Energy Consuming Comparison of Wastewater Treatment Technologies through Life Cycle Assessment

A Case Study of Sequencing Batch Biofilm Reactor

筑波大学生命環境研究科 孫 爽 氷鉋揚四郎

1. Introduction

In the summer of 2010, it is reported that the power shortage of China is about 15% of whole electricity production, and this trend is believed to be more serious in the coming future due to coal supplement shortage and global price growth. In 1996, the centralized processing rate of municipal wastewater in China was only 11.4%, and will reach to 40% in 2010, and over 1,000municipal wastewater treatment plans (MWWTP) will be constructed in future and most of them will be small and mid-scale ones (Wei, 2000). For a general wastewater treatment plan, energy, usually is electricity, takes 60%-70% of total maintenance cost (Tan, 2011).

From the view of life cycle, from construction stage to the final demolishment stage, the energy consumption is a key factor which could influence the resource, environment, and sometimes it also could lead social impacts. However, the traditional method has been unable to reflect the whole process of energy utilization due to its limited boundary. The traditional method usually is based on the economic and technology aspects, it could provide the view from production stage but not big one.

Life Cycle Analysis (LCA) is a new system of environmental impact assessment techniques and methods, which uses the technology facilities as the main line to collect, identify, quantify, analyze and assess resources consumption and the data and information of environmental impact of products throughout the life cycle, provides an environmental assessment tool of comprehensive, accuracy information

This paper try to identifies and analyzes quantificational the whole energy consumption process from designation, exploitation and manufacturing of raw material, construction, handling, running, reconstruction and expansion of wastewater plant, abandoning and back out of Life Cycle Assessment (LCA). Meanwhile this study tries to compares this technique to traditional activated sludge process (TASP), which aims to bring out new technical economy and environmental assessment method.

2. Objective and Scope

In this paper, two indicators have been analyzed and compared based on the energy consumption of the wastewater treatment under different technology: (1) The energy consuming of wastewater treatment is converted into electric energy (KWh) or heat energy (KJ), and the consumed energy for treating per unit polluted water capacity(m3) or energy consumption ratio; (2) The whole energy consuming every year of different wastewater treatment technology has been calculated in terms of the same scale and similar water quality condition.

In this study, Sheng Jian wastewater treatment plant is taken as the study object. The capacity of Sheng Jian wastewater treatment plant is 10,000m^3/d, a sequencing batch biofilm reactor with intelligent control system (ICSBBR) is adopted. The logical treatment process of this plant is as shown in Figure 1. Main technology parameters of ICSBBR as following: total hydraulic retention time (HRT) is 7 hr. The characteristics of designed raw domestic sewage were (average value): pH (5.9-7.5), COD (200-250mg/L), BOD5 (100-150 mg/L), suspended solids SS (100-150mg/L), (NH3-N (25-35 mg/L), and TP (4-6 mg/L). The reactor was seeded with activated sludge collected from Qing He Municipal Wastewater Treatment Plant, Beijing, China, which had a mixed liquor suspended solids (MLSS) and SS content of 1638 mg L^{-1} and 3562 mg L^{-1}, respectively.

2.1. Intelligent Controlled Sequencing Batch Biofilm Reactor

ICSBBR is a more advanced technology which could reach higher energy utilization rate by the information system. System will adjust aeration time based on the data of oxygen utilization rate collected by sensors automatically. Well-designed software will guarantee the dissolved oxygen (DO) maintains in the required level. Therefore, treatment and energy consumption rate could be improved respectively.

According to the previous study, a stable performance of ICSBBR under hydraulic retention time (HRT) of 7 h, at which point the removal efficiencies of NH_3-N, TP and COD reached 99%, 100% and 96%, respectively (Ding 2011). When compared with conventional SBBRs, the SBBR controlled by the ICS reduced the HRT and total aeration time by 56% and 50% (Ding 2010), respectively, and achieved better performance at removing the COD.

When carbon nitrogen （C/N）ratio is 12.5, an experiment scale ICSBBR could reach the best performance and COD, TN, NH3-N removal efficiency is 94.8%, 87.4% and 90.1% respectively (Ding, 2011).

