Environ Earth Sci (2016) 75:47
DOI 10.1007/s12665-015-4868-7

ORIGINAL ARTICLE

COD fraction analysis of anaerobic digester supernatant and piggery wastewater, using respirometric method

Jiyeol Im[1] · Daeik Kim[2] · Kyungik Gil[3]

Received: 29 October 2014 / Accepted: 28 July 2015 / Published online: 19 December 2015

Abstract When operating an activated sludge model (ASM), organic matters among input data criteria including pH, temperature, sludge retention time, and many more, can be categorized to its own characteristics. Such category includes chemical oxygen demand (COD) and biochemical oxygen demand. However, these are not likely to represent benchmark criteria meeting the conditions required by ASM. In this study, experimenting piggery wastewater and an anaerobic digester supernatant from municipal wastewater treatment plants (MWTPs) with the use of the microbial respirometric method, the true categories for organic matters were implemented and assessed for the requirements of ASM. It was found that piggery wastewater was categorized with biodegradable organic matters with high content of slowly biodegradable COD, while anaerobic digester supernatant was mostly composed of non-biodegradable organic matters in high content of inert COD. When the COD fraction ratio discovered in this study is applied to an ASM for an accurate monitoring of a treating process of piggery wastewater and anaerobic digester supernatant, the findings could make a useful database in designing a biological treatment process and operating it in MWTP.

✉ Kyungik Gil
kgil@seoultech.ac.kr

1 School of Civil, Environmental and Architectural Engineering, Korea University, Anam-Dong 5ga, Seongbuk-Gu, Seoul, South Korea

2 DechloriTek, 2575 Coventry Circle, Fullerton, CA 92833, USA

3 Department of Civil Engineering, Seoul National University of Science and Technology, Nowon-Gu, Seoul 139-743, South Korea

Keywords Anaerobic digester supernatant · Piggery wastewater · COD fraction · Oxygen uptake rate · Slowly biodegradable COD · Soluble inert COD

Introduction

The characteristics of organic matters in wastewater can be used importantly for wastewater monitoring and treatment process. However, analysis of COD fraction used for the modeling of wastewater treatment is complex. Thus, COD and BOD are used for wastewater treatment modeling. The division of organic matters only by COD and BOD would have a limitation for more exact wastewater treatment modeling, because COD and BOD could not represent different characteristics of organic matters (Ince et al. 1998; Roh 2006).

ASM was developed for the interpretation, prediction and modeling of wastewater treatment by the International Water Association (IWA) in 1987. Later, it evolved to ASM One in 1995, ASM Two in 1999 and ASM Three in 2000, and additional wastewater treatment modeling programs based on the previous versions of ASM came out. The organic matters in ASM are divided into soluble inert COD (S_I), readily biodegradable COD (S_S), slowly biodegradable COD (X_S), and suspended inert COD (X_I). There are various methods to analyze the COD fraction, for example, the method to use the specific growth rates of microorganisms (Samson and Ekama 2000) and the method to use filters (Bortone et al. 1993). However, in most studies, the microbial respirometric method was used for the analysis of the COD fraction (Dircks et al. 1999; Kim 2007; Wentzel et al. 1999). Generally, ASM provides the COD fraction of sewage, but this COD fraction is difficult to apply to a modeling of wastewater treatment.

Accordingly, the COD fraction from very different wastewater streams has been analyzed by a number of research teams in South Korea (Choi et al. 2003; Gil et al. 2012; Hong et al. 2003; Roh and Gil 2007). For the more accurate modeling of MWTP, researches on various wastewater streams are required, such as anaerobic digester supernatant and piggery wastewater. In particular, the recycle water from MWTP including digester supernatant, sludge dewatered water, and piggery wastewater would be in low flowrate, when compared to the sewage, but they are known to contain extremely high concentration of organic compound and nutrients of nitrogen and phosphorus.

