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Conceptual understandings of the ecological engineering issues in China and abroad

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Abstract: The research on ecological engineering has been lasting for more than four decades. As a new, cheaper, environmentally acceptable and alternative techniques, ecological engineering has been applied to many aspects, including ecoagricultural engineering, ecosystem restoration, environmental conservation, and pollution control. This paper presents a conceptual understanding on the issues of ecological engineering, including its origin, concepts, goals, principles and applications.

Key words: ecological engineering; ecologist; engineer

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Introduction

As a new branch of ecology and an interdisciplinary field, the ecological engineering was initially formulated in the early 1960s. During the last decades, it is applied with increasing frequency in pollution control, environmental conservation, ecosystem restoration, and ecoagricultural engineering. Many ecologists (Odum, 1962; 1971; 1982; Mitsch, 1988; 1989a; 1989b; 1992; 1993; Ma, 1978; 1984; 1985; 1988; Yan, 1986; 1987) have made great contributions to the theoretic development and advancement of this new subject. A series of international conferences have been held around the world, e. g. the Symposium of Ecological Engineering of the IV International Congress of Ecology at Syracuse, New York in 1986, International Conference of Agro-Ecological Engineering in Beijing in 1988, International Conference on Ecological Engineering for Wastewater Treatment in Trosa, Sweden in 1991, International Symposium on Ecological Engineering (Ecotechnics 95) in Ostersund, Sweden in 1995, International Conference on Ecological Engineering for Sustainable Agriculture in Beijing, China in 1996, International Conference on Ecological Engineering for Sustainable Development in Calcutta, India in 1998. An international journal《Ecological Engineering》was published in 1992. The International Society for Ecological Engineering (ISEE) was founded in 1993. A SCOPE project "Ecological Engineering and Ecosystem Restoration" was approved in 1994. All these events have promoted greatly the development of ecological engineering. This paper tries to present a conceptual understanding on the issues of ecological engineering concerning its concepts, goals, principles, and applications.

1 Conceptual understanding

1.1 The definitions of ecological engineering

The "ecological engineering" term was first introduced by H. T. Odum in the early 1960s and defined as "those cases in which the energy supplied by man is small relative to the natural sources,

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but sufficient to produce large effects in the resulting patterns and processes"(Odum, 1962), and as " environmental manipulation by man using small amounts of supplementary energy to control systems in which the main energy drives are still coming from natural sources"(Odum, 1963). He described the breath of ecological engineering as "an endeavor with singular aspects supplementary to those of traditional engineering. A partnership with nature is a better term" (Odum, 1971). He later pointed out that " the essence of ecological engineering is managing self-organization; traditional engineering replaces nature with new structure and processes, but ecological engineering provides designs that use environmental structure and process"(Odum, 1989).

Ma(1978; 1984a; 1985; 1988), Yan(1986; 1987), and their colleagues (Ma, 1987; 1984b; 1989; 1991; Yan, 1989; 1992; 1993; 1996) made significant contributions to the formulation and development of the theory and application of ecological engineering in China, especially the application of ecological engineering in agriculture. Ma(Ma, 1978; 1984; 1988) defined ecological engineering as "a specially designed system of production process in which the principles of the species symbiosis and the cycling and regeneration of substances with harmony between structure and function in an ecological system are applied by adopting the new technology of system engineering and optimum-seeking methodology, and introducing new technologies and excellent traditional production measures to make a multi-step use of substance".

Mitsch(Mitsch, 1988; 1991a; 1991b; 1993) and his colleagues (Mitsch, 1986; 1989; 1993) made notable contributions to the theory and practice of this field, especially in the controlling of nutrients in wetlands. Mitsch (Mitsch, 1988), Mitsch and Jφrgensen (Mitsch, 1989a) defined ecological engineering as "the design of human society with its natural environment for the benefit of both". This definition was slightly variated as " the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both" at the workshop on ecological engineering at the US National Academy of Sciences in May 1993 (Mitsch, 1996). Mitsch and Jφrgensen(Mitsch, 1989b) elaborated that "ecological engineering is engineering in the sense that it involves the design of the natural environment using quantitative approaches and basing our approaches on basic science. It is technology with the primary tools being self-design ecosystems, the components are all of the biological species of the world".

