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Gas Extraction from Sludge as Acquired from Oxidation Ponds of Community Wastewater and Cassava-Factory Wastewater Treatment through Nature-by-Nature Processes

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Abstract

The study was aimed on determining the gas volume from sludge of oxidation ponds for community wastewater treatment and UASB tank of cassava factory for wastewater treatment in which the organic matters of both units were digested through the nature-by-nature process. The amounts of oven- dry weight sludge about 200 g were collected in the light brow glass bottle with 2.5-l capacity. The fermentation of organic matters in sludge is the process to produce gases and being transferred to store in chamber by fluid displacement. The gases from sludge of oxidation pond was occurred on the second day and the maximum on the sixth day with the rate of 70 ml/d and average of 36.02 ml/d (total 360.23 ml for 10 days) while cassava factory sludge found the maximum volume on the first day with the rate of 142.6 ml/d and average of 72.2 ml/d (total 649.97 ml for 9 days). In other words, the oxidation pond sludge can produce gas 1.8 ml/g (oven dry weight) while the cassava factory sludge found gas 3.25 ml/g (oven dry weight). Research results found gases of oxidation pond sludge on the range of methane concentration between 545,686 – 9,560,606 ppm, hydrogen sulfide 55.94 to 360.27 ppm, and ammonia ND to 36.22 ppm, while the cassava factory sludge found methane gas concentration between 729,404 to 9,900,837 ppm, hydrogen sulfide 5,894 to 68,050 ppm, and ammonia ND to 44.15 ppm.

Keywords: gas extraction, sludge, oxidation pond

1. Introduction

There have been approximately 20,000 agro-industrial factories in the whole Kingdom of Thailand, but very high density in the central and the east. All factories go side by side with being obligated by laws to set up the effective wastewater treatment system without any exception. After bacterial organic digestion processing, the environmental indicators of treated wastewater must be equal or less than water quality standards for effluent, for example, the effluent BOD must legally equal or less than 20 mg/L. It is understood that the sludge has been formulated after bacterial digestion processing and moving down to the bottom of oxidation ponds. After that, the sludge will be gradually accumulated for some depth affecting the storage oxidation pond capacity in which the decreased rate of aerobic bacterial digesting process (Chen et al., 2008; Appels et al., 2008). In case of dredging up sludge, it has some difficulty to designate the dumpling areas due to oppose from the nearby dwellers. The only way can be done by using their own land which has very small part of the factory boundary. In basic principles, the dredged sludge can be usable for dumping on swamp land areas, some case for fertilizing croplands because it is supposed to comprise of plant nutrients. It is remarkable to stress that using the sludge from oxidation ponds for land dumping and cropland fertilizing would be probably insecure according to some toxicant contaminations from excess resources and residues from technology, especially community wastewater from bigger cities. Actually, flowing the excess water through communities and cities is normally contaminated with mostly organic wastes that becoming some part of stream pollution (Li et al., 1996). Theoretical point of views, the organic waste in stream water is normally digested by bacteria which needs dissolved oxygen as energy to conduct the processes, H.M. the King of Thailand calls this phenomena as nature-by-nature process. For clear understanding the nature-by-nature process, it has been explained as shown in Figure 1 that the dissolved oxygen in community wastewater is originated from three processes: firstly, photosynthesis of phytoplankton and algae; secondly, thermo-siphon process due to evaporation from surface water that cooling water to have more diffused oxygen and to sink down to the bottom; and thirdly, thermo-osmosis process according to aerenchyma cells (spongy cells) as pertained in very young leaves of aquatic plants can bring oxygen through phloem and xylem as pathways of elements and water to the rhizomes before supplying to bacteria as energy for organic digestion (Arneth & Stichlmair, 2001; Bearman, 1957; Buchel & Grosse, 1990; Chunkao et al., 2012; Deubigh & Raumann, 1952; Gehlin et al. 2003; Grosse, 1989; Grofse & Bauch, 1991; Pulford & Watson, 2003; LERD, 2012). In other words, the nature-by-nature processes are implied as photosynthesis, thermo-siphon, and thermo-osmosis means in supplying to oxygen as energy for naturally bacterial digestion of organic waste in community wastewater from point sources. In consequence of bacterial organic digesting processes, the sludge is normally produced at the bottom of oxidation ponds in which it is mainly composed of dead bacteria but small portion of dead plants and animals. It might be contaminated by toxic and non-toxic chemicals which would be depended on components of point sources. By all appearances, it could be brought to serve need of the Royal LERD project to use for wastewater treatment by the small wetlands and oxidation ponds as the pilot model for disseminating the technical know-how on community and/or municipal wastewater treatment to the concerned agencies in the whole Kingdom of Thailand.

