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Use of G3-DHS Bioreactor for Secondary Treatment of Septic Tank Desludging Wastewater

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Abstract- *Study was done for the use of the third-generation of downflow hanging sponge (G3-DHS) bioreactor for secondary treatment of septic tank desludging wastewater. The main objective of this study was to evaluate the prospective system of G3-DHS bioreactor to be applied in Indonesia. During experiment, the G3-DHS bioreactor kept a relatively high dissolved oxygen concentration under natural aeration. At a relatively short hydraulic retention (HRT) of 3 h, the G3-DHS bioreactor could remove up to 21% (SD □ □ 15%) of total COD, 21% (SD = 7%) of filtered-COD, 58% (SD = 24%) of unfiltered-BOD, and 33% (SD = 24%) of ammonium removal. The final effluent had an unfiltered-BOD of only 46 mg.L^{-1} (SD = 20 mg.L^{-1}) that it was below the Indonesian standard (unfiltered-BOD = 100 mg.L^{-1}) for thresholds of domestic wastewater treatment plants effluent.*

Keywords *– domestic wastewater, G3-DHS, septic tank, desludging*

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1. Introduction

Indonesia's economic growth in recent decade has not been corresponding by an increase in community sanitation facilities. Generally, cities in Indonesia have practically no suitable sewer system. Mainly, domestic wastewater produced by the communities is discharged either directly into canals and rivers or into septic tanks that are inadequate maintained. Most of septic tanks are poorly constructed, regardless water tight, and usually overflow into roadside drains. According to World Bank Report [1], in Indonesia Country Study, less than 5 percent of the sludge collected from septic tanks (desludging septic tank) is suitably treated, and merely about 1 percent of the wastewater generated by the population is treated, generating health and environmental problems. Moreover, approximately 14 percent of urban inhabitants still employ open defecation.

Historically, domestic wastewater management in Indonesia was starting since *Repelita* (five yearly development programs) in 1945-1980, through Kampong Improvement Program (KIP). The innovative KIP in Jakarta launched in 1969 is the world's first urban slum upgrading project. From 1974, the World Bank supported the KIP scheme with soft loans to accelerate the pace. By 1979, the Indonesian government endorsed the KIP scheme as national policy [2]. The program was continued focusing on the development of onsite sanitation facilities and rehabilitation on central system. Under the Integrated Urban Infrastructure Development (IUIDP) Program, a number of off-site sanitation systems (IPLT – *Instalasi Pengolahan Lumpur Tinja*) or sewerage systems were built in cities such as Medan, Prapat, Jakarta, Bandung, Cirebon, Yogyakarta, Denpasar, Banjarmasin, and Balikpapan [3].

Even though those IPLTs have showed appropriate design, in fact most of the IPLTs in Indonesia are operating on very low loading (under design capacity) and less maintenance [4]. Consequently, effluent from those IPLTs can not meet effluent quality standards and posing a potential for contamination of waters sources. Therefore, there is an urgent need to develop appropriate technology for treatment of domestic wastewater. Such treatment system must function according to some conditions, have non-complicated design, use simple equipment, accomplishes standard effluents, and be effective in operation and maintenance. The principal objective of this research is to evaluate the performance of the third-generation of downflow hanging sponge (G3-DHS) bioreactor for treatment of desludging wastewater from IPTL. DHS bioreactor was originally published in 1997 by Machdar *et al*. [5] and has been explored for extensive time by numerous researchers [6], [7], [8], [9], [10], [11], [12] for treatment of domestic wastewater.

Correspondingly, prior to experiment, an assessment was conducted to oversee sanitation condition at Banda Aceh City, Aceh Province, Indonesia. The objectives of this assessment were to verify the status of water quality in a domestic wastewater collecting pond (inlet, inside, outlet) at the Peuniti Village, Banda Aceh City, in terms of organic concentrations (COD, BOD), nutrient concentrations (ammonia, nitrite, nitrate, and total nitrogen), and suspended solids (TSS and VSS). Additionally, water consumption and sewage produce by the Peuniti Village communities were estimated based on data from water supply company and field survey. Therefore, this report includes current condition of sanitation service at around investigated area.

