled the formation of new species approximately every two months, especially in irrigation area.



(a)



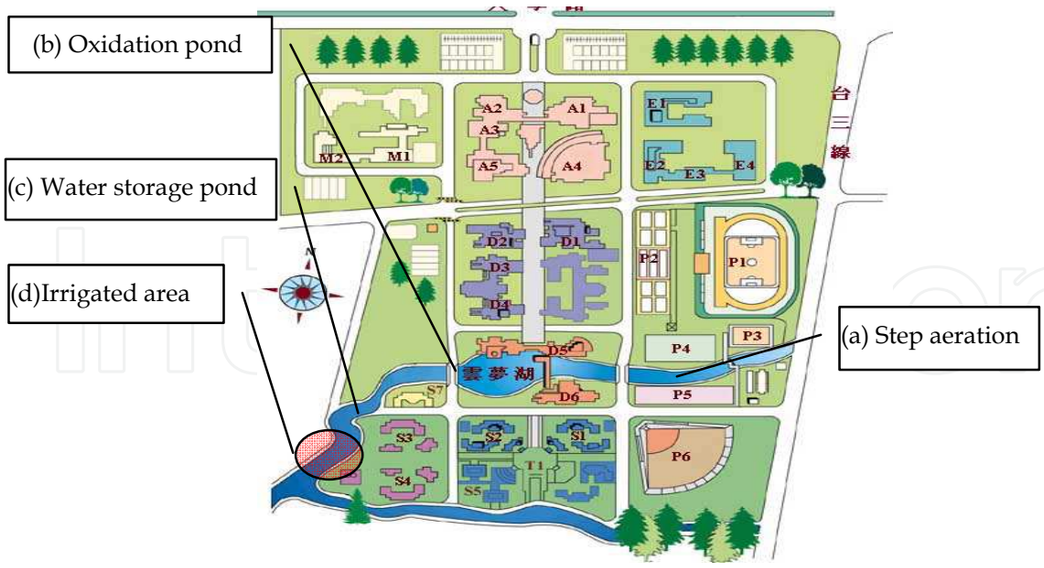
(b)



(c)



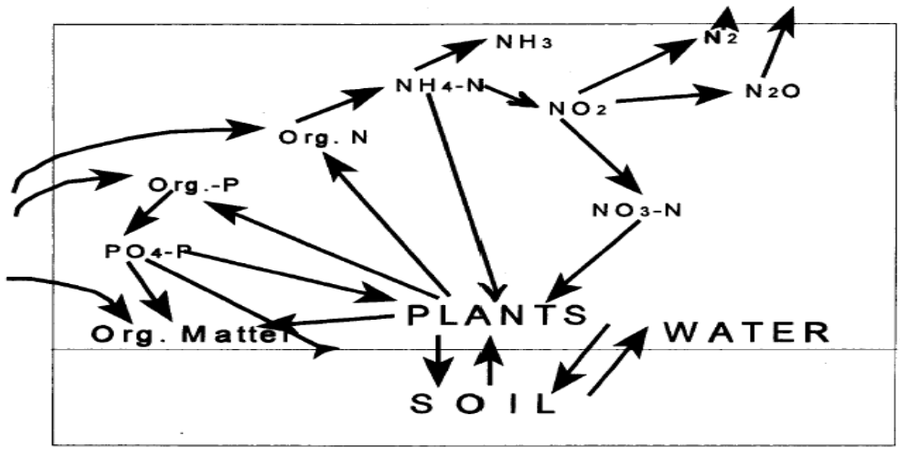
(d)



Picture 9. Main Parts that Consist Land Treatment System and location in the campus map: (a) Step aeration, (b) oxidation pond, (c) water storage pond and (d) irrigated area.

5.2 Functions of water purification

Generally speaking, common river pollution resources included industrial wastewater, livestock wastewater, irrigation runoff, and domestic sewage. For the waterways' external pollution sources, those many came from upper course of agricultural drainage and livelihood wastewater; therefore, nitrogen and phosphorus contaminations are the dominance. However, the nutrients transformation in the irrigation area covered physical, chemical and biological activities (picture 10); including soil filter retention, physisorptions, chemisorption, biological decomposition and phytoextraction.