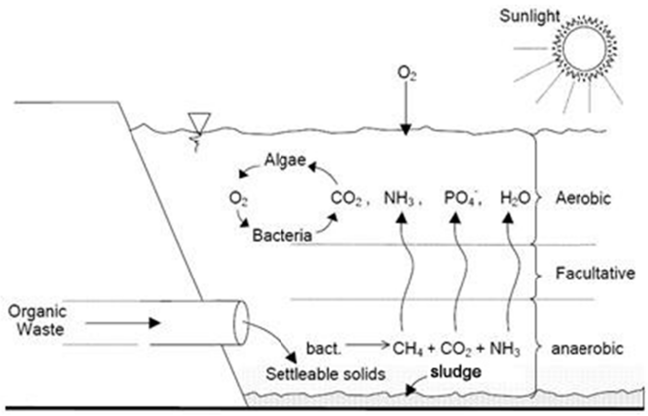


Figure 1. Hypothetical process of algae photosynthesis, thermo-siphon, and thermo-osmosis in producing oxygen as energy for bacterial organic digestion to treat in oxidation ponds for community wastewater treatment

Nowadays, the concept of zero waste management and bioenergy recovery is spread out to every country around the world which is induced to use sludge from oxidation ponds sometimes called sediment, for producing the biogas for energy supply. In general, sludge which obtained from engineering devices for wastewater treatment such as Activated Sludge (AS), Upflow Anaerobic Sludge Blanket (UASB), Rotating Bio Contact (RBC), and Trickling Filter (TF) had been available used for bioenergy because of high content of organic matters. It has been known among environmental scientists and engineers that there is very less number of report in using sludge of wastewater treatment in parts of Oxidation/ Stabilization Pond (OP/OS), and Lagoon Treatment (LT) which are undoubtedly, relied on natural processes for oxygen supply by algae photosynthesis, thermo-siphon, and thermo-osmosis processes. Nevertheless, the accumulative sludge masses are very much concerned with the variation in quantity and quality of effluent at the pipe outlet from three point sources such as community drainage system, municipal sewerage, and industrial factories. Besides, the wastewater treatment technologies, hydraulic retention time (HRT) for bacterial organic digestion processing are necessary in energy storage in sludge in terms of the completion of bacterial organic digestion processes which can produce an effect on organic matter and quality of sludge. Usually, the efficiency of bioenergy recovery from sludge is closely associated with the content of organic matters in sludge, the more substrate for anaerobic bacteria and the more production of bioenergy, such as methane, hydrogen, etc. (Yuanyuan et al., 2013).

The main purpose of this study is aimed to determine the amount of gas from sludge as obtained from oxidation ponds which are used for community wastewater treatment through nature-by-nature process (represent low concentration of organic matters) comparative with sludge from UASB tank of cassava factory wastewater treatment plant which represent high concentration of organic matters. Finally, the effect of factors on the potential of gas production from sludge was examined.

2. Methods and Procedures

2.1 Location of Experimental Sites

H.M. the King's Royally initiative Laem Phak Bia Environmental Research and Development Project (Royal LERD) has been established at Laem Phak Bia sub-district, Ban Laem district, Petchaburi province about 150 km from Bangkok and 50 km from Ratchaburi Province while the Cassava Factory is located at Banpong district, Ratchaburi province about 150 km from Bangkok as shown in Figure 2. The Royal LERD study area is located upper edge of mangrove forest nearby the Gulf of Thailand including 5-consecutive oxidation ponds as connected by 18.5-km HPDE pipe for transferring wastewater which pumps from Klongyang wastewater collection pond inside Petchaburi municipal. On the other hand, Banpong Tapioca Flour Industrial Company Limited is located in Banpong district, Ratchaburi province which produces native starch and various modified starch.