2.2. The unit of LCA appraised function

According to the general urban planning, most of the city’s wastewater treatment plants need to be rebuilt and updated to some extent with the increase of wastewater quantity and the increase of the discharge standard. For Sheng Jian wastewater treatment plant, the energy consumption problem should be considered in a 20 years’ runtime.

It is well known that the consumptions and functions of a wastewater treatment plant’s facilities have scale effects. The capacity of Sheng Jian wastewater treatment plant is 10,000m^3/d, which is a typical wastewater treatment plant for small or middle town. This article uses such scale as the function unit for LCA analysis to compute the input and output of the wastewater treatment system. The traditional activated sludge process (TASP), which is used as a contrast, also applies this scale as the function unit, in order to make them comparable.

3. The detailed analysis list of energy consumption

3.1. The input-output of wastewater treatment facility

During the life cycle of wastewater treatment facility, the energy, resource and the processing object input by environment and the contamination output to environment and their influence, are shown in Figure.2 .

The resources input by the environment include the various raw materials as well as natural resources for material production, such as water, air, natural ore etc; raw wastewater is the research object. The energy sources include coal, petroleum and the electric energy etc., which are converted into Joule conformably. Materials and energy may be used in the whole life cycle is shown in table 1.

Table 1 Materials and energy consumption in MWWTP

Stage	Raw material	Energy
Construction	Steel, iron, cement, sand, water, PVC, copper, clay, bitumen, epoxide resin etc.	Transportation, construct, mechanical Dissipations
Operation	Medicament etc.	Power consumption, fuel, equipment dissipation
Demolishment	Topsoil, filling material etc.	mechanical dissipations, fuel, etc.

3.2. The energy consumption in the construction phase

Table 2 material and energy of construction stage (10^6 Kw·h)

	ICSBBR	TASP
Total energy of raw material	1.63	1.74
Total energy of transportation	0.16	0.10
Total energy consumption for construction	0.323	0.51
Total energy consumption	2.113	2.35

The energy consumption during the construction phase includes raw material production, construction and transportation. The total energy of some kind of material is consisted of its natural calorific value and the energy consumption for production. Unified energy unit is adopted to quantify the different energy.

According to quantities analysis and concerned standards, the building materials quantity of ICSBBR can be calculated and the production energy consumption can also be quantified based on its material quantity and energy consumption for production. The construction energy consumption can be counted according to the construction area, and the construction energy consumption per unit area; the energy consumption for transportation building material can be counted according to the consumption amount of building material, transportation mileage, and energy consumption for transportation per unit.

3.3. Energy consumption in operation stage

The material consumption during running phase of treatment facilities is much low. The medicament consumption is the main portion. The energy consumption in this phase includes the power for wastewater treatment, the fuel and equipment loss for transportation, etc. Among them, the power consumption for wastewater treatment always occupy the total energy consumption more than 85%; in which, the electricity consumption of aeration systems is over 88.5% (Tan 2011). ICSBBR could reduce 40% electricity consumption rather than the traditional SBBR system due to its energy reduction design.

3.4. The energy consumption of the demolishment stage

The energy consumption in the demolishment phase is related with the machine equipment for demolishment mostly, normally, which includes two parts: demolishment and transportation. The energy consumption of demolishment is 90% of the energy consumption of construction according to concerned documents (Yang, 2000). The energy consumption of transportation for soil and filling material is calculated by construction area, the average density of soil and filling material (2.0 kg/m^3) and average transportation mileage (20 km).

Table 3: The list of main electrical equipment and energy consumption of process

Stage or process	Equipment	Power	Actual power consumption
Primary Treatment			
First Lifting	Lifting pump	1.5 Kw	1.5 Kw
Grid	Grid machine	1.5 Kw	1.5 Kw
Second Lifting	Lifting pump	0.75 Kw	0.75Kw
Secondary Treatment			
Stir	Stir pump	2.2 Kw *4	8.8 Kw
Aeration	Ventilators	4 Kw * 2	8 Kw
Advanced treatment			
Inverse flow	Pump	5 Kw * 2	10 Kw
Filter	Filter Pump	2.2 Kw * 2	4.4 Kw
Sludge treatment			
Sludge pumping	Sludge Pump	0.75 Kw	0.75 Kw
Sludge transportation	Belt dewatering machine	1.1 Kw	1.1 Kw
Total			36.8 Kw

3.5 Final result

Table 4: total energy consumption and material consumption of ICSBBR and TASP from LCA (10^6 Kw·h)

