〈Review〉

Typical Patterns of Ecological Engineering in Southern China

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ABSTRACT : With the emergence and development of ecological engineering in China, and also the research and demonstration of Chinese Ecological Agriculture (CEA), in recent 10 years many types of ecological engineering have been appeared in Southern China, they could be classified into 4 typical patterns. These typical patterns are: 1. Ecological Building (EB), such as ecological public toilet, ecological garden, ecological integrated building, farmers" ecological household, the combine of ecological building and CEA; 2. Ecological Engineering in Paddy Field (EEPF), like rice-fish system, water caltrop-wild ricestem-fish system, mulberry-silkworm-pig-fish system; 3. Ecological Engineering of Agroforestry Systems (EEAF), as tea-food crops intercropping system, rubber-tea-chicken system, bamboo-chicken system, fruit tree-chicken system, metasequoia-fish-duck system; 4. Ecological Engineering Linked with Biogas (EELB), such as animal (pig)-biogas-fish system, animal (pig)-biogas-fruit tree system, animal-biogas-food crops system. Some case studies were presented in the paper. It is showed that these typical patterns have better ecological, social and economic benefits, now they are deeply been extending in southern China.

Key words : Agroforestry systems, Benefits, Biogas, Ecological Building, Ecological Engineering, Rice-Fish System, Southern China

INTRODUCTION

Nowadays, people are facing cosmopolitan issues such as rapid increase of population, shortage of natural resources, and environmental pollution. In west developed countries, high developed industrialization and intensive agriculture have resulted in lots of problems including ecological and social issues; while in developing countries, such issues are more complex, such as rapid increase of population, excess exploitation and destruction of natural resources, production insufficiency and unreasonable development. And some environmental issues are also produced such as greenhouse effect, ozonosphere inanition, etc.

These problems are always been trying to settle by human. It is about 20 years ago when people coped with environmental problems mainly with the environmental technique. But this technique may result in transferring of polluted substances among the mediums, and at the same time consume a great deal of energy. Some economists suggested "zero effluent", namely forbidding the contamination flowing substance completely. As we all know that it is very difficult realize "zero effluent". Even others bring forward "limitation production and development globally", by all appearances it is unfair. The strategy of "sustainable developmental" for global environment and economic development was put out on the World Commission on Environment and Development at 1987 by Mrs. Blundtland, the former prime minister of Norway. And it was defined as "development that meets needs of the present without compromising the ability of future generations to meet their own needs" (World Commission On Environment and Development. Our common future, 1987). The concept of sustainable development combined with economy and environment, when the two aspects comes into conflicted, priority of ecological effect will be taken (Qing and Zhang 1998). Under the situation as stated above, ecological engineering emerges as the times required.

The Southern China, from north latitude 32°to various islands in South China Sea, and from Taiwan as well as the islands to Yunnan-Guizhou Plateau and Hengduan Mountain, the total area is about 2.1796×10^6 km^2, it is 22.7% of the total area of China. It is consisted of all areas of Zhejiang province, Jiangxi province, Hunan province, Fujian province, Guangdong province, Hainan province, Guangxi province, Guizhou and Taiwan province; greater part of Yunnan and Sichuan province; part of south of Hubei and Anhui province; and subsection of southeast of Xizang province as well as southwest of Jiangsu province (He 1994) .The geographic location of Sounth China is showed in Fig.1 as the area in color purple.

This area threads the tropic, south subtropics, middle subtropics and north to middle subtropics transition zone. It is very warm and rainfall is abundant. It is rich in light, heat, water, soil and biolo-

† This article was presented at the INTECOL meeting (Seoul, August 2002).
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Fig. 1. Schematic diagram of geography location of South China.

gical natural resources. Since the Reformation and Opening, economy was developed rapidly and population was increased speedy. Lots of experiences are piled up in these years at the aspects of dealing with the problems between economy development and ecological environment protection, population increase and food production as well as providing. And several ecological engineering patterns which adapt to the local conditions have been appeared.

