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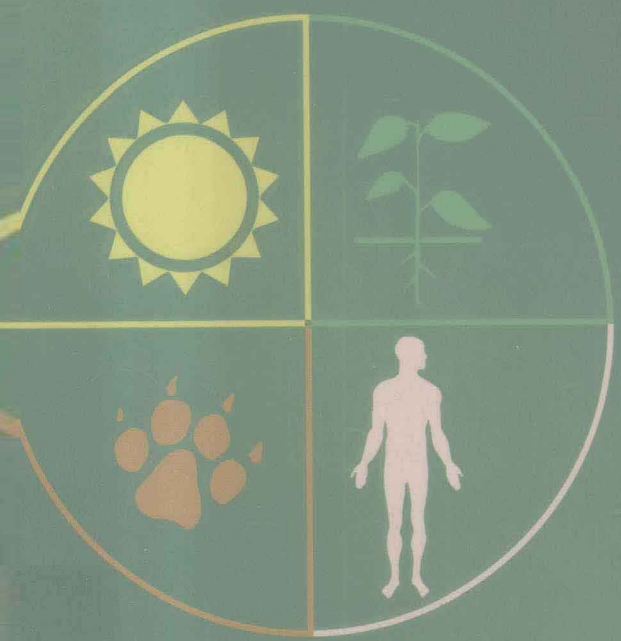
Applications in Ecological Engineering

应用生态工程

Sven Erik Jørgensen



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导　读

丹麦哥本哈根大学著名生态工程专家 Sven Erik Jørgensen 教授主编的《应用生态工程》（*Applications in Ecological Engineering*），由国际上从事生态工程的众多知名学者共同编著。本书以生态工程基础生态学原理、各种生态系统修复及可采用的各种生态工程方法和生态学原理在各种环境问题管理中的实际应用为主线。主要内容包括：生态工程发展与应用的基础理论；应用天然或半天然生态系统解决环境问题；生态系统修复；人工生态系统——模拟自然；环境管理中的生态学原理应用。本书内容系统、全面，反映了生态工程的最新进展，特别适合从事环境管理和环境问题研究的各类环境管理人员及环境科技工作者阅读、参考。

生态工程起源于生态学的发展与应用，至今不过五十余年的历史。随着科学技术的进步与社会生产力的提高，人类创造了前所未有的物质财富，加速了人类文明发展的进程。与此同时，人口激增、资源过度消耗、环境污染、生态破坏已成为全球性的重大问题，威胁着人类的未来生存与发展。在此形势下，人类不得不重新审视自己的社会经济行为和走过的历程，努力寻求一条人口、经济、社会、环境和资源相互协调，既能满足当代人口需求又不对后代需求构成威胁的可持续发展道路。认识和了解生态工程的产生背景对于我们在环境管理过程中应用生态工程的方法解决环境问题具有重要意义。

20 世纪 60～70 年代，以 R. Carson 的《寂静的春天》（1962）、罗马俱乐部《增长的极限》（Meadows，1972）和英国的 Goldsmith 等人的《生命的蓝图》（1974）为代表，人类开始关注自身行为对自然环境的影响。应用生态学在这种背景下得以迅速发展。但此时的应用生态学主要集中在监测和评估环境影响或进行自然资源管理工作，主要是描述性的，如生态毒理学和景观生态学，而描述性的语言无法解决现实中存在的问题，这就需要一门解决问题的学科——生态工程。系统论、控制论以及基础生态学、应用生态学等学科研究的进展为生态工程提供了基本的概念和原理，但这样并不能形成完整的生态工程体系，生态工程还被认为是生态学的分支和工程学的新领域。本书讲述了 19 条生态学原理并将其作为生态工程基础，同时解释了这些原理在每种生态工程方法应用背后的基本思想，为解决环境管理过程中实现环境可持续性发展提供了有益的理论和方法基础。

在生态工程产生之前，环境问题的产生是由于工业和生活中的大量物质以废弃物形式进入环境，造成正常的物质转化和能量流动过程中的阻滞和耗竭。而最直接的解决办法是在不改变原系统结构的情况下，将生产过程中产生的污染物，通过环境工程手段在生产过程之后解决，即末端治理（end-of-pipe），希望达到污染物的零排放。但是，二十多年的实践证明，将重点放到末端，即在危害发生后再进行净化处理的环境战略、政策和措施有很大的局限性。这是因为：首先，我们只有有限的资源来解决、控制污染问题；其次，当我们使用一种末端处理技术取代另一种技术的时候，往往只是把污染物从一个媒介转入另一个媒介，仅仅是污染形式的改变；第三，这种治理的投资越来越大，