Picture 10. Nutrients transformation in irrigation area

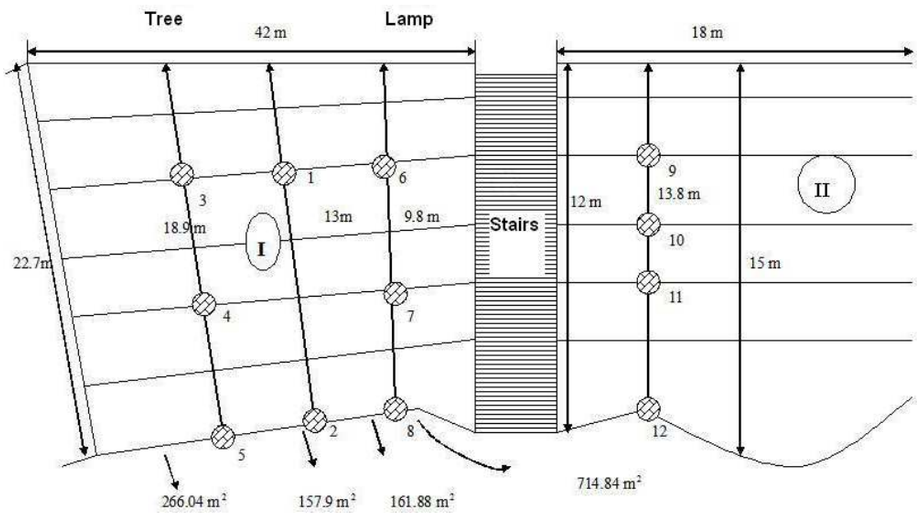
5.2.1 The removal of nitrogen

The element nitrogen (has the symbol N) in sewage is classified to four types when flowing into the soil: organic nitrogen, ammonian, nitrite and nitrate. Organic nitrogen mainly

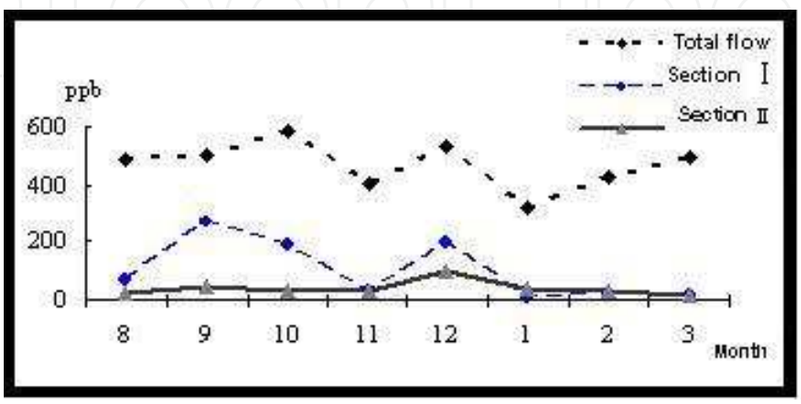
presents as a suspended state, affecting by filter retention and then mineralizes to ammonian (Wang, 1990). Ammonian can be eliminated after Atmospheric volatile, organification, and plants absorption; moreover, with an aerobic environment, because of oxidation, nitrogen would transform from nitrosomonas to nitrite; next, oxidized with nitrobacteria to nitrate, finally being eliminated in result of denitrification bacteria returning to nitrogen. Referring to the monitoring data, explanation is as followed:

1. The removal of nitrite

Even though the concentration of nitrate in livelihood and agricultural wastewater is lower, a few amounts of nitrate (100PPb) will cause great damage to human bodies. According to research, for eliminating nitrate in irrigation area, the effectiveness is superior, In light of the difference of nitrate concentrations, the flow concentrations of section 1 and section 2 (picture 11 and 12) are between 9-270, 16-94 ppb, respectively; moreover, the eliminating rate reaches 47-97%, 82-97%, respectively. In terms of the inferior eliminating rate in section 1, the reason might be from its bad plant growing since there are not too many dominant plants existed; therefore, eliminating rate in section 1 is not stabilized.