2. Materials and Methods

2.1 Assessment of sanitation condition

An assessment was conducted by taking sample from a domestic wastewater collecting pond located at Peuniti Village, Banda Aceh City. Three locations of sampling point were selected, i.e. inlet, inside, and outlet pond to observed performance of the pond. The pond received domestic wastewater through a channel (combined sewer – domestic wastewater and rain water). The wastewater produced from 1,850 households (7,172 people) of Peuniti Village. Incoming flowrate of domestic wastewater to the pond was measured by Float (Point) Method also it was known as the cross-sectional method. The measurement steps as follow: decide on a length of stream; using a meter stick, measure the water depth of stream; using a stopwatch, measure the time it takes the float to travel down the decided length of stream; repeat the steps three to five times and calculated the average flowrate. Data collection of household water consumption of the Peuniti Village was obtained from Banda Aceh's Water Supply Company (PDAM – *Perusahaan Daerah Air Minum* – Tirta Daroy).

2.2. Bioreactor configuration and start up

The G3-DHS bioreactor was installed at the IPLT of Banda Aceh City, Aceh Province, Indonesia. A schematic diagram and photograph of the bioreactor is presented in Figure 1. The G3-DHS bioreactor consisted three segments with a total height of 4 m and diameter of 30 cm. The segment allowed the bioreactor to be ventilated. The sponge module (G3-type) was a PUF (polyurethane foam) cube (30 mm) packed inside a cylindrical plastic net ring (30 mm diameter and 30 mm length).

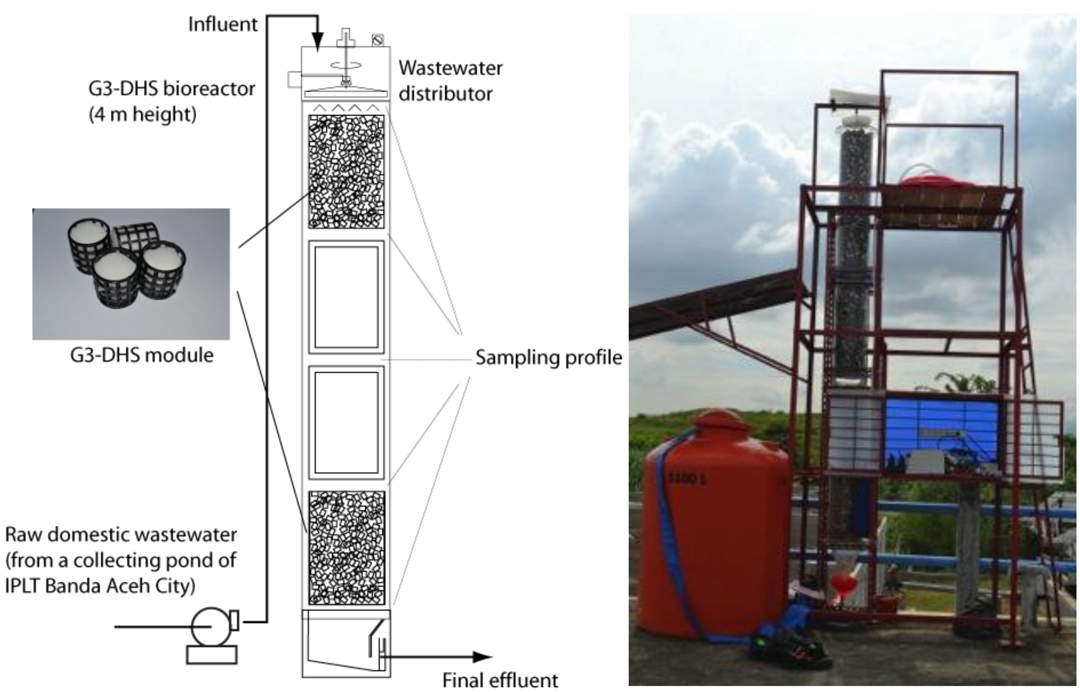

Figure 1. A schematic diagram and photograph of the experimental set up.