The recycle water is generated from a sludge treatment process in MWTP. It is returned to a main stream in sewage treatment process and naturally mixed with influent wastewater in an upstream of the plant. As a result, incoming loads of contaminants are likely to increase, resulting in a negative impact on a designed mass balance, its calculation, and overall operation of the plant. A piggery wastewater is also in low flowrate but with high concentration of contaminants. Normally, piggery wastewater is treated with sewage in MWTP or small size of piggery wastewater treatment plant (Gil 2006; Im and Gil 2011a, b; Tong et al. 2010). However, the researches on the COD fraction of such high concentration wastewater have not been much paid attention to. In this study, the COD fraction of the anaerobic digester supernatant from MWTP and piggery wastewater were analyzed, at the same time, categorized to S_I, S_S, X_S, and X_I, which was modeled with the ASM.

Materials and methods

Wastewater sampling and analysis

The analysis of COD fraction was conducted for four wastewater samples: anaerobic digester supernatants from J MWTP and S MWTP in Seoul, piggery wastewater from Y piggery wastewater treatment plant in Yong-in, and H piggery wastewater treatment plant in Hong-seung. The samples were periodically collected and kept at 4 °C to prevent change on COD fraction. Table 1 shows the characteristics of the wastewater samples. COD, BOD, and mixed liquor suspended solid (MLSS) were measured according to the Standard Method (APHA 1998), and dissolved oxygen (DO) and pH were measured with a DO meter (YSI-550A) and a pH meter (Accumet-AB15).

Methods by OUR determination

The schematic diagram of oxygen uptake rate (OUR) test device is displayed in Fig. 1. The OUR test device was designed with 3 L aeration reactor for batch test and 0.5 L DO measurement reactor for measurement of DO. DO concentration is maintained higher than 3 mg/L in aeration reactor to supply enough oxygen for treatment of biodegradable organic matter by microorganisms in aeration reactor. But in DO measurement reactor, DO was controlled for measurement of utilization DO for treatment of biodegradable organic matter by microorganisms. Using a flow control pump, it flows in and returns from the aeration reactor to the DO measurement at 5 min interval, and it uses the decreasing rate of the DO concentration to correspondingly calculate the OUR. In order to analyze the rapid aeration exhaustion in early part of the experiment, it was measured at a short interval, and in the later part where the change of the DO concentration was minimal, the measuring interval was lengthened to the change of the DO concentration. In particular, the upper part of the DO measurement in the device was closed to prevent the inflow of external air and to prevent the nitrification, where 1-Ally-2-thiourea (ATU) was injected. Sample wastewater for the OUR and endogenous respiration sludge were mixed in the aeration reactor. And MLSS was maintained

Table 1 Characteristics of piggery wastewaters and anaerobic digester supernatant

Sample	Y piggery wastewater treatment plant		H piggery wastewater treatment plant	
Parameters	Concentration ranges	Average	Concentration ranges	Average
pH	7.5–8.7	8.3	7.4–8.3	8.1
COD (mg/L)	11,520–16,840	13,150	9600–11,420	10,430
BOD (mg/L)	7280–9690	8,952	7630–9870	6970
MLSS (mg/L)	19,860–23,900	22,480	18,850–19,240	19,200
Sample	J MWTP		S MWTP	
Parameters	Concentration ranges	Average	Concentration ranges	Average
pH	7.3–7.39	7.37	7.3–7.7	7.4
COD (mg/L)	16,700–21,700	19,200	1830–5740	3940
BOD (mg/L)	700–6800	3750	550–870	510
MLSS (mg/L)	10,720–13,180	12,660	7850–9240	8280

with initial concentration during OUR test. The part consumed to show the point of inflection can be calculated with the following Eq. (1) for S_S.

$$S_S = \frac{Q_A}{1 - Y_H}\left(\frac{V_{AS} + V_{WW}}{V_{WW}}\right) \quad (1)$$