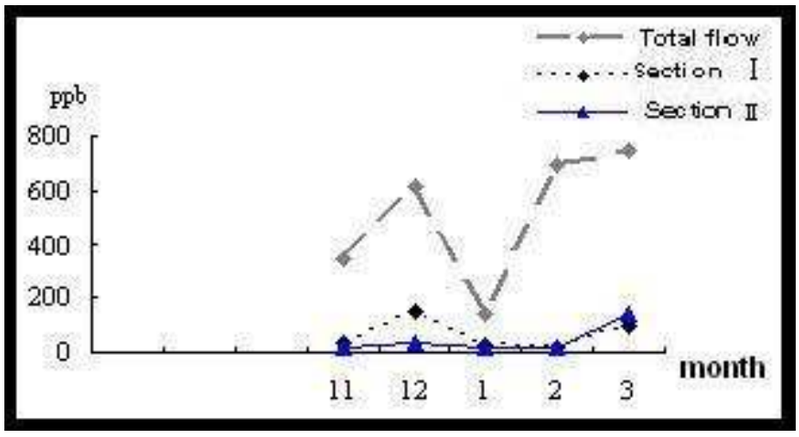
Picture 11. Sampling distribution of irrigation area (Stairs in the middle, section 1 at left side, section 2 at right)



Picture 12. Nitrate concentration of flow from section 1and 2 in irrigation area

2. The removal of ammonian

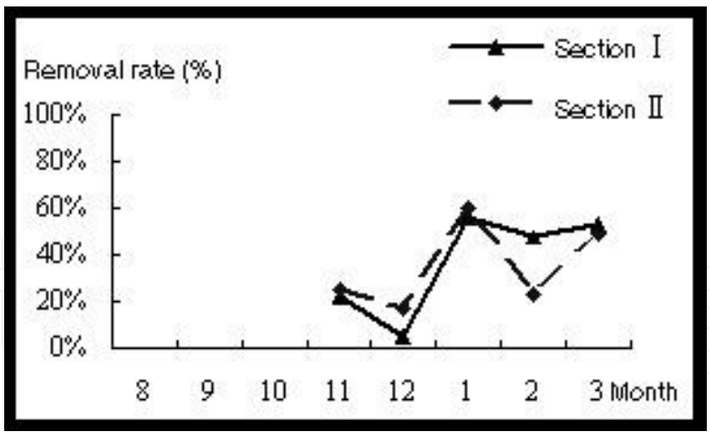
Picture 13 refers to the ammonian concentration of effluent water of section 1 and 2 in irrigation area; from this, it indicates the tendency similarity with picture 4. According to scholars Sz Gung, Tzeng and Jr Cheng, Jang, 1996, by conducting clayey soil treatment, approximately 16% ammonian in sewage would be absorbed by plants, 14% became organic ingredients after organification, 24% were removed either by denitrification or volatilization. Therefore, plants play an important role when removing water ammonian; thus, comparing the plants growing situation on both sections, the results were: In December, plants growing situation in section 2 was better than section 1, so the ammonian removing rate was higher in section 2 (92%); however, in March, plants growing situation got flourished in section 1 (mainly were Commelina paludosa), so ammonian removing rate in section 2 worsened (81%) than that in section 1 (84%).



Picture 13. The Concentration of Ammonian in Effluent Water of Section I in Irrigation Area

3. The removal of nitrate

In light of the removal of nitrate in Land Treatment System, usually it's nothing more than either plants absorption or biological denitrification and there are two environmental properties that would stimulate denitrification. (1) Anoxic sediments. (Oxidation reduction potential less than 300mV) (2) Carbon fuel supply from plants growing (Baker, 1998). In light of picture 14, it reveals the instable removal rate of nitrate, ranging from 5%-60%; nevertheless, from the perspective of plants absorption, nitrate is the main nutrient to plants, usually by root absorption. While comparing plants with dominant species of each month, Ageratum was the main dominant plant species in January, differentiating to other dominant plant species; also, the climate got warmer after January, which could be another factor that caused plants absorption. In terms of microbial denitrification, influence factors included pH, carbon nitrogen ratio and oxidation reduction potential (ORP), there were no specific findings during comparison. However, with higher plants density, there will be more microorganisms being absorbed around the roots. In addition to denitrification under anoxic situations, other microorganisms such as mycorrizae (Tsai, 1994) could accelerate the speed of plants absorption, and increase the removal rate of nitrogenous compounds in nitrate.



