



# Research on the Construction of Life Cycle Assessment Model for Sponge Facilities

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## ABSTRACT

As a key green infrastructure for urban storm water management, the life cycle environmental impact assessment of sponge facilities is crucial for optimal design and sustainable decision-making. This study systematically examines the methodological steps, software tools, and their comparative advantages in conducting life cycle assessment for sponge facilities. Furthermore, a framework for establishing a life cycle assessment model tailored to sponge facilities is proposed. This research provides methodological support for the precise environmental assessment of sponge facilities and low-carbon urban planning, and promotes the sustainable development of green infrastructure.

## KEYWORDS

Sponge Facilities, Life Cycle Assessment Model, Cost Assessment.

## 1. INTRODUCTION

With the rapid development of the city, a large amount of rainwater runoff in the city has become a major source of non-point source pollution, which has a great impact on the aquatic ecosystem of the water body and the eutrophication of the water body[1]. As an ecologically sustainable stormwater control and rainwater utilization facility, the sponge city is the main direction for the future development of Chinese cities and a Chinese solution to rainwater management problems. Its main function is to conserve groundwater resources and purify water quality. The purpose of establishing the life cycle assessment model of sponge facilities is to evaluate the attenuation degree of the main functions of sponge facilities and determine the reasonable service life of sponge facilities. According to the main functions of sponge facilities, the evaluation model mainly includes two parts: environmental impact assessment and life cycle cost of sponge facilities[2]. In terms of environmental impact assessment, the life cycle assessment software is used to quantitatively analyze the resource consumption, energy consumption and pollutant discharge of a specific sponge facility from the beginning of raw material mining and processing, through the whole process of construction, operation and maintenance until the final scrapping and demolition, and then quantitatively analyze and evaluate the life cycle environmental impact of the whole process of a specific sponge facility. In terms of cost analysis, the cost analysis of specific facilities based on the whole process life cycle is carried out. The specific content of the whole life cycle of the sponge facility includes material processing, construction, operation and maintenance, scrapping and dismantling, and other

environmental impacts such as air pollution, sewage discharge, and solid waste generated during the entire operation.

## 2. ENVIRONMENTAL IMPACT ASSESSMENT OF SPONGE FACILITIES

The life cycle environmental impact assessment of sponge facilities should first define the evaluation objectives and evaluation scope, and then determine the functional units. The third step is to collect and sort out the inventory data. Then, the life cycle assessment software is used for simulation. Finally, the results of software simulation are analyzed and evaluated.

### 2.1. Target and scope definition

The definition of objectives and scope is the first step in the study of life cycle assessment. When setting boundaries, the specific stages and processes included in the life cycle should be considered. The goal of life cycle assessment of sponge facilities refers to the evaluation according to the catchment area of the service object, the condition of the underlying surface and the function of the sponge measures (delaying the time of surface runoff production and confluence, reducing the peak flow, reducing the emission of pollutants, etc.). The overall purpose is to carry out environmental impact assessment.

If the sponge facility is regarded as the object of our research and analysis, the life cycle includes the acquisition of various resources and energy from nature, through the process of raw material mining, transportation, processing, construction and construction, until the facility is put into use, until the design service life is scrapped and dismantled, which constitutes a complete life cycle. It is usually divided into three stages: construction stage, operation and maintenance stage and scrap demolition stage. According to the analysis and research, the boundary definition of sponge facilities is shown in Fig.1.

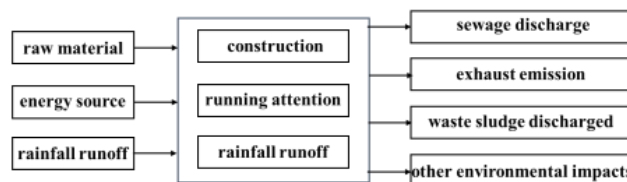


Figure 1. Boundary of sponge facility life cycle assessment system

### 2.2. Determination of functional units

In order to facilitate the quantitative analysis of the evaluation results, the functional units of the system research should be set for the sponge facilities to be evaluated. The functional unit of the life cycle assessment of sponge facilities refers to the confluence area of a certain facility service, the specific conditions of the underlying surface (the composition of the underlying surface, the surface runoff coefficient, et al.), the design return period, and the average annual rainfall in the project area.

### 2.3. Analysis of listing for LCA

In general, the environmental impacts of the whole life cycle of sponge facilities are divided into three categories : resource consumption, energy consumption and pollutant emissions. Resource consumption mainly refers to the need to collect raw materials from nature in the construction stage of sponge facilities. The raw materials themselves belong to natural resources, and the mining, processing and manufacturing of raw materials may also need to invest in other resources such as water resources. Energy consumption mainly refers to the consumption of coal, oil, natural gas and electricity. The process of energy consumption not only demands from nature but also produces a

certain amount of pollutant emissions to nature during its use, causing damage to the ecological environment. The whole process life cycle of sponge facilities has been introduced in the previous section.