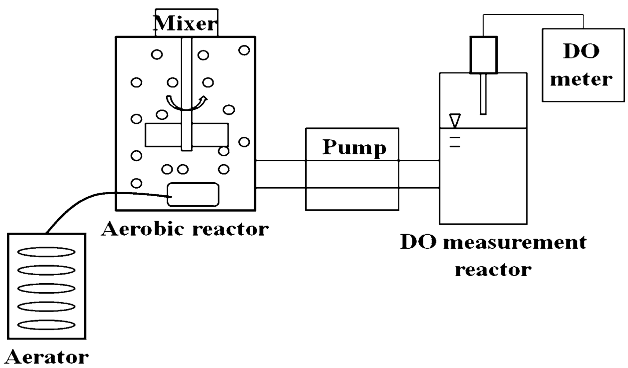

Fig. 1 A schematic diagram of the laboratory-scale OUR reactor

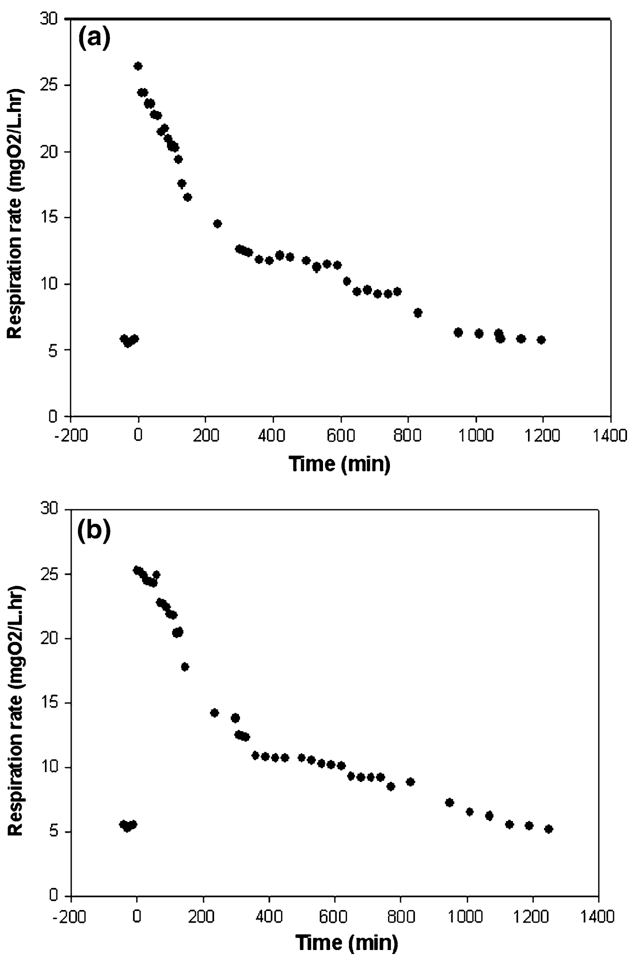

Fig. 2 The respirometric results of OUR with piggery wastewater. **a** Y piggery wastewater treatment plant, **b** H piggery wastewater treatment plant

Q_A = Oxygen consumed in area, mg/L, Y_H = synthesis yield coefficient for heterotrophic bacteria, g cell/g COD used, V_{AS} = volume of activated sludge used in test, mL, V_{WW} = volume of wastewater sample, mL

Results and discussion

OUR test results

Figure 2 shows the results of OUR test, experimenting piggery wastewater and Fig. 3 shows the results of anaerobic digester supernatant. Normally, the results of OUR test can be reportedly separated in three phases (Metcalf and Eddy 2001). The OUR value was immediately increased when sample wastewater was introduced to the testing system, then rapidly decreased when the point of inflection appeared. This change of OUR was due to the utilization of S_S consumed by microorganisms. As for the experiment of piggery wastewater, as the minute as the