The emergence and development of the ecological engineering in modern China

Ecological engineering is an aged and young, earthly and abstruse subject. Many simply and spontaneity ecological engineering patterns have been actualized in China for about 3000 years which is long existing (Ye *et al*. 2002). But there was no principle being concluded, the methodology had not been formed, and the study object was even uncertain, it is only homeliness and spontaneity practice and thought, it had not become into a new subject. The advancing of ecological engineering as a special study field in international ecological academia was begun at the early of 60 decade. At 1962, the American famous ecologist H.T. Odum used the word "ecological engineering" at first time, and put the definition, since then, he discourse and practice on it continually. And he is considered as the forerunner and founder of ecological engineering in the world. Ever since 80 decade, the ecological engineering study has been developed vigorously, especially at the field of agroecological engineering (Zhang *et al*. 1998). The famous ecologist Ma Shijun contributed outstandingly to ecological engineering movement in China, put forward the original concept, principle and method of ecological engineering. Based on lots of Chinese traditional practices of ecological engineering, Mr. Ma induced out the ecological engineering principle as "integrated, coordinate, recycling, regeneration", and defined the study object as social-economic-natural complex ecological system, then ecological engineering was made a new subject. The book "Ecological Engineering" was published in America in 1989, which edited by Mitsch and Jorgensen, wrote in collaboration with scholars from China, America, Canada, Denmark, Japan, etc. In this book, foundation principle and methods were advanced definitely. From then on, the ecological engineering has been considered as a new disciplinary in the international academia.

Though there are many similar points in ecological engineering principles and practice researches, there are some differences between Chinese and Western ecological engineering in the aspects of purposes of research and application, theoretic basis, design principle, technology, human manipulation of ecosystem structure and recognized values, with the various special background of society, culture, economy, science and technology (Yan and Mitsch 1994). Development of Chinese ecological engineering has its own characters. Patterns of Chinese ecological engineering, interposition and participation of human sometimes preponderate over maintain ability of system, a great deal of manpower has been devoted into systems. System framework of Chinese Ecological Engineering is more complex and multiplex, and it has higher species diversity, as well as the framework has more multilayer and multilevel. It is realized much of the substance circulation and plenitude utilize of resource, and ecology, economy and social benefits are required to obtain at the same time.

It has been witnessed great advances in ecological engineering in the past decade in China. The objective of the study has expanded to cover the entire social-economic-and-natural complex ecosystem, oriented for sustainable development, benefit to both human society and nature, coordinated development of economy and environment, and shift from one-dimensional pursuit of economic growth or environment and nature conservation to three-dimensional of prosperity of three-in-one complex ecology comprising wealth (growth and accumulation of both economic and ecological sets), health (physical and intellectual integrity of people and sound service function and metabolism of ecosystem) and culture (material, spiritual and ecological civilization). Based on four consummated rationales of integrated (of time, space and function), coordinate (symbiosis and co-evolution), recycling (material and information feedback) and spontaneity (competition and self-regulation), and eco-cybernetics. Eight principles for ecological engineering designing have been derived (as showed in Fig. 2). And these principles may be put into three classes: competition principle of striving for resource and exploiting niche; symbiosis principle between human and nature, human and human, as well as subsystem and mother-system; spontaneity principle with self-organization, self-regulation and self-compensation to maintain the structure, function and process. Its methodology has developed from physical quantification to ecological seriation, from optimization of engineering structure to evolution of ecological patterns, and from mechanical artificial intelligence to human ecological intelligence. Its technical route has been developed to include coupling of hardware, software and mindware, combination of multi-disciplinary and multi-technological systems, regulation of the entire ecological course of compound ecosystem, expression of environment protection in production and consumption and of waste deposal in utilization, and vertical and horizontal coupling of structure with function into food chain network, life cycle net work and ecosystem network (Wang and Yan 1998). More over, its application scope has been expanding to a variety of fields.

There have been about 1000 papers which is related Chinese ecological engineering, including more than 100 published on the international famous publications, as well as 3 Chinese ecological engineering monographs and 1 English agriculture ecological engineering monograph. The publishing "Ecological Engineering" published the "Chinese special issue" in 1992 and 1998, and "International Ecological Engineering Conference" was held in 1996 at Beijing. Then the Chinese ecological engineering not only occupies a space in international academia, but also becoming one aspect in the front fields in Chinese ecological field.