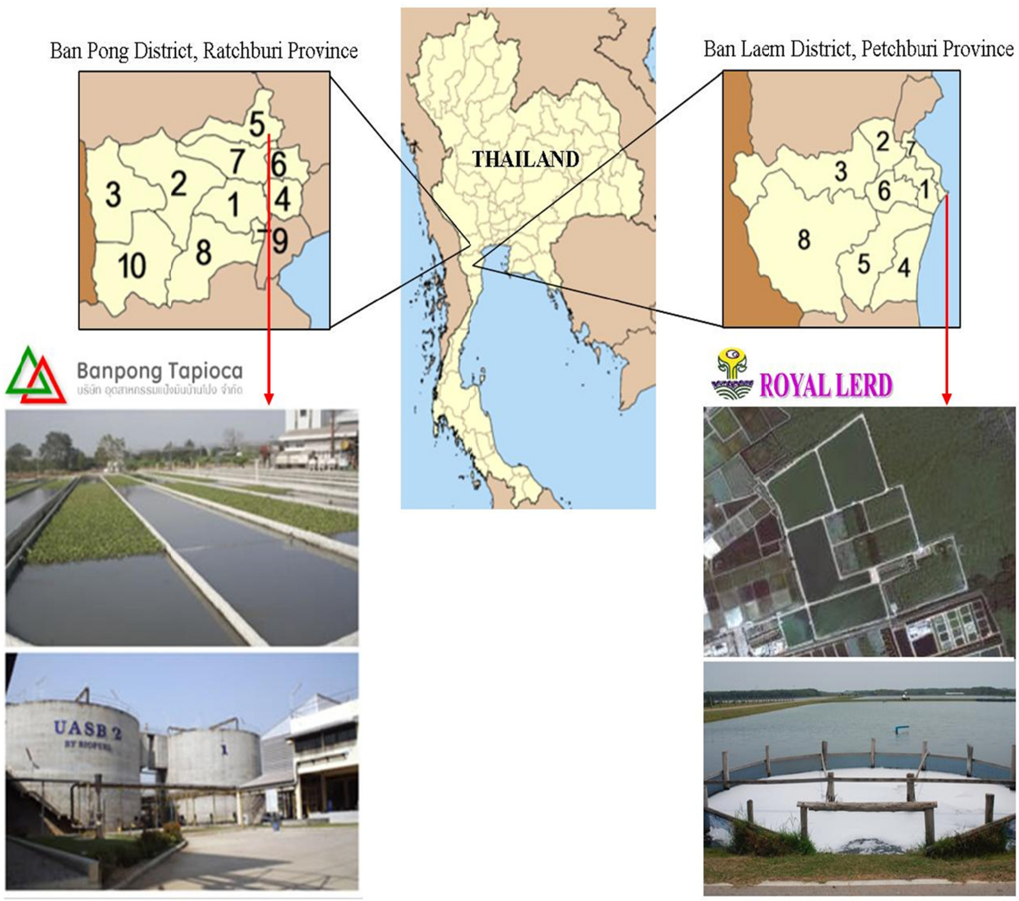


Figure 2. Location of the Royal-LERD project site in Petchaburi province and cassava factory in Ratchaburi province, and sampling station for collecting the fresh-weight sludge for extracting gases

2.2 Oxidation-Pond Sludge Products

THE Royal LERD oxidation ponds are made of compacted-clayed soils on ground floor and 4-side enclosures to form the trapezoid by 45-degree leaning to perpendicular sides with the water levels of 20-30 cm differences beginning from 2.50 m for sedimentation pond, 2.30, 2.00, 1.70, and 1.50 m for ponds no. 2, 3, 4 and 5, and formulating water storage capacity of $2.2x10^4$, $6.1x10^4$, 5.9 $x10^4$, 5.4 $x10^4$, and 5.9 $x10^4$ m^3, respectively (see Figure1). In addition, the water gate with smooth-round weir crest is also constructed as the pathway of treated wastewater from HPDE-pipe outlet to sedimentation pond through ponds 2, 3, 4 and 5 to the destination at the natural mangrove forest. Wastewater which came from Petchaburi municipal is continuously transferred by pumping from Klongyang collection pond about 6,000-8,000 m^3 per day through the 18.5-km HPDE pipe to the sedimentation pond in order to operate such community wastewater treatment by 5-consecutive oxidation ponds under nature-by-nature processes to produce oxygen supplying in bacterial organic digesting to become inorganic materials as plant nutrients for herbivore fishes consuming. Consequently, the sludge is produced during the bacterial digestion processing and moving down to the bottom of the oxidation ponds in terms of accumulative depth. In practicing point of views, such accumulated sludge has to be dredged out in every 5 years for encouraging the aerobic process of the excess and bigger size of organic wastes in community wastewater.

2.3 UASB Sludge Products

Banpong Tapioca Flour Industrial Company Limited is a Thailand leading manufacturer of native starch and various modified starch located in Banpong district, Ratchaburi province. The harvested cassava were washing and transferring to grind and manufacturing to produce the tapioca flour (cassava starch) as the product of cassava factory. At the same time, the wastewater from washing and cleaning of manufacturing process has to be drained into the UASB tank and consecutive-oxidation ponds for wastewater treatment before becoming effluent to the public water sources.

2.4 Sludge Collection

Purposively, the five sampling points were located on four corners and the middle of oxidation pond for Royal LERD project site in Petchaburi province (aged more than 3 years) for represent low concentration of organic matters and sampling sludge from UASB tank of cassava factory wastewater treatment plant in Ratchaburi province for represent high concentration of organic matters as shown in Figure1. Fresh-weight sludge samples were collected and kept them in close-dark containers for determining its moisture and using for energy extraction.

2.5 Sludge Moisture Determination

Every fresh-weight sludge that took from community wastewater treatment pond (oxidation pond of Royal-LERD) and cassava wastewater treatment plant (second treatment from UASB system) was to determine the moisture content. The method how to determine the sludge moisture content as in Equations 1-2:

$$M = [(Fw - X)/X] \times 100 \quad (1)$$

$$W = (MX/100) + X \quad (2)$$

Where: M = sludge moisture (%).

