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THE IMPROVEMENT OF ANAEROBIC WASTEWATER TREATMENT WITH STRUCTURED MEDIA GROWTH SYSTEM

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Abstract

The anaerobic domestic wastewater treatment plant at communal scale are seen not be sustainable and the process has to be improved by anaerobic and aerobic process - structured media growth system, in regard with still high water source quality degradation and water reuse development. This paper aims to research the improvement of communal wastewater treatment system through anaerobic –aerobic of structured media growth system which had applied in some urban areas. The treatment system applied the anaerobic baffled reactor (ABR), submerged media growth system and rotating biological contactor (RBC) system has low area requirement and has to concern optimization energy. The treatment system applied the hybrid upflow anaerobic sludge blanket - submerged media growth system and hybrid sub surface of constructed wetland has low cost operation and maintanence. Both of the systems have many *advantages and could consider as improvement of the anaerobic communal wastewater treatment plant. The evaluation of performance of these systems show the treated water can meet effluent standard and can be reused as non potable source in urban areas.*

Keywords

Communal, Wastewater, Improvement, Structured Media, Growth

1. Introduction

The challenge of wastewater treatment is increasing as a result of still high degradation of water sources and low coverage of sewer system in Indonesia. According to data from the Ministry of Public Works, Directorate of Human Settlements, 2015, Indonesia' access to the sanitation reached 61.04 %, consist of 74.15 % in urban area and 44.74 % in rural area. Approximately 74.15 % of the urban population and 44,74% of the rural population live in unsewered area, rely on onsite wastewater treatment plant (WWTP). To achieve safe access to sanitation which stated in sustainable development goal (SDG) for all by 2030 requires also more international cooperation to encourage water efficiency and support treatment technologies in developing countries (the 2030 Agenda of SDG).

Many practical design and operational decisions on wastewater treatment plants use anaerobic treatment technology. Anaerobic treatment has been shown to provide a cost effective alternative to aerobic processes with saving in energy and reactor volume (Mara, 2003). The provision of the anaerobic WWTP are seen not be sustainable options due to fluctuation of influent quality, more strict effluent standard, potential to nitrification and disease-producing microorganisms, high mobile substances like detergents, and ions such as chloride and nitrate which can contaminate of both surface and underground water sources. The improved wastewater treatment should be based on wastewater characteristic, community in the serviced area and also other countries experiences. The sustainability the wastewater management will be ensuring safe sanitation, and encourage water efficiency or water reuse based society scale. The most important criteria for long-term sustainability of wastewater management implementation are affordability (capital and operational & maintenancecosts), functionality (possibly with locally available staff and support), reliability (e.g. safe effluent for water reuse), environmentally sound (e.g. little sludge production and low energy consumption) and climate suitability (temperature specific) (Al Baz, 2008).

Improvement of treated water quality from domestic wastewater treatment has to be developed according to the purpose of proper attention to sanitation, public health and environment. The strategy of communal wastewater infrastructure improvement is important to have impact on safe sanitation access, clean water sources protection and development of water reuse practices. The strategy has to consider awareness of community and local government, organization and human resources, institutions cooperation, partnership, practical design and operation of WWTP. This paper aims to study the technical and non-technical aspects of some application of communal WWTP with anaerobic or aerobic structured media growth system. The combination of anaerobic and aerobic system at structured media growth or biofilm reactor, result effectively nitrogen reduction through two stages nitrogen removal, nitrification and denitrification processes. In generally the structured media growth systems has some advantages include the following: reduced operating and energy costs, smaller reactor volume, minimized need for settling capacity, operational simplicity. Some general concerns associated with fixed-film processes include the following: potential clogging of the media system as a result of inadequate screening; excessive growth, which could plug the media system or cause free-floating media to sink; and inadequate mixing or short-circuiting, resulting in inefficient use of the media (WEF, 2010). Some urban areas had been conducting the upgrading of existing wastewater treatment which consists anaerobic suspended system to be developed to structured media growth system by fixed or rotated film media for achieving greater removal of organic or nutrient. The sustainability of upgrading wastewater treatment plant at individual or communal scale can contribute to the effort towards wastewater recycling. However the application of wastewater treatment based community management should be have low land requirement, simple, low cost in operation and maintenance. It is also to have factors of green technology which are directly related to reduced plant footprint, high quality effluent (as far as suspended solids related contaminants are concerned), pathogens removal capacity, avoided use of chemicals for disinfection, reduced sludge production, etc. (Lofrano, G., 2012).

2. Methodology

The study of improvement of anaerobic wastewater treatment had been done in the dense urban areas for one to two years which applied community based management of communal WWTP with anaerobic-aerobic system. The application of waste water treatment has structured media growth system which operated well in Yogyakarta City, Yogyakarta Special

Region Province and in Sumedang City, West Java Province. The primary data collection done through field observation, laboratory analysis, community and stakeholder approach. The data analysis of this study use comparative descriptive method at each wastewater treatment which consist of unit process, unit operation and community based management of WWTP.