The typical ecological engineering patterns in southern China

With the emergence and development of ecological engineering in China, and also the research and demonstration of Chinese Ecological Agriculture (CEA), in recent 10 years many types of ecological engineering have been appeared in Southern China, which is adapted to local attentions. And these patterns have contributed to resolve ecological problems such as population, environment, and resource. These patterns have their own characters with adaptation to various natural and socioeconomic conditions, and they could be classified into 4 typical patterns as follows:

Ecological Building

So called ecological building, it should be said that buildings have sound recycling or greenness building. There are three characters of the ecological building: the first, biogas pool is set up under ground, and the biogas pool is not the ordinary biogas pool, it is the biogas purified pool whose mainly objective is depuration and this is the key problem; the second, solar energy utilize setting or fishing pool is planting and founding at the housetop; the third, the wall green is planted by uprightly planting with flowers, grass, etc. It can be called ecological building only when it has the three building characters stated upwards.

According to the difference of composition, configuration and the function of ecological buildings, ecological buildings are in following types: ecological public toilet, ecological garden, ecological integrated building, farmers" ecological household, the combine of ecological building and CEA, etc.

There are gardens, farmland, fish pool, etc. in the ecological garden. The energy and matter have been made into comprehensive utilization with the core function of ecological building according to the difference levels as high, medium and low. The schematic diagram of energy and matter flowing in ecological garden model is showed in Fig. 3.

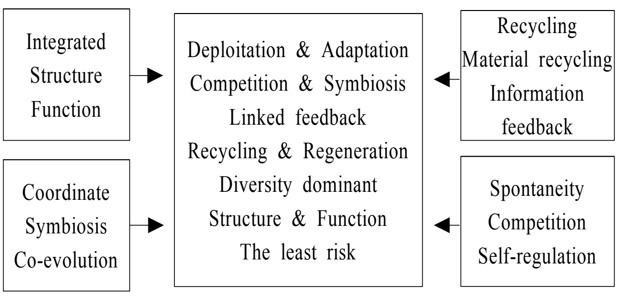

Fig. 2. Basic fundamentals and design principles for ecological engineering.

Ecological Engineering in Paddy Field (EEPF)

In Southern China, hypsography is lower, and water resource is sufficient and convenient, so the main grain crop is rice. Recently years, with alteration and design in inhered farmland, practices of agro-ecological engineering were applied in large scale. The ecological engineering patterns in paddy field are developed rapidly, such as rice-fish system, water caltrop-wild rice stem-fish system, mulberry-silkworm-pig-fish system, etc. And they have gotten remarkable economic and ecological benefits.

Water around paddyfield contains abundant organic chippings, planktons and manifold insects, and these are good feeds for aquatic products such as fish, shrimp, crab and turtle, etc. The schematic diagram of breeding aquatics in the paddyfield is showed in Fig. 4.

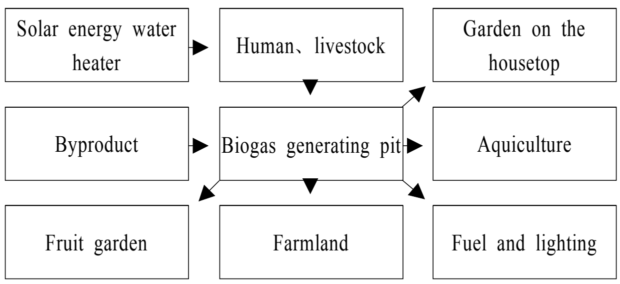

Fig. 3. Schematic diagram of energy and matter flow in ecological courtyard model ecological building.

Yan Jingping and Lu Jianbo 2001. Agroecological Engineering and Technology. Chinese Chemical Industry Press. Beijing. pp 294~299.

When aquatic is introduced into paddy field, they can find sound inhabited places, and also kill pest and improve water quality as well as soil texture in the paddyfield simultaneity, and then on they will increase the fertility in the paddy field. As a result, raising aquatics in paddy field is an ecological technology which uses water to ensure animal and plant to receive mutual benefit and symbiosis, make matter and energy in sufficiency utilization, and get results as double bumper of rice and aquatics. Furthermore, rice-fish system can save a great deal of land and water resources, economize corresponded expense on pound digging, then it lead finity soil and water resources into a sufficient utilized way. Simultaneity, it lightens stress of aquaculture compressive in reservoirs and lakes, and then reduces eutrophication press in breeding water bodies. So it can be said that it creates solid integrated benefits in singleness field.