The ecological engineering is described by ISEE as a "a new developed discipline integrating science and technology. It deals basically with the building of sustainable and self designing ecosystem, which will contribute to the solution of environmental problems in the direction to achieve maintaining a eco-friendly nature".

In Eastern Europe, ecotechnology is regarded as a synonymous term with ecological engineering. It was designed as "the use of technological means for ecosystem management based on deep ecological understanding, to minimize the cost measures and their harm to the environment" (Uhlmann, 1983; Straskraba, 1985a; 1985b; 1986; 1993). There are some other synonymous terms similar to ecological engineering (see Discussion).

1.2 The goals of ecological engineering

Ma(Ma, 1978) and his colleague(Ma, 1984) described the goal of ecological engineering as the design of co-ecosystems or social-economic-natural complex ecosystem to achieve economic, environmental, and social benefits simultaneously. Mitsch(Mitsch, 1991b) defined the goals of ecological engineering or ecotechnology as: (1) the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution, climate change or land disturbance; (2) the development of new sustainable ecosystems that have human and ecological value; and (3) the identification of the life-support value of ecosystems to ultimately lead to their

conservation. Yan and Zhang(Yan, 1992) defined the specific objectives of ecological engineering as: high production, high energy efficiency, low consumption of resources, low or no pollution, and healthy ecosystem self-regulation, all based on harmonious relationships (dynamic coordination) among structural components and functional processes of the co-ecosystem.

1.3 The principles of ecological engineering

Ma(Ma, 1985) and Yan(Yan, 1986) proposed the main principles for ecological engineering as "species symbiosis, cycling, regeneration, and harmony between structure and function in ecological systems". Later it was summarized as four words: holism, harmony, regeneration, and cycling(Yan, 1991).

Mitsch(Mitsch, 1989a), Straskraba (Straskraba, 1993) formulated the basic ecological principles of ecological engineering as 12 guidelines or commandments: (1) ecosystem structure and function are determined by the forcing function of the system; (2) homeostasis of ecosystems requires accordance between biological function and chemical composition; (3) it is necessary in environmental management to match recycling pathways and rates to ecosystems to reduce the effect of pollution; (4) ecosystems are self-designing systems; (5) process of ecosystems have characteristic time and space scales that should be accounted for in environmental management; (6) chemical and biological diversity contribute to the spectrum of buffering capacities and the self-designing ability of ecosystems; (7) ecotones, transition zones, are as important for ecosystems as the membranes are for cells; (8) the coupling between the ecosystems should be utilized to the benefit of the ecosystems in the application of ecotechnology and in environmental management of agricultural systems; (9) the components of an ecosystem are interconnected, interrelated and form a network, which implies that direct as well as indirect effects are of importance; (10) it is important to realize that an ecosystem has a history in application of ecotechnology and environmental management in general; (11) ecosystems are most unlinerable at the geographical edges; (12) ecosystems are hierarchical systems and all the components forming the various levels of the hierarchy make up a structure, that is important for the function of the ecosystem.

1.4 The applications of ecological engineering

Eco-agricultural engineering is the application of ecological engineering in agriculture, which is most popular type of ecological engineering in China. There are about 1200 ecological farms, 273 eco-agricultural villages, and 19 eco-agricultural counties in 29 provinces in China(Yan, 1991). There are many eco-agricultural engineering models in China(Chai, 1988; Ma, 1988; Wu, 1988; Yan, 1989; Sun, 1991). Chinese eco-agricultural engineering emphasizes that the increase in economic benefits must be based on the increase in ecological benefit. Transformation of wastes into useful resources is an important component of Chinese eco-agricultural engineering (Mitsch, 1991a; Yan, 1992).

1.4.1 Pollution control

It is now common to see the application of ecological engineering with the use of wetlands for treatment of domestic or industrial wastewater(Odum, 1977; Ewel, 1984; Godfrey, 1985; Mitsch, 1986; Hammer, 1989; Guterstam, 1991; 1996; Vymazal, 1996), and mine wastewater (Brook, 1985; Hammer, 1989; Wieder, 1989; Fennessy, 1989a; 1989b; Sobolewski, 1996). In China, transformation of pollutants into useful resources though multi-layer and multi-step utilization is a key approach of ecological engineering for pollution control in China. There are many case studies concerning the application of ecological engineering for waste treatment and utilization (Yan, 1987; 1992; 1996; Ma, 1989).