Fw = field-fresh weight of sludge (g.).

X = oven-dry weight of sludge (g.).

W = calculated fresh weight of sludge.

For the anaerobic conditions, moisture content have been considered to be important factor indicated that the amount of biogas should be directly depended on the moisture content and organic matters in sludge (Lay et al., 1997). Therefore, this research was focused on sludge moisture variation of M/4, M/2, M, 2M, and 4M as the stimulant for gas producing. It is obvious that M/4 and M/2 obtained by water pressing machine, M is normally fresh moisture content as obtained directly during sludge sampling from oxidation ponds, while M2 and M4 obtained by adding water. Consequently, the fresh-weight sludge for this experiment should be as in Equations 3-7:

$$W1 = (X\ M/4 \times 100) + X \quad (3)$$

$$W2 = (X\ M/2 \times 100) + X \quad (4)$$

$$W3 = (M\ X \times 100) + X \quad (5)$$

$$W4 = (2M\ X \times 100) + X \quad (6)$$

$$W5 = (4M\ X \times 100) + X \quad (7)$$

Based on oven-dry weight of 200 g (X), the fresh-weight sludge of W1, W2, W3, W4, and W5 were filled into the light brown color of 2.5-l narrow-mouth glass jar with two holes, first hole for thermometer for measuring inside temperature and second hole for silicone rubber tube for transferring gas during/after anaerobic digestion process in fermentation stage. However, there must be sealed any leakage by transparent silicone, and also the glass jar must be wrapped by aluminum foils in order to imitate the closed system for anaerobic process as illustrated in Figure 3.

3. Measurement of Gas Products and Separation

In principles, the amount of gas can be determined by taking an amount of oven-dry sludge 200 g into 2.5-l narrow mouthed-glass jar for gas extraction by fermenting it in anaerobe conditions. The amount of gas can be measured by taking the silicon rubber tube of light-brown narrow mouthed-glass jar which wrapped by aluminum foils connecting to pure-water bottle as gas acceptor by fluid displacement method as illustrated in Figure 3. The obtained gas is gradually replaced with pure water in the bottle after beginning of fermentation processing until the fermenting time is up. The gas volume will be manually recorded from scaling marks on the outer part of the pure-water bottle and collected data every hours (7 am-5 pm). In this study the gas yield was reported as the amount (milliliter) of gas generated per gram.

After the amount of oven-dry weight sludge 200 g was filled in to chamber with unopened cover and connect to three-way stopcock with overtopping for 1 hour in order to settle down of sediment. Use syringe was sucked up gas from the chamber through three-way stopcock for once a day. Then after, the gas inside syringe was injected into vacuum-blood tube. The concentration of gas such as hydrogen sulfide (H_2S), methane (CH_4), and ammonia (NH_3) was analyzed by gas chromatography techniques.

Figure 3. Method of fluid displacement (displacement bottle) for determining the amount of gas from fresh sludge as obtained from oxidation ponds of Royal-LERD project site in Petchaburi province and UASB tank of cassava factory in Ratchaburi province

4. Results and Discussion

In fact, the depth of oxidation pond is normally ranged between 1.5 - 3.0 m according to neglect the thickness of anaerobic zone as well as facultative bacterial digestion processing in which the bad smelling gases should be diffused through the above the surface. Even though the aerobic bacterial oxidation process is dominant, the facultative and anaerobic processes could be occurred in all parts of the oxidation ponds. This is why the accumulative sludge depth of the Royal LERD and cassava factory wastewater treatment system can be eligibly accumulated during the bacterial organic digestion processing.

4.1 Characteristics of Sludge

The dried Royal LERD oxidation pond sludge texture is comprised of sand 70%, silt 18 %, and 12% which classified according to the Unified Soil Classification System as sandy loam texture and cassava factory UASB sludge texture as loamy sand (sand 86%, silt 4%, and clay 10%) as shown in Table 1. It is remarkable to stress that the organic matter content was indicated in the cassava factory sludge (22.43%) more than findings as belonged to the oxidation pond sludge (12.77%) in which it was opposite from pH values of 7.8 and 7.1 for the Royal LERD oxidation pond sludge and cassava factory UASB sludge as indicated in Table1.