Nowadays, technology of breeding in paddy field has been developed rapidly in Southern China. Raising fish in paddy field pattern was distributed in Jiangsu, Zhejiang, Sichuan, and the rice-duck-weed-fish pattern in Guangdong and Fujian. And these patterns have gotten sound economic and ecological benefits. For instance, rice-fish system was distributed widely in Dazu county Sichuan province; the total area is about 1.3×10^4 hm^2, and there are eight towns whose area of rice-fish system is up to 700 hm^2. The total input per hectare is added up to 7770 yuan, which is used to buy seed, mulch film, fertilizer, fry and feedstuff. The output from the system is about 23338.5 yuan, including 7575kg rice and 1875kg fish. The ratio of output to input in this system is 3:1 (Yan and Lu 2001). Many experiments indicates that the ecological engineering in paddy field can increase nitrogen, phosphorus, potassium and organic matters content in soil, and has the function of preventing weed, disease and insect simultaneity (Wang and Lei 2000, Lu and Huang 1988).

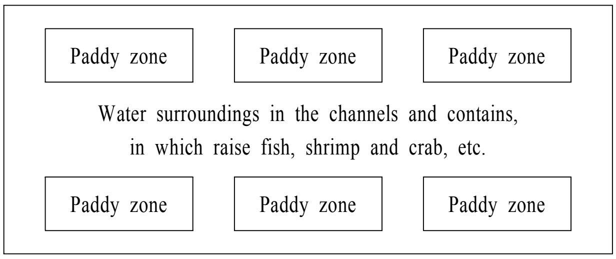

Fig. 4. Schematic diagram of breeding aquatics in the paddyfield. Qing Pei, An Shuqing and Yan Jingsong 1993. Science of Ecological Engineering. Nanking University Press, Nanking. pp140~146.

Ecological Engineering of Agroforestry Systems (EEAF)

Agroforestry is a complex term which compounded by technology and system of land utilization. Agroforestry has recently been defined as a dynamic, ecologically based, natural resource management system that, through integration of trees into farm- and rangeland, diversifies and sustains smallholder production for increased social, economic, and environmental benefits. Clearly, such increased benefits are an objective of any successful land-use system. Farmers in developed and developing countries have devised literally thousands of agroforestry practices and systems that are in active use.

In southern China, a wide range of woody plants such as arbor, fruit tree, mulberry tree, tea, and bamboo, are integrated with crops to produce diverse agroforestry systems with ecological and economic linkages (Liu 1987). Ecologically, components of agroforestry systems make full use of natural resources, and mutually and complementarily benefit from one another. Economically, short-term income from annual crops can be mixed with long-term purposes, shaping a balanced integration between short-term and long-term benefits so as to achieve system sustainability (Yang 1996). The patterns of agroforestry ecological engineering which distributed widely in Southern China are as follows: tea-food crops intercropping system, rubber-tea-chicken system, bamboo-chicken system, fruit tree-chicken system, metasequoia-fish-duck system, etc.

Rubber-tea-chicken agroforestry model is a typical tropical agro-forestry system in Wenchang city of Hainan Province, ecological and economic benefits were studied with quantitative study and qualitative analysis compared with single culture and inter-cropping rubber gardens by Zhejiang University. Results showed that the model could improve soil physical structure and fertility (as showed in Table 1), which increases the yield of rubber and tea, the quality of chicken. This traditional plus breeding model qualified the new technology of garden breeding conquered the disadvantages of long cycle length and excessive cost of foodstuff, with holding local traditional browsing fashion.

As showed in the Table 1, the organic matters, total nitrogen, total potassium, available nitrogen and available potassium content of soil in inter-cropping rubber garden is higher than that in single culture, and each soil fertility index in rubber-tea-chicken system is much higher than that of the other two systems. It must be resulted of the higher humidity in soil and air, and there are more deciduous leaves and branches in inter-cropping garden, while in rubber-tea-chicken system there is more organic input with chicken dung.