2.3 Operating condition and analysis method

The raw desuldging septic tank wastewater, taken from a collecting tank, was feed to the bioreactor by using a peristaltic pump after a brief settling priode in a 2000-liter-container-plastic tank. The wastewater was distributed from the top of the G3-DHS bioreactor and trickled down through the sponge module by force of gravity. The first setting hydraulic retention time (HRT) based on the sponge module volume was 3 h. The bioreactor was started up without inoculation and operated without media replacement or washing. Performances of the bioreactor were examined by analyzing samples of its influent and effluent streams. Water quality parameter measured includes TSS, VSS, COD (unfiltered and filtered), BOD (unfiltered and filtered), ammonia, nitrite, nitrate, and TN. All analytical methods adopted for determination of the parameters were based on theAPHA-AWWA-WEF [13].

3. Results and discussion

3.1 Assessment of sanitation condition

Peuniti Village is covered about 48.75 ha consisting of 35 ha for settlement. The investigated pond received domestic wastewater through a channel (combined sewer – domestic wastewater and rain water). The wastewater came from 1,850 households (7,172 people) of Peuniti Village. Population distribution of Peuniti Village and wastewater production is presented in Table 1.

Table 1. Population distribution and wastewater production of Peuniti village

Area	Household	Population	Wastewater Production (m^3.d-1)
Cut Nyak Dhien	519	1,871	271
Malahayati	227	986	143
Ratu Safiatuddin	612	2,576	374
Cut Meutia	266	965	140
Fakinah	226	774	112
Total	1,850	7,172	1,040

The information concerning the total of water consumption (a reflection of wastewater discharge to the pond) by Peuniti Village communities was gathered from the PDAM. Table 2presents water consumption by the communities. It was found that the average water consumption at three months continues data was approximately 676 $m^3.d^{-1}$ or water use per capita per day is 94 Liter. According to the PDAM staff (personal communication), up to 25% to 40% of the total water entering supply-line system is lost to leaking pipe and illegal connection. In most cases, illegal connection is the most frequent events. The main cause of the illegal connection is poverty when people have no money to pay water bill. On the other hand, some communities also use water from other sources like shallow well, rainwater harvesting, and water bottle. Therefore, the value of water use per capita at Peuniti Village may be corrected.

Table 2. Water consumption by Peuniti village*

Month	Water consumption		
	Total (m^3)	$m^3.d^{-1}$	$L.cap^{-1}.d^{-1}$
January	21,831	704	98
February	22,189	716	100
March	18,883	609	85
Average	20,968	676	94

*) Calculated based on water consumption from Banda Aceh's Water Supply Company (PDAM Tirta Daroy, 2014). Water from shallow well, rain harvesting, water bottle, and other sources, as well as leaking pipe and illegal connection of PDAM pipe do not include.

Peunity village population represents almost of 3% of Banda Aceh City people using septic tank. However, none of the city government agency has accurate record numbers of septic tanks and whether those individual/communal sewage treatments follow the government regulation regarding septic tank specification. This is due to several reasons: septic tanks were installed without permitting requirements (no specific regulations); and permits for building and septic system are included in one building permit.

The total of wastewater produced by Peuniti Village was determined by measurement of flowrate intake at the inlet of the collecting pond for ten-day continuously. The measurement was conducted three times a day, morning (8:00 am), afternoon (14:00 pm), and night (18:00 pm). Estimation of the inlet flowrate to the pond is presented in

Table 3. The influent wastewater to the pond was found approximately of 943 m^3. d^{-1}or 145 $L.cap^{-1}.d^{-1}$on an average based on full-time residence. This result compares the value of Table 3 shows that water loss (uncountable by water supply company) is approximately 25% (assumed 10% contributed from shallow well, rain water harvesting, and water bottle).