Table 1. Sludge oven-dry weight, properties, moisture content, elements of the Royal-LERD project and cassava factory including water quality and separated biogas

No.	Items	Oxidation Pond of Royal-LERD site	UASB tanks of Cassava factory
1.	Sludge Properties		
	1.1 Texture (%)		
	1) Sand	70	86
	2) silt	18	4
	3) clay	12	10
	1.2 Soil Texture	Sandy loam	Loamy sand
	1.3 pH	7.8	7.1
	1.4 Organic matter (%)	12.77	22.43
	1.5 Nutrients (mg/kg)		
	1) Phosphorus (P)	175	1,714
	2) Potassium (K)	370	6,420
	3) Calcium (Ca)	4,876	1,541
	4) Magnesium (Mg)	777	1,749
2.	Sludge Moisture		
	2.1 Fresh weight (g)	381.55	443.71
	2.2 Oven-Dry Weight (g)	53.97	36.35
	2.3 Moisture Weight (g)	606.97	1,120.66
	2.4 Fresh Wt: Dry Wt. Ratio (times)	7	11
3.	Organic Elements in Sludge		
	3.1 Carbon (%)		
	1) sample 1	10.48	38.55
	2) sample 2	4.64	18.86
	3) sample 3	3.48	21.07
	Average	6.20	26.16
	3.2 Hydrogen (%)		
	1) sample 1	2.41	7.26
	2) sample 2	1.53	3.19
	3) sample 3	1.16	4.53
	Average	1.70	4.99
	3.3 Nitrogen (%)		
	1) sample 1	1.04	8.2
	2) sample 2	0.50	2.76
	3) sample 3	1.34	3.66
	Average	0.96	6.89
5.	Water Quality		
	5.1 BOD (mg/l)	36.50	335.00
	5.2 NH_3 (mg/l)	13	156
	5.3 Nitrate (mg/L)	0.83	5. 63
	5.4 TKN (mg/l)	28.00	233.00
	5.5 Sulfide (ppm)	1.93	6.92
6.	Separated Biogas		
	6.1 NH_3 (ppm)	ND – 36.22	ND – 44.15
	6.2 H_2S (ppm)	55.94 – 360.27	5,894 - 68,050
	6.3 CH_4 (ppm)	545,686 – 9,560,606	729,404 – 9,900,837

Remarks: ND = Non-Detectable.

The Royal LERD oxidation pond sludge due to bring more silt and clay particles in the study area by estuarine water from the Gulf of Thailand which obtained them from the main-five rivers (Bang Pakong, Chao Phraya, Tha Chin, Mae Klong, and Petchaburi). It is noticeable that there were pH of cassava factory sludge on the value of 7.1 because the wastewater came from freshwater as used for manufacturing activities, while pH 7.8 for the Royal LERD sludge came from the mixing between the freshwater wastewater and estuarine water. Moreover, it is believed that in reality texture are highly percent silt which have adhered and attached together during the long term stock and degradation of sludge. (Arulrajah et al., 2011) Unfortunately, cassava factory UASB tank dried sludge texture was loamy sand because sludge from UASB tanks always likes granules sometimes called seed. A sludge granule is an aggregate of microorganisms forming during wastewater treatment in an environment with a constant upflow hydraulic regime. After when sludge granules were dried eventually the aggregates form into dense compact and texture like sand. So, the texture of cassava factory sludge was classified as loamy sand.

Research results had to pay more attention to the content of organic matter in sludge of UASB tank from cassava factory higher up to 22.43% by weight while the Royal LERD oxidation pond sludge found only about one half (12.77% by weight) as indicated in Table1. The hydraulic retention time (HTR) should pay role in higher reduction rate of organic wastes by the bacterial organic digestion processing as belonged to the Royal LERD community wastewater treatment system while less rate found in UASB for cassava factory wastewater treatment. In other words, the Royal LERD wastewater treatment system (in-pipe anaerobic process plus 5-consecutive oxidation ponds through nature-by-nature processes about 65 days until drain out) would be functioned more completely degradation than UASB system (engineering technology) as belonged to the cassava factory wastewater treatment. This was why the organic wastes left in the cassava factory sludge (22.43% by weight) higher than in sludge from the Royal LERD project site (12.77% by weight).

The research findings were obtained from analyzing some plant nutrients in sludge as designated in Table 1. The averaged values of phosphorus (175 mg/kg), potassium (370 mg/kg) and magnesium (777 mg/kg) for the Royal LERD sludge were lower than phosphorus (1,714 mg/kg), potassium (6,420 mg/kg) and magnesium (1,749 mg/kg) for the cassava factory sludge because of higher organic matter content in cassava and its adhered soils which are expected to contain more phosphorus and potassium elements. However, the value of calcium (4,876 mg/kg) of the Royal LERD sludge showed about 4 times higher than calcium of cassava factory sludge (1,541 mg/kg) as illustrated in Table1. Technically speaking, both sources of sludge could be able to apply for growing economic crops, only if they had to be safe from toxic chemicals which might be contaminated in the sludge.

Actually, cassava factory sludge is composed of much more carbohydrate in which the main structure is exactly pertained to carbon, hydrogen, and oxygen. It is no doubt that why the cassava factory sludge can absorb more water than sludge as obtained by oxidation pond of the Royal LERD wastewater treatment system. Besides, there were much more nitrogen, TKN, NH_3, and nitrate that indicated high moisture absorption in part of cassava factory sludge (31 times of its oven-dry weight) than the oxidation pond sludge (11 times of its oven-dry weight). Furthermore, the bacterial organic digestion under nature-by-nature process in oxidation pond sludge was presumably fulfilled much more than occurring in cassava factory sludge from UASB anaerobic process as stated previously.