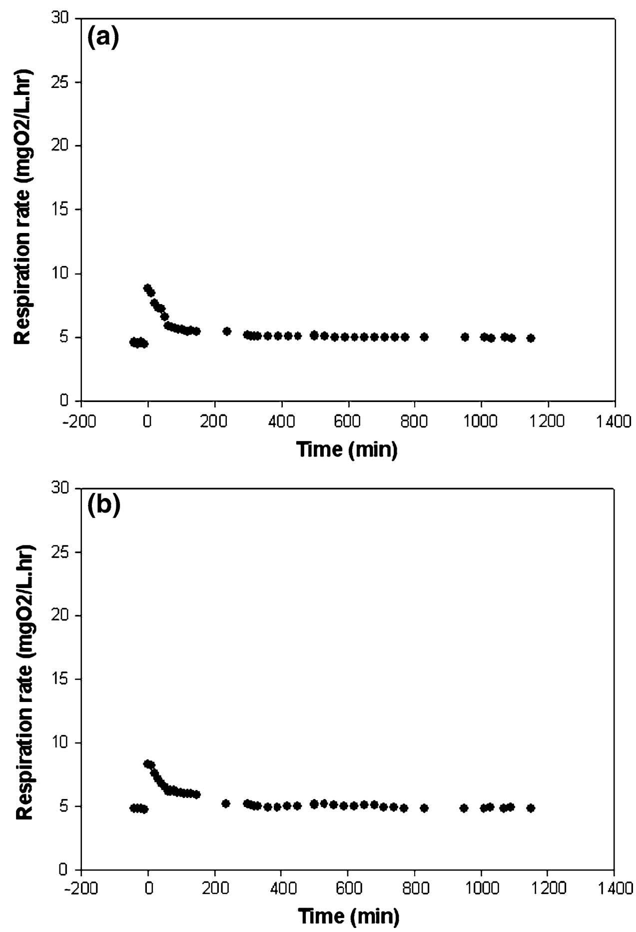

Fig. 3 The respirometric results of OUR with anaerobic digester supernatant. **a** J MWTP, **b** S MWTP

sample wastewater was mixed with the sludge, the oxygen uptake from the microbial activity was shown to rapidly increase, compared to that of anaerobic digester supernatant. And piggery wastewater was shown to have higher OUR than anaerobic digester supernatant, in terms of consumption of S_S. As for the experiment of anaerobic digester supernatant, the increased OUR value was minimal, compared to the piggery wastewater. Before the point of inflection period, the gap of OUR value was the highest during the OUR test, meaning that some amount of oxygen was utilized for decomposition of S_S. Overall, the OUR value increased for the anaerobic digester supernatant. The high concentration of BOD in piggery wastewater led to such amount of oxygen utilized for the decomposition of BOD. Point of inflection time was approximately 3 h for the piggery wastewater, while it was 1 h for the anaerobic digester supernatant. The point of inflection time was relatively shorter for anaerobic digester supernatant. The required time for treating biodegradable organic matters in anaerobic digester supernatant found itself shorter than the piggery wastewater. And this time difference will make an impact on sizing a treatment plant, a reactor dimension, and the specification for selecting a pretreatment system.

COD fraction and its analysis

Figures 4 and 5 exhibit the statistical analysis on the COD fraction for each sample wastewater, and the average values were also presented in Tables 2 and 3. The COD fraction for piggery wastewater is relatively larger than that of anaerobic digester supernatant. Higher content of biodegradable organic compounds are shown in the piggery wastewater, on the contrary, anaerobic digester supernatant displayed higher concentration of non-biodegradable organic compounds. From the COD fraction of each sample wastewater, it was discovered that the sump of S_S and X_S, and BOD were similar, possibly translating into that amount of S_S and X_S will represent BOD in the wastewater.

Figure 6 shows the COD fractions of sewage in ASM and wastewater in South Korea (Roh 2006; Roh and Gil

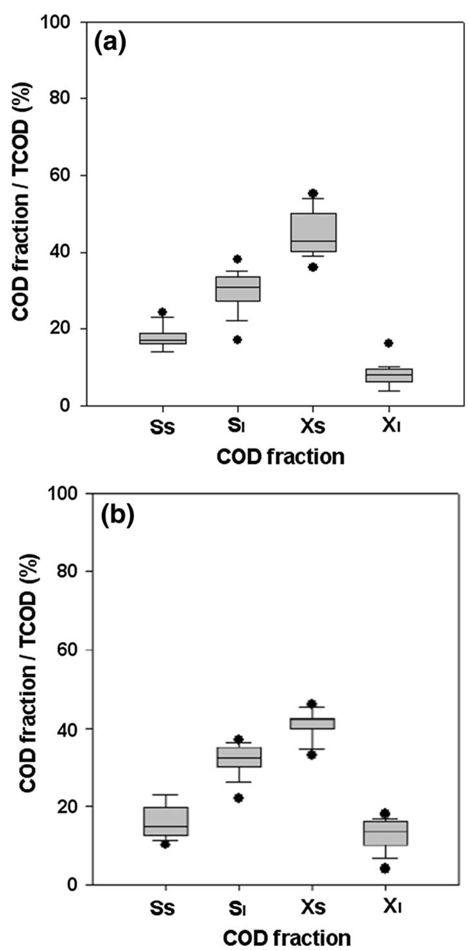

Fig. 4 COD fractions of piggery wastewater. **a** Y piggery wastewater treatment plant, **b** H piggery wastewater treatment plant