Stage		ICSBBR	TASP
Construction	Material consumption	2.31	2.25
	Energy consumption	2.113	2.35
Operation	Material consumption	2.34	4.09
	Energy consumption	5.56	17.11
Demolishment	Material consumption	0.01	0.01
	Energy consumption	0.441	0.46
Total energy consumption		12.653	19.92

It can be concluded from the Table 4, both of the construction consumption and energy consumption of operation stage are lower than the TASP because of the intrinsic property of ICSBBR. As far as energy consumption, energy utilization and environmental impacts caused by the energy produced process; the environmentalism of ICSBBR is superior clearly to the TASP. The total energy consumption and material consumption is shown in table 4.

4. Conclusion

During the life cycle of wastewater treatment plants, energy consumption is a key factor of cost. To reduce or utilize energy efficiently is very important, which could also reduce other environmental impacts. Based on ideas of LCA, from the very beginning of construction stage to the final demolishment stage, several methods are put forward to improve energy efficiency. This paper, applied the thought of LCA, recognizes and quantizes the ICSBBR in Sheng Jian wastewater treatment plant in Yun Nan province, China, from the stage of design, exploitation and machining of raw material to wastewater plant construction, running, reconstruction or extension, and demolishment, which had been compared with the TASP. The results show, the energy consumption of ICSBBR during each stage is lower than ordinary means of active sludge; and with intelligent mode is applied to the operation stage, the energy consumption is much lower than the TASP and even than traditional SBBR (Ding 2011). The results show that the ICSBBR, because of its small land occupation, simple maintenance, little foul smell, and environmentalism, is superior clearly to the TASP.

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Appendix

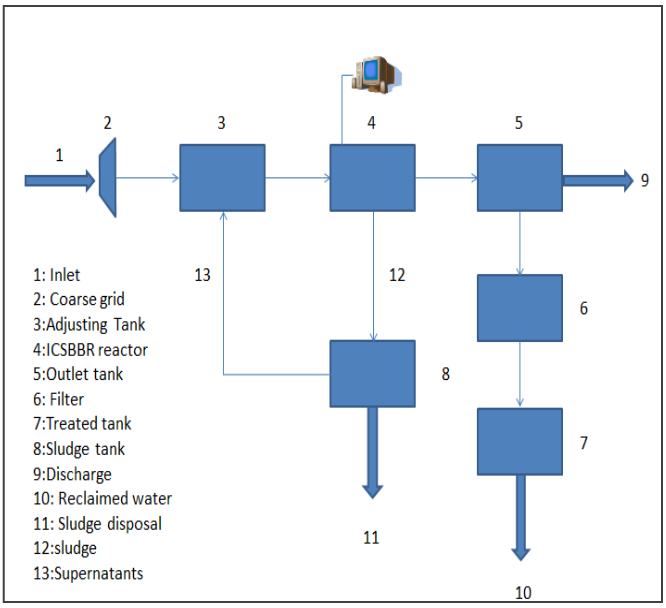

Figure 1 ICSBBR process flow

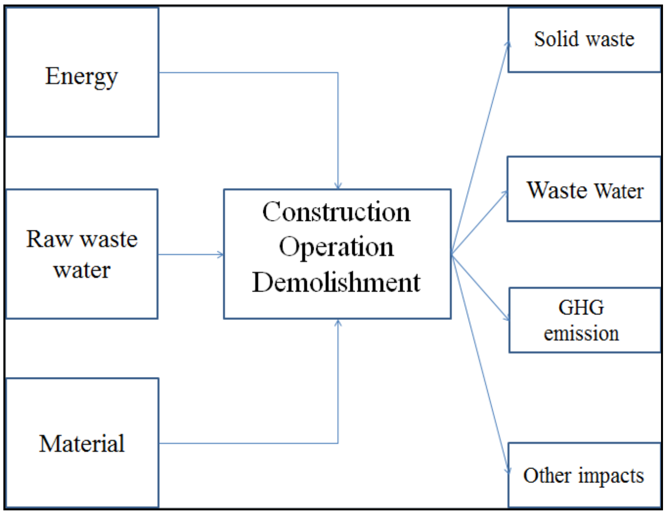

Figure 2 The input output flow of ICSBBR wastewater treatment