4.2 Moisture Content of Sludge

The evidence can be seen in the research results for sludge moisture determination as shown in Table 1. The results found the moisture content in oxidation pond sludge 606.97% or higher about 7 times of its oven-dry weight while in cassava factory sludge 1,120.66% or about 11 times as shown in Table1. The reason will be emphasized on the water absorptivity of organic matter, normally more than 7 times of its oven-dry weight, that induced to think of the more organic matter content are the more water absorption in sludge. The previous statement could be pointed out that this is the reason why the cassava factory sludge was shown in higher water absorption capacity than results found in the oxidation pond sludge as designated in Table1.

Theoretically speaking, the digested organic matter, mostly called as inorganic materials, is normally capable to absorb water in three forms: firstly, in form of chemical-combined water; secondly, in form of the particle pores (both macropores and micropores of greater and less 50 microns in diameter); and lastly, coating on particle surface by adhesive and cohesive forces. Field observation found that the oxidation pond sludge was comprised of more coarse particles than cassava factory sludge, in which the diameter size of micropores should be existed more than macropores. In contrary, the micropores and specific surface of cassava sludge would play vital role in more water absorption capacity not only in-cavity function but also coating on the finer particle surface. This is why the cassava factory sludge showed its water absorption capability than the oxidation pond sludge as illustrated in Table 1. In the same way, the sludge that is characterized somewhat friable structure like oxidation pond sludge can normally absorb less amount of water than fine particles of cassava sludge.

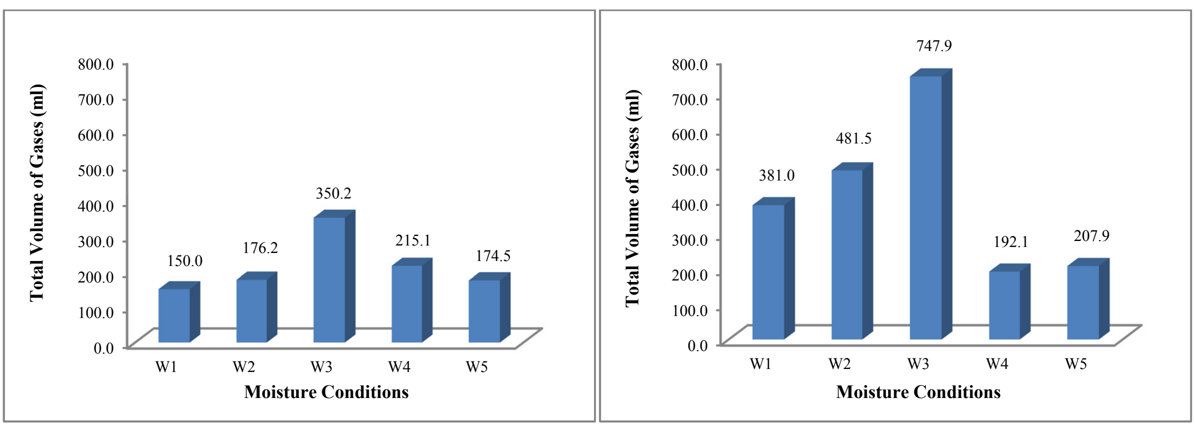
4.3 Gas Producing from Sludge Fermentation

A comparison of gas producing from sludge fermentation under anaerobic process in 200-g of Royal-LERD oxidation pond sludge and cassava factory sludge as represented low organic and high organic content groups was shown in less amount of NH_3, H_2S, and CH_4 for low rather than high organic ingredients (Table1). The gas producing from the sludge fermentation found (1) ammonia gas (NH_3): ranging ND – 36.22 ppm, (2) hydrogen sulfide (H_2S): ranging 55.94 – 360.27 ppm, and (3) methane (CH_4): ranging 545,686 – 9,560,606 ppm for the Royal LERD project; and (1) ammonia gas (NH_3): ranging ND - 44.15 ppm, (2) hydrogen sulfide (H_2S): ranging 5,894 - 68,050 ppm, and (3) methane (CH_4): ranging 729,404.00 – 9,900,837.00 ppm for the cassava factory sludge as shown in Table1.