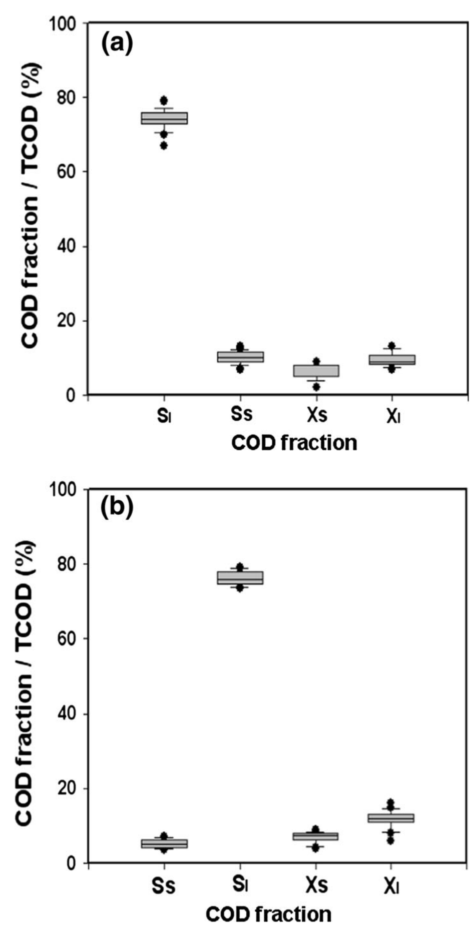

Fig. 5 COD fractions of anaerobic digester supernatant. **a** J MWTP, **b** S MWTP

Table 2 COD fraction of piggery wastewater

	S_I (%)	S_s (%)	X_s (%)	X_I (%)	$(S_S + X_S)$/COD (%)	BOD/COD (%)
Y piggery wastewater	17.7	29.5	44.8	8.0	74.3	68.1
H piggery wastewater	15.8	31.9	40.7	11.6	72.6	66.8
Average	16.8	30.7	42.7	9.8	73.5	67.5

Table 3 COD fraction calculation of anaerobic digester supernatant

Anaerobic digester supernatant	S_I (%)	S_s (%)	X_s (%)	X_I (%)	$(S_S + X_S)$/COD (%)	BOD/COD (%)
J MWTP	76.2	5.1	6.9	11.8	12.0	19.5
S MWTP	74.2	10.3	5.9	9.6	16.2	12.9
Average	75.2	7.7	6.4	10.7	14.1	16.2

2007). The piggery wastewater was shown to have higher part of soluble inert COD (S_I) than those of other wastewaters. The COD fraction of the piggery wastewater was represented with S_I (16.8 %), S_S (30.7 %), X_S (42.7 %), and X_I (9.8 %), respectively. That of anaerobic digester supernatant was represented with S_I (75.2 %), S_S (7.7 %), X_S (6.4 %), and X_I (10.7 %), respectively. It was found that the piggery wastewater had high part of S_S and X_S, and the anaerobic digester supernatant had high part of S_I and X_I. Specifically, biodegradable organic compounds in piggery wastewater were approximately five times higher than anaerobic digester supernatant. Comparing with the COD fraction in the sewage provided by ASM and advanced South Korea sewage research data, the COD fractions of piggery wastewater and anaerobic digester supernatant were noticeably different. This will hinder a biological process consuming organic compounds, especially when anaerobic digester supernatant with high content of non-biodegradable COD will be treated along with sewage in a typical MWTP. Therefore, such wastewater stream with high non-biodegradable COD should be differently treated. The analysis of COD fraction would make fundamental base data when for designing and operating treatment process for a MWTP.