Picture 14. Nitrate Removal Rate Comparison of Effluent Water in Section I

5.2.2 The removal of phosphorus

In terms of removing phosphorus in land treatment, soil and plants absorptions are the dominant approaches. (Tzeng, Jang, 1996) Total phosphorus includes orthophosphate, polyphosphate and organophosphorus; almost all inorganic phosphates exist in phosphate types. Such as orthophosphate (PO43-,HPO42-,H2PO4-) or polyphosphate(P2O74-,P3O105-,HP3O92-,CaP2O72-).

From the aspect of removing orthophosphates, research shows that the removal rate is higher during spring and summer (about 35%-80%); whereas in autumn and winter, the rate is much lower (less than 57%); sometimes release phenomenon even occurs. From other documents (Wu, 2001; Tanner etal. ,1993), similar situations also were mentioned; possible reasons were because of higher temperatures during spring and summer so that lead to prosperous plants and microorganisms activities, resulting in the strengthen of absorption and metabolism. However, the removal of total phosphates ranged from 23%-73%.

5.2.3 Removal of other materials

According to researches, Commelina communis L. had the strongest absorption and resistant abilities to iron; for cadmium absorption and resistant ability, Patchouli thistle and Bidens had better performance; for absorbing and resisting magnesium, all plants affected well, especially Mikania cordata. As for copper and zinc absorption and resistant ability, Patchouli thistle and Commelina communis L. were superior to the former, whereas Ageratum to the latter; Micrantha, Bidens and Humulus functioned averagely. (Jeng, 2003)

In addition to functions of plants above, soil microorganisms surely could also absorb the heavy metal element: manganese; the best absorption time is 96 hours and its adsorbent concentration could rise to 1000 ppm (mg/L) whereas the maximum limitation of resisting manganese is 2000 ppm. (Yuang, Fang, Chang, 2003)

Besides, relevant researches about microorganisms' absorption and resistant ability of copper, zinc and cadmium showed that soil microorganisms which existed near by Commelina communis roots could exposure to maximum limitation ranges- copper (2500 – 3000 ppm), zinc (16800 – 19200 ppm) and cadmium (2400 – 3000 ppm); this indicated how tough the microorganism could take while resisting heavy medals, and was in line with the reaction of the plant (Commelina communis). (Yuang, Guo, 2003)

Furthermore, irrigation area not only had a clearly processing function to heavy medals, but also superior removal effects on the weed killer- glyphosate. Basic on the research done by

Yuan, Chang and Fan in 2004, after applying glyphosate in irrigation area, the dominant plant which absorbed the most glyphosate was Mikania Cordata, the absorption amounts was 2986.53 mg glyp/kg (plant net weight); next came Humulus and the worst absorption ability belonged to Bidens. In terms of those three plants' metabolic condition of glyphosate, Mikania Cordata was capable of extremely high metabolic effect, thus could eliminate about 90.1% of glyphosate in plants, next came Humulus japonicus, the least was Bidens.
As a consequence, plants can play the role of decontamination only with microorganisms' assistance, if not, it would not be functional. Therefore, the basic irrigation system based on plants-microorganism-soil can actually process water purification thoroughly, and all water quality parameters are in line with water quality standard.

5.3 Impacts of global changes

The flora composition has an obviously water purification function but is influenced by temperature changes. Therefore, observing the flora composition changes, especially the succession of dominant plants with high level of affection, can be an useful water quality standard indicator.
Humulus japonicus was the most stable and dominant plant before 2006, though not thoroughly in irrigation area, still contributed to water purification in certain level (Jen, 2004; Huang, 2011). However, because of global changes, during May 2009 to March 20011, Humulus japonicus only dominated 30% of all regions.
According to Huang's research (2011), the removal affection of nitrate nitrogen in Land Treatment System would rise up as the temperature got higher; the effect would decline if the average temperature decreased. This result was in accordance with relevant documents, showing the removal rate of ammonian in artifitial wetland system was about 0.3-1.1g/m2/d, and would change by the changes of temperature. It was because of plants grow slower during winter, thus it decreases the nutrients usage; as a result, the nitrogen removal rate would be affected by temperature obviously, with higher temperature comes better removal rate (Sikora et al., 1995 ; Van Oostrom, 1995). As for orthophosphate, the correlation was not something obvious.
Moreover, with adequate climate, the flowering period of Mikania cordata starts from October to December annually, after this period, the orthophosphate removal rate will decrease. However, due to La Nina occurred during 2009-2010, at this period, rainfall and temperature changed rapidly which lead to either earlier or delayed flowering period of Mikania cordata.