It is clearly understood that the sludge of cassava factory which obtained treated wastewater from anaerobic process of UASB system can be produced more concentration of gas in terms of NH_3, H_2S, and CH_4 as stated above because of the high content of carbohydrate which is composed of carbon, hydrogen, and nitrogen as the main structure. In basic principles, the more carbohydrate (as received from UASB wastewater treatment system) is more gas to produce, especially NH_3, H_2S and CH_4. Nevertheless, with the anaerobic digestion methods, almost of the organic matter are mineralized and subsequent biogas generation increase in biogas/methane generation (Gonzalez et al., 1998; Singh et al., 1999; Tyagi & Lo, 2013). In opposite, the aerobic and more or less facultative fermentation under the nature-by-nature processing of oxidation pond sludge did not produce more biogas due to the completeness of bacterial organic digestion as stated above. The reported on an anaerobic pond found that biogas was formed decreased as the pond aged. It proposed that the higher biogas production related with period of sludge accumulation in pond. (Heubeck & Craggs, 2010; Cruddas et al., 2014) Additionally speaking, UASB wastewater treatment system has some constraints to apply for high organic waste content in wastewater, particularly high concentration of BOD, COD, TDS, and SS as well as high content of carbohydrate and proteins.

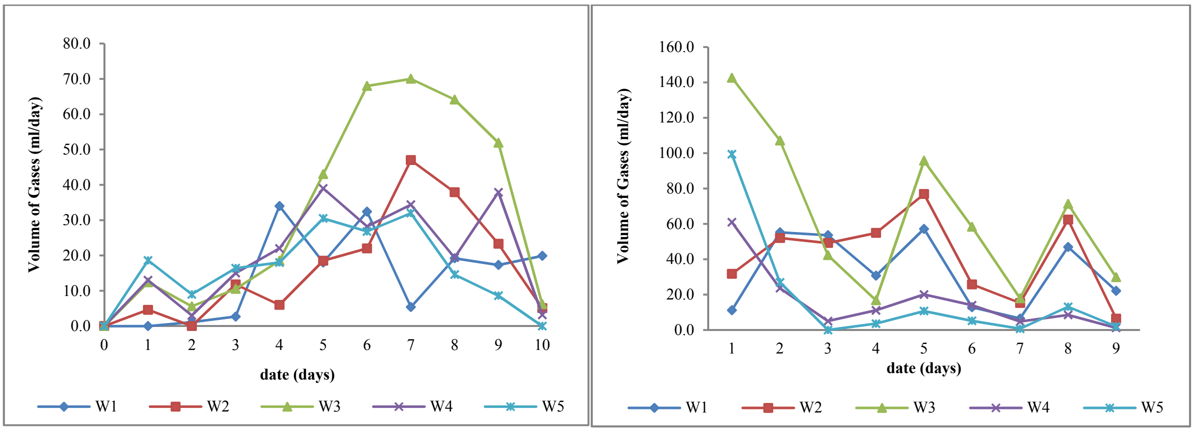
4.4 Biogas Releasing Period from Sludge

The bacterial organic digestion process of oxidation pond sludge (200 g oven-dry weight) caused immediately the gas occurrence at the beginning stage, then gradually increased on the third day, and reached the maximum quantity on the ninth day for field fresh weight (W3). The results was also pointed out that the same trend occurred on the moisture levels of W2 and W4 but the biogas seemed lower amount. In contrary, the moisture content on levels of W1 and W5 were found in irregularly trend from beginning period until to the tenth day (Figure 4). For gas producing from cassava factory sludge, gas was immediately occurred after the start- up period of fermentation due to its high concentration of C, H, N, and sulfate. In anaerobic digestion process with high sulfate and organic content is a useful characterization technique because sulfate is the terminal electron acceptor and is reduced to sulfide gas, with reducing equivalents derived from the degradation of many organic compounds (Widdel, 1988; Sinbuathong, 2007) but after change organic to gas form, gas production rate was gradually decreased with rapid rate until to the minimum during the third and fourth days (Figure 5). In anaerobic digestion with high sulfate and organic content Then after, it trended to increase again on the fifth and the eight days before stopping on the tenth day.



a) sludge from oxidation pond b) sludge from UASB tank

Figure 4. Histogram of gas volume from (a) sludge of oxidation pond comparable with (b) sludge from cassava factory UASB tank



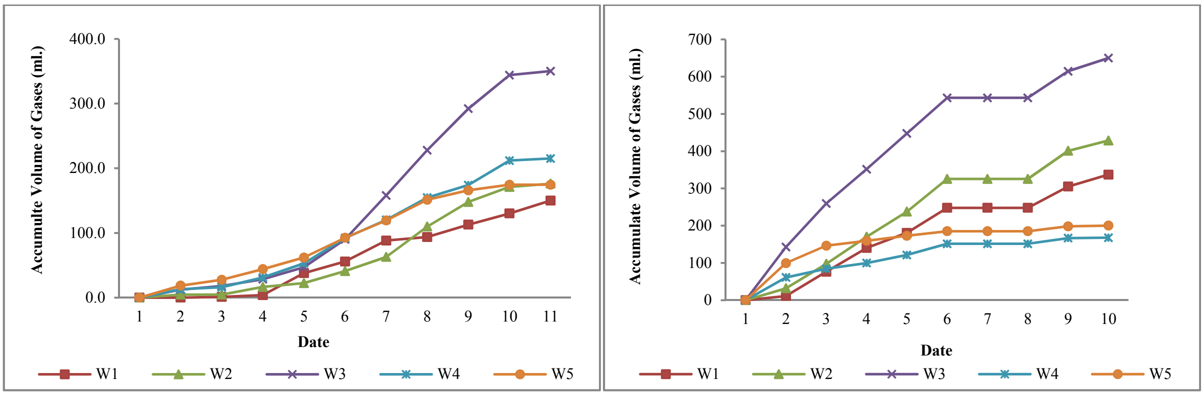
a) sludge from oxidation pond b) sludge from UASB tank