No water quality monitoring is conducted in the domestic wastewater collecting pond at the Peuniti Village. It is probably due to the pond was originally proposed only for flooding anticipation or budget for water analysis do not provided by the government. Therefore, no other reference data can be used to evaluate the pond performance and compare to this study.

From this study it was found that incoming COD unfiltered and filtered are about 19 to 94 mg unfiltered-COD.L^{-1} and 15 to 40 mg filtered-COD.L^{-1}, respectively, probably dilute by rain water. Regarding concentration of in the pond and the pond outlet, the COD is almost similar but increased compare to the inlet concentration. It probably due to contributes from digest of sludge accumulation in the pond. The pond receives low BOD concentration during the investigation and the BOD slightly increase at the effluent (Table 4).

Nutrients investigated in this study include four species of nitrogen, i.e. nitrite, nitrate, ammonia, and total nitrogen. Results for these parameters are found in Table 4. Residual nitrogens in from of ammonia, nitrite, and nitrate in the pond effluent remain very low, generally below 1.0 $mg.L^{-1}$.

Table 3. Daily wastewater influent to the domestic wastewater collecting pond

Dayth	Flow rate, $L.h^{-1}$ or ($m^3.d^{-1}$)			
	Morning (08:00)	Afternoon (14:00)	Night (18:00)	Average
1	106,500 (2,556)	38,727 (929)	31,950 (767)	59,059(1,417)
2	71,000 (1,704)	31,171 (748)	29,721 (713)	43,964 (1,055)
3	44,069 (1,058)	36,514 (876)	33,632 (807)	38,072 (914)
4	85,200 (2,045)	28,400 (682)	25,560 (613)	46,387 (1,113)
5	75,176 (1,804)	25,560 (613)	24,577 (590)	41,771 (1,003)
6	75,176 (1,804)	32,769 (786)	27,783 (667)	45,243 (1,086)
7	71,000 (1,704)	29,721 (713)	24,113 (579)	41,611 (999)
8	36,514 (876)	38,727 (929)	31,171 (748)	35,471 (851)
9	58,091 (1,394)	35,500 (852)	29,045 (697)	40,879 (981)
10	47,333 (1,136	38,727 (929)	32,769 (786)	39,610 (951)
			Average	43,201 (943)
			Discharge wastewater ($L.cap^{-1}.day^{-1}$)	145

Table 4. Water quality of inlet, inside, and outlet of the pond at Peuniti village

Parameter	Location		
	Pond Inlet	Pond Inside	Pond Outlet
VSS ($mg.L^{-1}$)	41 – 49	41 – 49	38
TSS ($mg.L^{-1}$)	76 – 93	68 – 145	63 – 84
Unfiltered-COD ($mg.L^{-1}$)	19 – 64	38 – 40	32 – 69
Filtered-COD ($mg.L^{-1}$)	15 – 40	34 – 38	28 – 32
Unfiltered-BOD ($mg.L^{-1}$)	10 – 30	19 – 23	15 – 29
Filtered-BOD ($mg.L^{-1}$)	8 – 22	18 – 19	13 – 14
NH_4-N ($mgN.L^{-1}$)	0.2 – 0.6	0.3 – 1.0	0.4 – 0.6
Nitrite ($mgN.L^{-1}$)	0.08 – 0.09	0.09 – 0.1	0.09 – 0.12
Nitrate ($mgN.L^{-1}$)	0.30 – 1.90	0.20	0.04 – 0.20
Total-N ($mgN.L^{-1}$)	23 - 27	16 – 17	6 – 11

3.2 Performances of G3-DHS Bioreactor

One of the most important factors for an aerobic reactor to achieve a good performance in treatment process is dissolved oxygen (DO) concentration. The DO level of effluent from the G3-DHS bioreactor was all time kept around 5.7 mg $DO.L^{-1}$ (SD 0.3 mg $DO.L^{-1}$) though the DO was almost zero at the inlet (corresponding to the preliminary tank effluent). No substantial difference in COD removal performance was observed during 3 month operation. The average unfiltered-COD of the final effluent was 373 $mgCOD.L^{-1}$(SD 119 $mgCOD.L^{-1}$). Accordingly, the unfiltered-COD removal in the G3-DHS bioreactor was around 21% (SD 16%).