需要大量能量。如书中所述，人们为此提出了其他三种方法：环境立法、清洁生产和生态工程。

环境立法通过制定法律防治污染。它是一种非常有效的和节省成本的控制污染措施。我国已制定了数百条相关法律用于控制污染和保护环境。但是仅仅通过立法并不能解决所有环境问题，这个社会仍然需要农业、食品加工、工业制造、交通运输等以满足人类各种需求。就像一些有毒化学品可以通过立法轻易禁止，但不能禁止健康食品的生产。

在20世纪80年代后期，人们又设想将末端治理改为以全过程控制的清洁生产技术，通过对生产的组织、操作及产品消费过程的管理，达到最大限度实施清洁生产的时空安排。但是，清洁生产多数缺乏可行的良好的工艺手段，使得清洁生产问题无法达到产业化的最终目标。在这样的情况下，生态工程应运而生。

生态工程属于全新的、多学科相互渗透的应用学科领域，是一门应用科学。其思想基础是污染问题可以在生态系统内通过天然生态组分的应用得以解决，而不是依赖人工强化技术作为环境问题的解决途径。为了控制生态系统，人类应用来自自然的能源作为辅助能对环境进行控制。管理自然就是生态工程。它是对传统工程的补充，是自然生态系统的一个侧面。

20世纪80年代后，生态工程在欧洲及美国逐渐发展起来，出现了多种认识与解释，并提出了相应的生态工程技术，即“在环境管理方面，根据对生态学的深入了解，花最小代价的措施，对环境的损害又是最小的一些技术”。美国生态学家Mitsch在《生态工程》一书中认为，生态工程和生态技术是同义词，生态工程或生态技术就是人类社会利用自然环境所进行的有益于二者的设计。生态工程（或称生态技术）是一种全新的技术和方法，它在无需投入大量能量的情况下，保护我们的生态系统，并且解决了污染问题，避免污染的转移，将污染物转化为人类可以利用的再生资源。生态工程或生态技术可以为很多环境问题提供可持续的解决方案，是一种非常有力的工具，为此我们有必要认真阅读本书所阐述的各种生态工程方法，并深刻体会在解决我国环境问题时如何有效利用其中的思想和方法。

白晓慧　博士

2011年1月30日于美国密歇根大学Arbor Village寓所

前　言

生态技术，也称作生态工程，为当前环境管理提供了大量可供利用的方法。本书对这些方法进行了广泛的介绍，包括它们的优点和缺点，以及如何将它们应用于环境管理中。所有这些方法都体现了对生态学原理的充分应用。在生态学基本原理一章中讲述了19条生态学原理作为生态工程基础，解释了应用每种生态工程方法时对应的基本原理。这些原理为生态学和各种方法在环境管理中的具体应用搭起了一座坚固的桥梁。

本书以近期出版的《生态学百科全书》中有关生态工程或生态技术部分为基础。由于Jan Vymazal在编辑《生态学百科全书》生态工程部分的出色工作，使得本书中对生态工程方法进行全面细致的介绍成为可能（见书中采用天然或半天然生态系统解决环境问题，生态系统修复，人工生态系统——模拟自然及生态学原理在环境管理中的应用）。为此我想向Jan和所有生态工程部分的作者致谢，感谢他们对《生态学百科全书》的贡献，并将生态学非常重要的这一分支的全面且最新的内容呈献给读者。

Sven Erik Jørgensen

2009年4月于哥本哈根

（白晓慧　译）

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PREFACE

Ecotechnology, also called ecological engineering, offers today a wide spectrum of methods to be applied in environmental management. This book gives a broad overview of the methods, their advantages and disadvantages, and how they can be applied in environmental management. All the methods are rooted in the application of sound ecological considerations. Nineteen ecological principles are presented in the chapter Basic Ecological Principles as Basis for Ecological Engineering and it is shown how these principles can explain the basic ideas behind the application of the ecological engineering methods. The principles build a solid bridge between ecology and the practical use of the methods in environmental management.