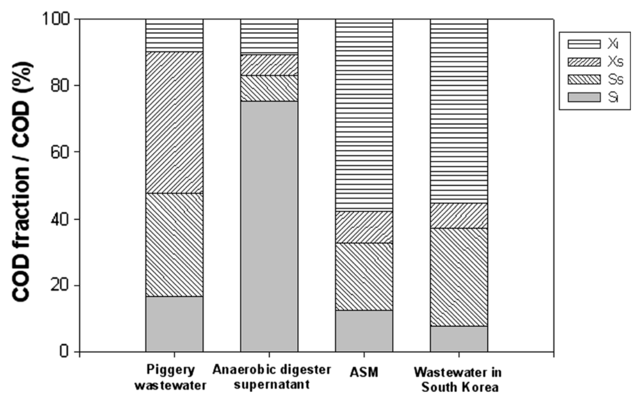

Fig. 6 The comparison of COD fractions of anaerobic digester supernatant, piggery wastewater, ASM, and a sewage in Korea

Conclusions

The COD fraction of piggery wastewater and anaerobic digester supernatant were analyzed, using the respirometric method. The results of the COD fractions of the piggery wastewater were high with more than 70 % of organic compounds, which are biodegradable. Anaerobic digester supernatant had more than 80 % of organic compounds, which represents as non-biodegradable. For the more accurate modeling programs based on ASM, input data of organic compounds from a variety of wastewater streams including digester supernatant and piggery wastewater, as well as a sewage, must be considered. The findings from this study, when computer-based modeling a piggery wastewater and an anaerobic digester supernatant, will make an important base data in terms of designing a treatment process and predicting a trend of a process.

Acknowledgments This work was funded by the National Research Foundation (NRF) of a grant program from the Korea government (MSIP) (No. 2013R1A2A2A01068579).

References

APHA (American Public Health Association) (1998) Standard methods for the examination of water and waste water, 20th (edn), Washington, DC

Bortone G, Cech JS, Germirli F, Bianchi R, Tilche A (1993) Experimental approaches for the characterisation of a nitrification/denitrification process on industrial wastewater. Water Sci Technol 29(7):129–136

Choi YG, Kim KD, Kim HJ, Kim YJ, Jung TH (2003) Respirometry for COD fractionation of wastewater. J Korean Soc Water Wastewater 17(4):503–509

Dircks K, Pind PF, Mosb KH, Henze M (1999) Yield determination by respirometry—the possible influence of storage under aerobic conditions in activated sludge. Water SA 25(1):69–74

Gil KI (2006) Nitritation of anaerobic digester supernatant from sludge processing in MWTP. J Korean Soc Water Qual 22(3):540–545

Gil KI, Rho HY, Kim DI, Michael KS (2012) Comparison of bio-P module and the modified bio-P module in the step-feed biological nutrient removal process. Environ Earth Sci 65:929–936

Hong JY, Shin EB, Kim YK, Kim BJ (2003) Evaluation of the changes of microbial biomass fraction using OUR measurement. J Korean Soc Water Qual 19(4):445–454

Im JY, Gil KI (2011a) Evaluation of nitritation of high strength ammonia with variation of SRT and temperature using piggery wastewater. J Korean Soc Water Qual 27(5):563–571

Im JY, Gil KI (2011b) Effect of anaerobic digestion on the high rate of nitritation treating piggery wastewater. J Environ Sci 23(11):1787–1793

Ince O, Babuna FG, Kasapgil B, Anderson GK (1998) Experimental determination of the inert soluble COD fraction of a berwery wastewater under anaerobic conditions. Environ Technol 19(4):437–442

Kim DH (2007) Presumption of nitrogen compound of nitritation of sewer by the respirometric method. J Korean Soc Water Wastewater 21(3):295–303

Metcalf and Eddy (2001) Wastewater engineering, 4th edn. Mcgraw Hill, New York

Roh HY (2006) Optimization of operational conditions of existing BNR process using simulation method, Dissertation, Seoul National University of Science and Technology

Roh HY, Gil KI (2007) Modeling of existing BNR process using ASM3 and modified bio-P module. J Korean Soc Water Qual 23(3):309–313

Samson KA, Ekama GA (2000) An assessment of sewage sludge stability with a specific oxygen utilization rate (SOUR) test method. Water Sci Technol 42(9):37–40

Tong L, Wang Y, Li P, Wang J, Shao Y (2010) Headspace solid-phase microextraction (HS-SPME) and solid-phase extraction (SPE) concentration for quantification of malodorous substances in piggery wastewater. Environ Forensics 11(4):355–362

Wentzel MC, Dircks A, Pind PF, Mosb KH, Henze M (1999) Yield determination by respirometry—the possible influence of storage under aerobic conditions in activated sludge. Water SA 25(1):69–74