It was clear that the minimal DO concentration needed for nitrification is in the range of 0.3 to 4 $mgDO.L^{-1}$. Since the DO level in the G3-DHS bioreactor was relatively high, nitrifiers in the bioreactor could be compete on dissolved oxygen with autotrophs. Even though ammonia-N in the influent to the bioreactor considerably fluctuated from 50 to 15 $mgN.L^{-1}$, the bioreactor performed stable nitrification, yielding 15 $mgNO_3$-$N.L^{-1}$throughout the experimental duration. The result indicated that the ammonia-nitrogen removal efficiency achieved was nearly 33% (SD 24%). A summary of the water quality influent and effluent of the bioreactor is presented in Table 5.

Table 5. Summary of influent and effluent in the G3-DHS bioreactor

Parameter	Influent	Effluent
pH	5.45 – 5.92	6.31 – 6.56
DO ($mg.L^{-1}$)	2 (0.8)	5.7 (0.3)
Unfiltered-COD ($mg.L^{-1}$)	477 (145)	373 (119)
Filtered-COD ($mg.L^{-1}$)	232 (61)	198 (54)
Unfiltered-BOD ($mg.L^{-1}$)	155 (120)	46 (20)
Ammonium-N ($mgN.L^{-1}$)	26 (12)	19 (11)
NO_2-N ($mgN.L^{-1}$)	0.4 (0.8)	1.2 (0.8)
NO_3-N ($mgN.L^{-1}$)	7 (2)	15 (3)
TN ($mgN.L^{-1}$)	37 (11)	37 (11)
TSS ($mg.L^{-1}$)	198 (41)	168 (50)
VSS ($mg.L^{-1}$)	151 (31)	128 (41)
Removal		
Unfiltered-COD (%)	21 (16)	
Filtered-COD (%)	15 (7)	
Unfiltered-BOD (%)	58 (24)	
Ammonium (%)	33 (24)	
NOx-Production ($mgN.L^{-1}$)	2 (1)	
HRT (h)	3	

The profile analysis of the wastewater stream along the height of the G3-DHS bioreactor treating desluging septic tank wastewater showed that soluble COD (organic substance) and ammonia were removed mainly in the upper portion (Figure 2). This finding has also similar presented by other studies [7], [6], [9], [14]. It could be implied that the microenvironment almost certainly differs along the bioreactor height.

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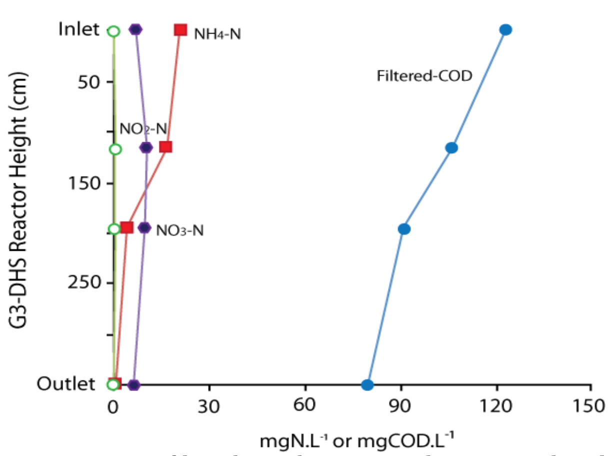

Figure 2. Profiles along the G3-DHS bioreactor height

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