5.4 Regular harvesting in irrigation area

Using plants as a water purification approach has been proved in terms of the long term observation in irrigation area. Yet, with the growing of plants, the problem of leaching out nitrogen and phosphorus is the current issue. According to research, after harvesting plants in irrigation area, the nitrate removal rate would drop to the lowest on the third day, gradually rise to 10%; for orthophosphate removal rate, it would maintain stable on the third day and increase to positive value on the thirtieth day. What peculiarly is that in the harvesting area, the average removal rate of chemical oxygen demand (COD) was 41.41%, comparing to the figure 26.09% and 22.63% in contrast area, the former one was much higher obviously (Huang, 2011). Since the harvesting season is in summer with higher temperature, plants grew much faster, thus it was fit for harvesting.
Therefore, conduct regularly harvesting benefits to refresh the plant system and also a wonderful maintenance approach of water purification.

5.5 Sustainable development

With the rapid development of urbanization in Taiwan, farmlands decrease and polluted irrigation water are undeniable facts. Thus, how to apply current facilities and resources to improve deteriorating environment and ecology will be an urgent issue for Taiwan even other developing countries.

If the government can scheme a new plan for the west of Taiwan with irrigation waterways, making the best of water conservation areas with the concept of community empowerment to conduct sewage ecological treatment by designing superior hardware facilities and simple management and operational guidebook, any unprofessional community citizen can play the role of management and maintenance. Considering the advantages of low cost of settings and simple maintenance work, the outcome in National Yunlin University of Science and Technology can be a good reference.

In 21st century, the influence of global changes gradually becomes serious; meanwhile, drought and flood disasters might be common in the future; therefore, how to cope with this issue has been an inescapable task to face of all countries on earth. Surely Taiwan is no exception; therefore, starting from management by reallocating water resource in order to transfer redundant agricultural irrigation water to livelihood and industry. For polluted irrigation water, streams and rivers, conducting remediation with the concept of Land Treatment System such as process with ecological engineering on slopes of irrigation waterways in water conservation area would be a useful way of finding new sources and reducing water expense. Facing this inescapable challenge, Land Treatment System would be on of the solutions to develop sustainably.

6. Conclusion

The design of Land Treatment System was made to meet the trends of irrigation system. Making use of current irrigation waterways by implementing ecological engineering as to foster mother nature to heal and develop herself and to purify polluted water, thus to increase available water resources. Functioned by the combination of "earth-microorganism-plants" effect, it can be applied not only to livelihood wastewater usage but also irrigation; most importantly, the outcome is satisfying.

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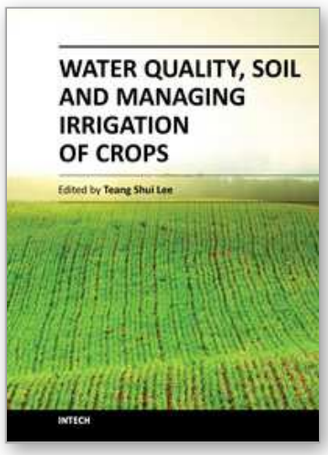
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Water Quality, Soil and Managing Irrigation of Crops

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The book entitled Water Quality, Soil and Managing Irrigation of Crops comprises three sections, specifically: Reuse Water Quality, Soil and Pollution which comprises five technical chapters, Managing Irrigation of Crops with four, and Examples of Irrigation Systems three technical chapters, all presented by the respective authors in their own fields of expertise. This text should be of interest to those who are interested in the safe reuse of water for irrigation purposes in terms of effluent quality and quality of urban drainage basins, as well as to those who are involved with research into the problems of soils in relation to pollution and health, infiltration and effects of irrigation and managing irrigation systems including basin type of irrigation, as well as the subsurface method of irrigation. The many examples are indeed a semblance of real world irrigation practices of general interest to practitioners, more so when the venues of these projects illustrated cover a fair range of climate environments.

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