Figure 5. Periods of gas producing from (a) sludge of oxidation pond comparable with (b) sludge from cassava factory UASB tank

It should be noted that the maximum amount of gas from oxidation pond sludge was occurred at the sixth days on the field fresh weight (W3) about 70 ml/day (1.8 ml/g of its own oven-dry weight) and a little small amount after squeezing sludge moisture about a half (W2) and one-fourth content (W1) but lower biogas production found by adding moisture for 2 and 3 times (W4 and W5 respectively) of the field fresh weight (W3) as shown in Table1 and Figure 4. The cassava factory sludge, gas was occurred in the maximum rate at first day on cassava factory sludge found the maximum volume on the first day with the rate of 142.6 ml/d and average of 72.2 ml/d (3.25 ml/g of its own oven-dry weight). In other words, the existing moisture in sludge showed higher potential to produce more biogas than dewatering or adding moisture. For practicability, the direct grab of sludge from oxidation ponds should be immediately brought to ferment in order to get more biogas products. The results presented in Figure 4(a) show that gas releasing activity of oxidation pond at low moisture content was also remarkably lower than at high moisture content. In contrary, Cassava factory sludge found the high moisture content (about 11 times of its oven-dry weight) when adding more water to increase moisture (W4 and W5), the results presented in Figure 4(b) show that gas releasing activity at low moisture content was also remarkably higher than at low moisture content. Obviously, the moisture content is important environmental factors for organic digestion process and has specific relationship with methanogenic activity in anaerobic digestion process (Cheremisinoff, 1994; Ghosh, 1984; Lay et al., 1997).

4.5 Role of Sludge Moisture in Gas Releasing

As mentioned before, moisture content of sludge played vital role in gas releasing, particularly cassava factory sludge because of its structure being composed of more carbohydrate. From the previous statement, the field fresh weight of sludge which belonged to the original moisture content (W3) as taken at the sampling site was shown as the most probable factor to release gas from both the oxidation pond and UASB sludge. Following such statement, the 200 g oven-dry weight of both sludge were used to determine the gas releasing and found the product for the ninth and tenth day of cassava factory sludge through UASB wastewater treatment system and oxidation pond for treated community wastewater, respectively (Figure 3). The experimental results showed the amount of gas product from oxidation pond sludge (1.80 ml/g oven-dry weight) lower than the amount of gas that released from cassava factory sludge (3.25 ml/g oven-dry weight) due to less C, H, N, sulfate, and carbohydrate which are the main structure of sludge. Anyway, no matter the moisture was dewatered or adding to get wet sludge, the released gas was evidently reduced almost about 50 % of field moisture samples as illustrated in Figure 6 and Table 2.



a) oxidation pond sludge b) cassava factory UASB tank sludge

Figure 6. Accumulate gas releasing from moisture content variation of (a) oxidation pond sludge under nature-by-nature process and (b) cassava factory sludge as obtained from UASB anaerobic process

Table 2. Role of moisture content in gas releasing from sludge of oxidation pond and cassava factory UASB tank

No.	Sludge Moisture	Gas Releasing (ml/g oven-dry weight)	
		oxidation pond sludge	cassava factory sludge
1	W1: one-fourth decreasing W3	0.75	1.78
2	W2: half decreasing W3	0.88	2.14
3	W3: field fresh weight	1.80	3.25
4	W4: two times adding W3	1.08	0.84
5	W5: four times adding W3	0.87	1.01

5. Conclusion

For serving satisfaction on the concept of zero waste management and bioenergy recovery, the Royal-LERD sludge that obtained from oxidation pond of the community wastewater treatment under the Thailand King's initiative nature-by-nature process can be fermented for producing gas in terms of comparison to the cassava factory sludge as obtained from UASB system under anaerobic processes. Some necessary chemicals were analyzed from field fresh sludge for determining moisture and gas producing. Much more moisture content found in the cassava factory sludge about 11 % oven-dry weight and 7 % for oxidation pond sludge because of higher content of C, H, and N as the same trend as BOD, TKN, ammonia, nitrate, and sulfide. In the same manner, the sludge fermentation can directly produce gas that showing higher amount of gas from the cassava factory sludge (3.25 ml/g) than the oxidation pond sludge (1.80 ml/g). However, the fresh field sludge was indicated as the most maximum gas production rather than dewatering and adding some more water before fermenting for gas producing.

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