The book is based on the presentation of ecological engineering or ecotechnology as an ecological subdiscipline in the recently published *Encyclopedia of Ecology*. Due to an excellent work by the editor Jan Vymazal of the Ecological Engineering Section in the *Encyclopedia of Ecology*, it has been possible to present a comprehensive and very informative overview of the ecological engineering methods in this book (see parts Use of Natural and Semi-Natural Ecosystems to Solve Environmental Problems, Restoration of Ecosystems, Constructed Ecosystem – Imitation of Nature, and Application of Ecological Principles in Environmental Management). I would therefore like to thank Jan and all the authors of ecological engineering entries for their contributions to the *Encyclopedia of Ecology*, which made it possible to produce this broad and up-to-date coverage of a very important subdiscipline in ecology.

Sven Erik Jørgensen
Copenhagen, April 2009

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生态学原理在环境管理中的应用

（白晓慧　译）

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BASIC THEORY FOR THE DEVELOPMENT AND APPLICATION OF ECOLOGICAL ENGINEERING

Ecological Engineering and Environmental Management

S E Jørgensen, Copenhagen University, Copenhagen, Denmark

Introduction

Rachel Carson's book *A Silent Spring* started in the mid-1960s the first green wave. Pollution problems were able to attract the political attention in line with other important problems such as social problems, traffic problems, economic problems, and educational problems that the society would have to deal with and solve. The pollution problems, often called the environmental problems, could be solved at that time only by use of one tool box: environmental engineering. The tool box contained a wide spectrum of cleaning processes such as settling tanks, filters, scrubbers, aerators, trickling filters, and biogas reactors – all man-made components. **Figure 1** illustrates the idea behind the use of the environmental engineering tool box. The pollution problems were a result of our activities – particularly industrialization and urbanization. The problem was that nature could no longer absorb the increasing pollution due to the growing production, population, and urbanization. The obvious solution of the problem was therefore to use a technology that could remove the polluting components from all types of waste before discharge to the environment.

The environmental engineering tool box was, however, expensive to use and insufficient to resolve all environmental problems. Therefore, three additional tool boxes were developed during the 1970s and the early 1980s: environmental legislation, ecological engineering, and cleaner technology.

Environmental legislation prevents pollution by use of legislation. All uses of DDT for instance were banned in 1970 in North America and Europe. It was an effective and very cost-moderate method to solve the pollution problems associated with the use of DDT.

It is, however, far from possible to solve all environmental problems by use of environmental legislation. The society needs for instance agriculture, food production, transportation, and so on. A few toxic chemicals can easily be banned, but it is of course not possible to ban the production of healthy food items.

Environmental legislation is therefore a tool box with effective tools and solutions but the number of problems that can be solved are limited and are very specific, too.

It is obvious from **Figure 1** that it would also be possible to solve the environmental problems if we could change our production in a direction that would involve less pollution. It is named cleaner technology or alternative technology and has developed rapidly since the early 1980s. There are numerous examples of minor and major changes in the production, in the construction of buildings and roads, and in our urban planning that all have reduced the pollution significantly. A very evident example is the use of a new technology based on recycling of waste components, whereby the amount of waste and the use of raw materials are reduced simultaneously.

Ecological engineering – the third new tool box – started like cleaner technology around the year 1980. The idea is that the pollution problems could also be solved in the ecosystems and by use of ecological components instead of only thinking in terms of man-made technological components as possible solutions of the environmental problems. The questions behind the development of ecological engineering are as follows:

- How can we help the ecosystems to cope better with the pollution and enhance their ability to decompose and absorb pollutants?
- As ecosystems are able to absorb pollution and reduce pollution problems, would it be possible to solve the environmental problems by installation of a man-made ecosystem before the natural ecosystem?
- Could a better planning of our use of nature based on ecology solve some of the environmental problems?
- Could a proper use of nature's ecosystems solve or at least reduce the environmental problems?

Environmental planning included in **Figure 1** presumes an ecologically acceptable planning, which implies that often it has to draw on the ecological engineering methods presented in the part Application of Ecological Principles in Environmental Management.

Today, we have had all the four tool boxes available for almost 30 years, and the experience shows that all the four boxes are urgently needed if we want to solve the environmental problems properly and at reasonable costs. Ecological engineering or ecological technology is probably the least known and least applied of the four tool boxes. It contains, however, very powerful tools