## 2.4. Evaluation software

Life cycle assessment is a method that can quantitatively analyze the environmental impact and potential impact of the whole life cycle of products, services or processes. As early as the 1990 s, LCA has been used to assess the sustainable development of the urban water system environment.[3] Since 2005, the number of LCA studies has increased dramatically, especially for the environmental impact assessment of sewage treatment processes and drinking water production processes. There has been a lot of research at home and abroad. With the deepening of life cycle assessment research, many evaluation model methods and software tools have been developed internationally. The convenience and accuracy of evaluation have been greatly improved, but the evaluation results will still be affected by the selected evaluation methods and software tools. At present, there are dozens of life cycle assessment software in the world, such as GaBi, SimaPro, eBalance, Boustead CLEAN, LCAiT, EcoManager, EcoPack2000, KCL-ECO, TEAM, LIMS and so on. Combined with the characteristics of sponge facilities, the comparison of several mainstream life cycle assessment software is shown in table 1.

**Table 1.** Comparison of Several Common Life Cycle Assessment Softwares

software	core advantage	limitation	serviceability
SimaPro	Most comprehensive function, support dynamic modeling	High price, complex operation	Suitable for in-depth analysis of scientific research institutions or large projects
GaBi	Powerful supply chain database and friendly interface	Deficient localized data	Suitable for large sponge facilities with complex supply chain
OpenLCA	Free open source, strong scalability	Slow calculation speed, advanced features require plug-ins	Research on Customization of small and medium-sized teams (basic programming required)
Umberto	Intuitive flow chart and suitable for industrial process simulation	Few ecological engineering cases such as sponge facilities.	More suitable for the optimization of the production process of permeable pavement materials

## 2.5. Life cycle impact assessment method of sponge facilities

In the environmental impact assessment of life cycle assessment, it is necessary to determine the type of environmental impact and select the appropriate method to quantify the environmental load of the evaluation object. According to the different types of impact, life cycle impact assessment methods are mainly divided into two categories: Midpoints impact assessment method and Endpoints impact assessment method[4]. Among the two method, the midpoint method considers the causal chain of the influence category, and the topic influence type is transformed from the list result; the end-point method is guided by environmental damage and simulates the environmental impact related to human environmental protection goals caused by the inventory results. The endpoint method is further extended to environmental protection related issues on the basis of the midpoint method.

## 3. LIFE CYCLE COST ASSESSMENT OF SPONGE FACILITIES

There are many classifications and calculation methods for the life cycle cost of sponge facilities. According to the relevant contents of investment and operation stages, it can be divided into resource

consumption cost, energy consumption cost, maintenance and management cost. Investment-related costs include project construction-related costs, residual value, etc. Utility-related costs include resource consumption costs and energy consumption costs. Operation-related costs include maintenance costs, repair costs and management costs during the operation of sponge facilities.

The life cycle cost of a sponge facility is calculated by adding the present value of each cost and subtracting the present value of cash inflows. The general formula is: life cycle cost of sponge facilities = initial construction cost + operation + maintenance + repair + resource + energy + replacement-residual value.

## 4. CONCLUSIONS AND PROSPECTS

It is of great significance to carry out the life cycle assessment of sponge facilities for the construction and development of sponge city. The construction of the life cycle assessment model of sponge facilities should be based on the whole life cycle perspective, covering the whole process of 'material processing-building construction-operation and maintenance-end-of-life demolition'. The research needs to combine the characteristics of sponge facilities (permeable pavement, rainwater garden, bioretention tank, etc.), clarify the system boundary, functional units and environmental impact types (carbon emissions, water consumption, ecological toxicity, etc.). In the construction of the life cycle assessment model of sponge facilities, it is also necessary to adapt the method to the dynamic hydrological effects of sponge facilities (rainwater runoff control, pollutant reduction for example). In terms of evaluation data acquisition, it is necessary to combine the measured data (facility operation and maintenance energy consumption for example) with the database to fill the blank of localization parameters and improve the regional applicability of the model. The construction of life cycle assessment model of sponge facilities is the core tool to promote the scientific and fine management of green infrastructure. In the future, it is necessary to break through the limitations of static evaluation and provide more accurate decision support for low-carbon and sustainable development of sponge cities by combining dynamic system analysis, multidisciplinary intersection and data-driven methods.

## CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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