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Carbon audit and cost analysis of an innovated wastewater resourcing system by process simulation

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Summary of key findings

An innovated wastewater resourcing system (WRS) was formal proposed to couple the production of polyhydroxyalkanoates (PHAs) and electricity generation by microbial fuel cell (MFC) with the proper controlled acidification digester. This paper gave the carbon audit and cost analysis of WRS to estimate its carbon emission, energy saving and profit production. Results showed WRS extracts 18% of influent carbon source and thus lowered energy consumption, excessive sludge discharge and carbon emission from traditional nutrient removal process. Three ways to utilize the carbon source were estimated to give the theoretical profits, alluding the possibility of wastewater resourcing.

Background and relevance

Nowadaya many scientists considered wastewater as resources to restore clean water, recover energy and recycle resources. Among the promising techniques, synthesis polyhydroxyalkanoates (PHAs) from carbon extracts in activated sludge is feasible in green biochemistry (Jia et al., 2013). And utilizing organics to generate electricity by microbial fuel cell (MFC) is considered an impressive bioelectrochemical system combined clean energy and pollutant reduction (Zhang et al., 2013).

An innovated wastewater resourcing system (WRS) was proposed formally by professors in School of Environment in Tsinghua University, in order to recover the carbon source to produce environmental friendly materials and to generate green electricity. The basic idea is to extract utilizable alkanoates from solid wastes (Yu et al., 2012), and further to produce valuable materials and electricity. In this paper, we presented the carbon audit and cost analysis of WRS by establishing the process models in BioWIN platform, demonstrating the advantages over traditional ones.

Results

Carbon Audit. The carbon flowchart of the core process in WRS system were presented in Figure 1, including wastewater treatment and solid digestion. The Theoretically, 18% of the carbon source in typical municipal wastewater influent could be transformed into valuable alkanoates by proper controlled sludge digest. The advantages of WRS over AO process were further explicated in Table 1 by the operational indices.

Cost Analysis. Except of the carbon emission reduction, the wastewater resourcing system is profitable due to the different utilization of the carbon sources. Here we calculated three methods: (1) raw acetate; (2) PHAs synthesis; (3) PHAs coupled MFC generation. Table 2 listed the calculation process, and the final possible profit.

Discussion

Carbon Audit. By comparison with carbon flow in traditional AO process, the carbon dioxide emission of WRS was reduced from 60% to 38% of influent carbon footprint. Therefore, the part of valuable carbon source in WRS was thought to be originally discharged to atmosphere in traditional AO process, as the final product of biochemical oxidation of organics and cell lysis.

The aeration energy in WRS saved 34% from AO process in terms of the air supply rate to stabilize dissolved oxygen in bioreactor at 2 mg/L. The excessive sludge generation in WRS was 25% less than

AO process, due to the acidification treatment in the digester. Therefore, WRS shows less energy consumption, less carbon emission and less hazardous solid waste than AO process.

Cost Analysis. (1) Raw acetate. The price of industrial acetate is 5000 RMB/ton. By considering 0.4 gCOD/gAcetate by mass, then the price of raw acetate is calculated as 1.25 RMB/kgCOD. The final profit is 0.068 RMB/m3 influent, occupied 10-15% operational cost of current wastewater treatment plants in China.

(2) PHAs synthesis. Here we assume all the raw acetate was used to produce PHAs. The yield of PHAs from COD is about 30% by mass, and the profitable ratio is assumed to be 30% of the price, which is now 30 RMB/kg PHAs. Then the final profit is 0.146 RMB/m3 influent, covered 30-40% of the operational cost.

(3) PHAs synthesis coupled with MFC electricity generation. The exhaust of PHAs fermentation could be used as material for MFC operation. The current of MFC was calculated by the theoretical electron transfer rate of COD utilization, and the efficiency of 10% by MFC apparatus. The final profit is 0.0035kWh/m3 influent, about 1% of the total electricity consumption in the plants. However, with the improvement of MFC efficiency, the benefit will be increased.