1.4.2 Environmental conservation

There are many large-scale strategic ecological engineering projects in China for desertification control, soil and water conservation, coastal protection, and natural disaster alleviation. For instance, the three-north-shelter-forest program which began from 1978, and covers 400 million hm^2 of area in 13 provinces in the northeast, north and northwest China. The Yangtze River shelter-forest system project which was implemented in 1990 with the goal of increasing the forested area of this region by 20 million km^2 over a 30- to 40-year period. The coastal area shelter-forest system project which has being underway for 7 years, and is a famous ecological engineering project for coastline conservation(Chung, 1989; 1993).

1.4.3 Ecosystem restoration

The ecological engineering plays an important role in restoring the ecosystems degraded by over exploitation of resources and excessive discharge of wastes. Efforts have been made to restore lakes(Straskraba, 1986; Pu, 1993; Li, 1995, Xu, 1996), rivers(Hey, 1989; Mitsch, 1990; Herny, 1996), other aquatic ecosystems(Chung, 1989), and terrestrial ecosystems damaged by surface mining (Gupta, 1996). The efforts of ecological engineering for ecosystem restoration should start during development, in order to minimize negative impacts during the development or resources exploitation process(Yan, 1993).

2 Discussions

With the rapid development of ecological engineering on many fronts, including a new journal, society and interest by both ecologists and engineers, the future is promising. However, the rapid development does not mean without questions. There are some other understandings on ecological engineering issues different from that presented in this paper. It can be found from literatures that there are several synonyms, subdisciplines or fields similar to ecological engineering, e. g. restoration ecology, synthetic ecology, engineering ecology, industrial ecology, agroecology, reclamation ecology, habitat reconstruction, ecosystem rehabilitation, biospherics, biomanipulation, river and lake restoration, wetland restoration, bioengineering, nature engineering, ecotechnology, eco－tech, ecotechniques, ecological process technology and so on (Mitsch, 1993; 1998). In many ways ecological engineering is not a new field but an amalgam of several fields dealing with restoration and creation of ecosystems for the benefit of humans and natures(Mitsch, 1998). Term such as biomanipulation(Hosper, 1990), bioengineering(Schiechtl, 1980), ecotechnology and eco-tech(Straskraba, 1993; Moser, 1996) convery a sense of ecological engineering. Restoration ecology and its fields(e.g. terrestrial, aquatic, wetland, etc.) also have features of ecological engineering, just as that pointed out by Brandshaw (Brandshaw, 1997) "ecosystem restoration can be, in fact, the best kind of ecological engineering".

Ecological engineering in China and abroad has different development ways. In China, the practices of ecological engineering have undergone for more than two thousands years; however, its theory had not come into being until 1970s. In western countries, especially in the United States, the practice and theory of ecological engineering started in 1960s from non-point pollution control and wetland ecosystem restoration. During last two decades, ecological engineering has co－evolved in the West and in China(Mitsch, 1993). Ecological engineering in China is mainly applied to eco-agriculture, sewage, treatment, and environmental conservation, which it is mainly used for non-point pollution control and ecosystem restoration in the western countries. It is therefore very important to transport western ecological engineering technology to China, and to bring ecological engineering approaches from China to developed countries.

In order to insure a health development of ecological engineering, there are some fundamental questions that have to be solved. For instance, what are the major principles of ecological engineering? What are the relationships between ecological engineering and ecology science? What are the measures of successful ecological engineering project? How can we integrate the ecological and the engineering paradigms? How can we popularize ecological engineering technology in different countries with different values and cultures? How do we perform ecological engineering education? Therefore, it is indispensable to keep continuous dialog and cooperation among ecologists and engineers from different parts of the world. Ecologists need to recognize the applied nature of their field to offer prescriptions for environmental problems, and make ecology to be more involved in solving problems through engineering approaches. Engineering need to understand that biological and ecological sciences are fundamental to their tasks. A solid understanding of ecological principles coupled with an engineer's problem approach offers a new opportunity for dealing with some of our environmental problems(Mitsch, 1998).

3 Conclusion

A conceptual understanding on the ecological engineering issues has been presented in this paper. There are some synonyms, subdisciplines or fields similar to ecological engineering. The new journal, society and frequent international conferences indicate a new development period. The continued development of the field depends on both ecologists and engineers working together.

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