An Revised Factors Model for Estimation and Prediction of Greenhous Gas Emission in Wastewater Treatment Plant

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Abstract. A comprehensive mathematical model has been revised to estimate greenhouse gas (GHG) emissions by urban wastewater treatment plants (WWTP) resulting from on-site activities. The contribution of individual processes and well-management levels of WWTPs to the production of GHGs in hybrid treatment system has been determined. Using the revised mathematical model, we estimate the total CO_2 equivalent mass and per unit COD removal mass of emission in Dalian City from year 2004 to 2013. According to the results, our prediction is that the overall CO_2 equivalent mass of emission will continue to increase, but improvement of wastewater treatment technology and automatic detection can efficiently reduce the growth. The revised emission factor of GHG emissions from nutrient removal in the overall GHG emissions of WWTPs increased the accuracy and completeness of this estimation, lending support to the novelty of the present study.

Introduction

The IPCC's fourth assessment report pointed out that the rising concentrations of greenhouse gases (GHGs) in the atmosphere is one of the main factors of global warming[1]. The reduction of GHG emissions in this system has great potential[2], but the relevant domestic research is presently inadequate. In the real situation the recommended default value can't exactly reflect the real characteristics of emissions of GHGs in urban WWTPs, which often changes by the characteristics. So using the default value will reduce the accuracy of the estimation greatly[3]. Considering this situation, the study suggested a more accurate estimation which requires adjusting the default values on the basis of good practice recommended.

Methodology

For data limited state, using the GHG emission factors and the activity data to estimating is a good practice[4]. In this paper, we have done some adjustment to the existing methods and ideas by using expert scoring method. And we investigated and survived all the WWTPs in Dalian City from 2004 to 2013, the contents are the key impacting factors, which are sewage treatment processes, sewage load, management operations.

Determination of emission factors

(1) Determine the evaluation factors

According to field investigation results, the main evaluation standard of wastewater treatment process is: anaerobic tank, anaerobic reactions in aerobic process. The key evaluation standards of management levels are: anaerobic reactions in plants, which mainly operated by aerobic process, caused by equipment management.

(2) Evaluation standards of expert scoring method

According to the survey results, we grade all the treatment processes between 0-1, which were used in Dalian City from 2004 to 2013 in this paper (table 1). According to

Table 1

A	percentage of the plants which operate with both aerobic and anaerobic treatment in inventory year, %		
B	percentage of the plants which are well managed, %	MCF	methane correction factor
i	particular year		
Q_i	operation capacity of each plant, ton/day	q_i	scores
EF	emission factor, kg CH$_4$/kg BOD		

different anaerobic degree, we average the results using expert scoring method. Then we can use the following formula to get the evaluation factor of every year:

$$A = \frac{\sum_{i=1}^{n} Q_i \times q_i}{\sum_{i=1}^{n} Q_i} \times 100 \qquad (1)$$

Table 2 Evaluation standards of wastewater treatment processes

Evaluation Factor (treatment process)	AS	BAF	CAST	SBR	A$_2$/O	A/O
Score (q_j)	0.1	0.3	0.7	0.9	1	1

We grade the management level from 1 to 0 for all the urban wastewater plants in Dalian City, using the survey results (table 3). By using the following formula, we can get the final evaluation result.

$$B = \frac{\sum_{i=1}^{n} Q_i q_i}{\sum_{i=1}^{n} Q_i} \times 100 \qquad (2)$$

(3) Choice methane emission factors

According to the experts' opinions, we believe that for wastewater plants that run by both aerobic and anaerobic treatments, 25% pollutants are removed in anaerobic

Table 3 Evaluation standards of well-management level

Evaluation Factor	Production and Operation	Equipment	Laboratory
Score (q_j)	0.4	0.4	0.2

phase, and 75% removed in aerobic phase. The annual MCF value calculation process and results of sewage treatment plant in table 4.

Table 4 Calculation method of MCF_i of WWTP

Treatment Process	WS_i	MCF_i
Anaerobic Treatment	A%×25%	0.8
Aerobic Treatment but not well managed	(1-A%×25%)×(1-B%)	0.3
Aerobic Treatment and well managed	(1-A%×25%)×B%	0
$MCF = A\% \times 25\% \times 0.8 + (1 - A\% \times 25\%) \times (1 - B\%) \times 0.3$		

Results

Emission of CH$_4$ from wastewater treatment. According to the estimation mode recommended by GPG2000, the revised emission factors and the data from Chinese statistical yearbook [5], the MCF is calculated in table 5. The methane emission mass is increased year by year, with the annual average increasing rate of 7.48%. The main reason is the substantia increase of processing capacity, rising from 5 plants, capacity of 372000 tons of sewage in 2004 to 25 plants, capacity of 1.317 million tons of sewage in 2013.

But the revised emission factors can have small range of fluctuation on methane emission mass. According to the result, we can predict that the CH4 emission mass will continue to increase. But

the CH4 emission mass can be reduced in a relatively small range with the technological innovation and management upgrading of wastewater processing.

Table 5. MCF from WWTPs of Dalian City in year 2004-2013

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
MCF	0.189	0.171	0.161	0.159	0.145	0.138	0.129	0.134	0.136	0.132

Emission of CO$_2$ equivalent from wastewater treatment. In order to ensure continuity and comparability of the international GHG emissions data, we followed the requirements by the UN framework convention on climate change (UNFCCC) to converted CH4 and N2O into CO2 equivalent and added them. And this paper calculates the per capita of total GHG CO2 equivalent emissions
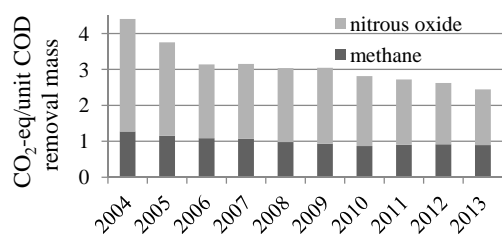

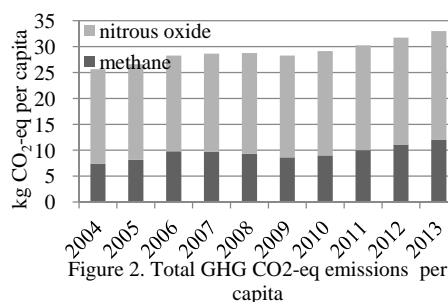Figure 1. Total GHG CO$_2$-eq emissions produced by unit COD removal mass

Figure 2. Total GHG CO2-eq emissions per capita

produced by per COD removal mass unit. Figure 1 shows the total emissions produced by unit COD removal mass, the annual average decreasing rate of 6.05%. Figure 2 shows the per capita of total GHG emissions, the growth number is from 25.6 kg CO2-eq/year in 2004 to 33.06 kg CO2-eq/year in 2013.

After presenting all the data from 2004 to 2013, we hold the opinion that the amount of CH4 and N2O produced by WWTPs increased year by year. And the trend that emissions produced by unit COD removal mass gradually reduced shows the new wastewater treatment technology has positive influence on GHG emission control.

Summary

(1) During 2004-2013, CH4 and N2O emissions of municipal WWTPs in Dalian City are keep increasing year by year. Per capita CO2 equivalent emissions increases with population growth, but the total emissions per unit COD removal mass decreased with time. It shows that the addition of population is key factor to addition of COD removal mass.
(2) WWTPs should focus on decreasing anaerobic treatment processing, improving automatic detection, using upgradation technology and recycling methane gas.

Acknowledgements

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