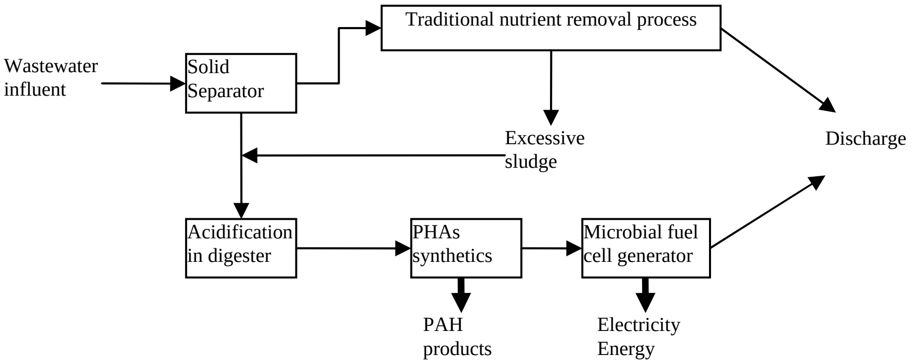

Figure 1 The proposed wastewater resourcing system

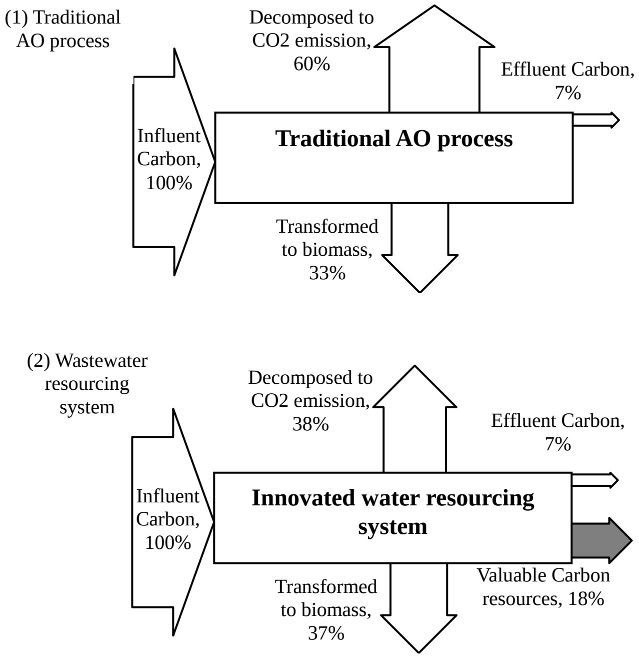

Figure 2 Carbon audit of the core process in the (a) traditional AO process; and (2) new wastewater resourcing system

Table 1 Operational parameters of wastewater resourcing system and traditional AO process

Group	Item	Unit	AO process	WRS system
Influent	Flow	m^3/d	100	100
Effluent	COD	mg/L	27.3	20.2
	TN	mgN/L	11	12.5
	Ammonia	mgN/L	0.8	0.5
Excessive	Flow	m^3/d	5	1
Sludge	MLSS	kg/d	12.7	9.5
	MLVSS	kg/d	7	4.9
Operation	Air	m^3/hr	27.9	18.3
	SRT	d	14.4	11.9
COD loading	Influent	kg/d	30	30
	Emission	kg/d	17.20	11.52
	Cell storage	kg/d	10.52	11.20
	Effluent	kg/d	2.25	1.97
	Carbon source	kg/d	0	5.28

Table 2 Operational parameters of wastewater resourcing system and traditional AO process

		(1) Raw Acetate	(2) PHAs	(3) PHAs+MFC
Control	item	Influent	Carbon loading	PHAs Exhaust
	value	100 m^3/d	30 kgCOD/d	3.7 kgCOD/m^3
Source	item	Carbon loading	Acetate COD	COD electron
	value	30 kgCOD/d	5.3kgCOD/d	7.2e6 C/kgCOD
Yield	value	18%	30%	10%
	product	5.3kgCOD/d	1.62 kgPHA/d	2.62e4 C/m^3
Price	value	1.25 RMB/kgCOD	30RMB/kg	
	product	6.75 RMB/d	48.6 RMB/d	
Profit	value	100%	30%	10%
	final	0.068 RMB/m^3	0.147 RMB/m^3	0.0035 kWh/m^3

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Is the presenting author an IWA Young Water Professional? N

Bio: Bing Li is a postdoc at School of Environment , Tsinghua University. Her research interests focus on operation optimization and assessment of wastewater treatment plants, and application of microfluidic techniques to the study environmental microbe.