This agroforestry integrated system achieved the purpose of high product, high quality and high efficiency, with keep of especially taste of chicken. The economic flows are faster and the repayment period of investment becomes shorter, then it can bring high increment in this pattern. And chicken subsystem pays an important role in the system with the contribution rate of 94%. The rubber-tea-chicken agroforestry integrated model linked with chicken subsystem introduced dung into rubber, tea garden by manners of com-

Table 1. Soil fertility of single culture, inter-cropping and chicken rubber gardens

System	Soil layer (cm)	Organic matters (%)	TN (%)	TP (%)	TK (%)	AN (mg/kg)	AP (mg/kg)	AK (mg/kg)
Single culture	0~20	1.81	0.10	0.07	0.23	55.23	1.87	31.50
	20~40	1.34	0.09	0.06	0.25	42.16	1.32	28.30
Inter-cropping garden	0~20	2.30	0.11	0.07	0.27	63.45	1.19	43.20
	20~40	1.53	0.09	0.05	0.29	53.06	1.17	37.10
Rubber-tea-chicken garden	0~20	3.83	0.18	0.09	0.29	110.72	2.98	49.00
	20~40	2.02	0.12	0.07	0.30	98.87	2.01	42.10

TN: total nitrogen, TP: total phosphorus, TK: total potassium, AN: available nitrogen, AP: available phosphorus, AK: available potassium.

Meng Qingyan et al. 1999. Study on ecological benefits of rubber-tea-chicken agro-forestry model in tropical area of China. ACTA AGRICULTURAE ZHEJIANGENSIS 11(4):193~195.

prehensive utilization, then the multilayer solid spatial structure is built up. The various growth rhythms of rubber, tea and grass ensure the model make full use of the soil, light, heat and atmosphere (Meng *et al*. 1999, 2001).

Ecological Engineering Linked with Biogas (EELB)

In recently decades, the animal production industries have developed very quickly due to a variety of stimulations including, developed technologies, abundance of funds, sufficient feed, abundance of improved animal species, markets. And they have brought about significant economic benefits. However, an enormous amount of animal excrement was also produced, which consequently led to serious environmental pollution. Confronted with these new problems, with the leading of experts, several types of integrated ecological engineering models have emerged. And according to the sufficient light and heat resources, the biogas-project-linked ecological engineering model developed quickly in Southern China. The typical systems are: animal (pig)-biogas-fish system, animal (pig)-biogas-fruit trees system, animal-biogas-food crops system. In this paper using the Fushan Integrated Ecological Farm in Fushan village, Zhejiang Province, a typical ecological engineering project in south China, as an example, introduced the structure and the benefits of this type of ecological engineering pattern.

The system structure as well as the relationships between the components of the Fushan Integrated Ecological Farm is illustrated in Fig. 5. The rational design of system structure, with biogas project as central linkage, connects the various components of farm and enables multi-level utilization of resources and establishment of an ecologically sound material circulation within the integrated system (Ye *et al*. 2000).

As illustrated above, the rational design of system structure enables the farm to produce fuel-gas, regenerative feed and high-

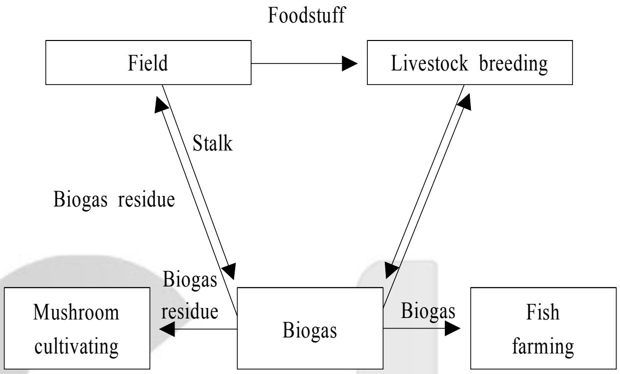

Fig. 5. Schematic diagram of the system structure of Fushan Integrated Ecological Farm, Zhejiang Province.

Yan Jingping and Lu Jianbo 2001. Agroecological Engineering and Technology. Chinese Chemical Industry Press, Beijing. pp 144.

quality organic fertilizer while improving the rural environment, thus achieving significant social, economic and ecological benefits.

According to statistics, during 1983~1993, the Fushan Integrated Ecological Farm produced a total of 28 000 pigs, 962 000 meat-type chickens, 3148 Mg of chicken eggs, 3057Mg of duck eggs, 800Mg of fish, 3.7Mg of turtles, and some minor 276 products such as tea, grape, vegetable, etc. In addition, it also produced a total of 7300Mg of feed and 1 million young animals, providing good services to animal husbandry development in the surrounding rural areas (Ye and Wang 1999). The Farm established new production projects at 1985, such as egg-type chicken, egg-type duck, young animal and aquaculture production, and expanded the production scale, with a sharp increase after the completion of the biogas project in 1988. This has successfully solved the problem of eco-environmental deterioration caused by increased animal husbandry production (Ye *et al*. 2000). The biogas project has a daily gas-generating capacity of

700m^3, producing a total of 254 000m^3 per year. This amount of biogas used as fuel saves 500Mg of coal and 40 000kWh of electricity every year, according to statistics, for the Farm and the village community on average. The use of biogas liquid as aquaculture feed saves an input of 2500 kg of feed, and as feed additive for pig production reduces an input of 25 kg of feed per pig, saving a cost of US $2.5. The use of biogas residues as regenerative feed and fertilizer saves 120Mg of feed and fertilizer in total annually (Ye *et al*. 2000). The expansion of the Farm"s production also created a large amount of job opportunities for the society. During 1983~1993, the total number of laborers in Fushan village maintained stability with the proportion engaged in animal husbandry production in the Farm increasing dramatically (20.6% per year) (Ye and Wang 1999). The Farm"s absorption of labor power takes advantage of surplus rural laborers resulting from the readjustment of cropping structure in response to rural enterprise development in modern China.

The dynamics of economic development of the Fushan Integrated Ecological Farm during 1983~1993 is shown that the economic indicators in terms of fixed assets, annual output value and annual net income all showed an increasing trend during this period. The various indicators increased as follows: fixed assets from US $27 805 in 1983 to US $1 567 073 in 1993, annual output value from US $29 707 to 4 295 244, and annual net income from US $6122 to 294 146, in the order of 55.4, 143.6 and 47.1 times more, respectively. In 1988, the village raised US $25 000 to construct the biogas project, and after only a year did the farm achieve a net income of US $78 415 in addition to the restoration of the funds invested the year before, laying a solid foundation for the expansion of production scale, readjustment of production activities and introduction of new production projects during the following years (Ye *et al*. 2002). The expansion of production scale was only possible whenever an opportunity to avoid the eco-environmental problems caused by the expansion itself was foreseen. The reduction in input costs of the whole system, because of utilizing biogas for heating and byproducts-biogas liquid and residues-as feed for animals and fertilizer for crops within the own system, is a partial benefit of the attempt to remove wastes produced in the farm.

As discussed above, the biogas project connects various sectors, which are originally separate, but forms a favorable recycling of agricultural resources. The animal excreta produced by animal husbandry production flow into biogas ponds through underground pipes and are treated under anaerobic conditions. This process sterilizes the parasites and pathogens, thus keeping the environment from being polluted and cross-infected by diseases. In addition, the produced methane replaces traditional fuel woods that used to be harvested on nearby mountains for household cooking, thus greatly contributing to the maintenance of vegetation and the improvement of rural ecological environments. Analysis of soil samples indicated that the state of soil structure and nutrient composition had been greatly improved through applying biogas residue. In addition, application of biogas residue also contributed to reduction in chemical fertilizer application and increase in crop yields. According to statistics, the amount of chemical fertilizer application was reduced from 2310 kg ha^{-1} in 1988 to 675 kg ha^{-1} in 1991, while the crop yield increased from 10 875 to 14 430 kg ha^{-1} (Ye *et al*. 2000). This greatly alleviates the possibility of pollution caused by constant application of excessive chemical fertilizer and improves the agricultural sustainability in the Fushan village community area.

CONCLUSIONS

The ecological engineering methodology is to reconstruct ecological system, and the detail method is to adjust components species and proportion among components in the system. And then it makes the disadvantage factors converted into favorable factors and makes them into good utilization (Guo and Li 1993). According to the abundance of light, heat, water and living resources in Southern China, and based on the foundation of reconstruction on traditional production pattern with advanced technology, much practical ecological engineering patterns with variable characters were appeared within the past decade. These patterns got sound economic, social and ecological benefits, and play important functions in economic development, ecological environmental protection and social cultural advancement in rural area. Some patterns as paddy fishing and biogas ecological engineering have been extended all over the country and provided great deal of sound cases in ecological engineering for the world.

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(*Received December 18, 2003; Accepted February 8, 2004*)