3. Results and Analysis

3.1 Improvement of Waste water Treatment System

Urban area with uncontrolled wastewater treatment system or conventional anaerobic system resulted pollution with still high organic and nutrient concentration that will generally need for further treatment. Some urban areas have to improve wastewater system through the combination anaerobic aerobic system in regard with still highly water source quality degradation and water scarcity problem. A number of different anaerobic processes have been developed in urban areas for removal of the carbonaceous organic matters in wastewater. Because of limitation of nutrient degradation in the anaerobic process, the further treatment is required for nitrogen, phosphorus removal or waste stabilization. The treatment can apply anaerobic aerobic system with the principal process of biofilter system or structured media growth system which considered the most effective and economic reason in wastewater treatment.

The biological processes with attached growth system for wastewater treatment can adapt with local condition, such as structured media growth system (submerged or mobile biofilter), Rotating Biological Contactor (RBC) or semi aquatic plant system (constructed wetland) (Metcalf and Eddy, 2007). The attached growth process, include also trickling filter system have higher efficiency of organic removal in wastewater treatment (Vianna et al, 2012). The principal advantages of biological technologies for the removal of pollutants, including biological processes can be carried out in situ at the contaminated site, bioprocess technologies are usually no secondary pollution, and they are cost-effective (Vijayaraghavan, K, 2013). Generally the major treatment of communal WWTP system divided into physical treatment systems and biological treatment systems, which the systems mainly consits of :

- Pretreatment system consists of screening, grit chamber and sedimentation.
- Primary treatment system consists of Anaerobic Baffled Reactor (ABR), Biofilter, Upflow Anaerobic Sludge Blanket (UASB) or Biodigester System.

- Secondary treatment system consists of Rotating Biological Contactor (RBC), Trickling Filter, Constructed Wetland (CW) or Membrane Bioreactor System (MBR).
- Tertiary treatment system consists of adsorption, filtration and desinfection.

Table 1: *The Improvement of communal wastewater treatment system*

Type of Communal WWTP	Waste water source	Tank Material	Capacity (Househould/HH)	Water Reuse purposes
Type of A Pratreatment, ABR, Biofilter and RBC, Sedimentation	Mixed domestic wastewater	concrete (ABR, Biofilter), polypropilene, stainless steel(RBC)	50,120	river water quality improvement, garden watering
Type of B Pratreatment, hybrid UASB- biofilter/ aerobic biofilter, hybrid wetland, sand filtration	Mixed domestic wastewater	Fiber reinforced plastic (UASB-biofilter), concrete (Constructed Wetland)	100	Fish pond, agriculture irrigation

Source: Analysis

The application of wastewater treatment system for 50-120 households in the study area described in the Table 1. The unit of physical treatments consists of screening, sedimentation, adsorption and filtration. The biological treatment as primary and secondary treatment have anaerobic, semi aerobic and aerobic process. The shallow sewers was applied to service housing area to carry mixed domestic wastewater and has managed by community. In the WWTP of type A which located mostly in Yogyakarta City, the wastewater treatment using the anaerobic system applied plug flow system (ABR, up flow biofilter) then continue treated by RBC system of 3 D lattice media (Tanaka, 2015). In the RBC process the microbes grow at the entire surface area of the discs is covered with a 1- to 3 mm layer of biological slime. When the discs rotate, they carry a film of wastewater into the air, this wastewater trickles down the surface of the discs and absorb oxygen. When the discs complete their rotation, the film of water mixes with the reservoir of wastewater, cause the adding of oxygen in the reservoir and the mixing of the treated and partially treated wastewater. The excess growth of microbes is sheared from the discs as they move through the final sedimentation unit (Water Environment Federation, 2010). The effluent of RBC system can meet the regulation of Environment and Forestry Ministry no.68/2016 and be reliable as reclaimed water according to EPA standard, 2004. Some residents, especially in

Karangwaru District, Yogyakarta City, has been reused the treated wastewater for urban farming (Pusat Penelitian dan Pengembangan Permukiman, 2014).

In the WWTP of type of B at Table 1, the communal WWTP applied hybrid UASB-biofilter system where the anaerobic and denitrification process in the same unit. The efluent of this system flows to sub surface of the constructed wetland combine vertical flow and horizontal flow. This system has as objective to evaluate removal efficiency of COD and nitrogen (Sousa et al, 2008). In the process unit of the hybrid constructed wetland, local hydrophyte were chosen to plant in wetland medium (sand, gravel) which have proved an ability to remove organic, nitrogen and phosphor such as *Canna edulis*, *Cyperus papyrus*. At the denitrification stage in wetland system, we can use also local wood material as medium which based on some researchs show the natural material as solid carbon sources available such as woodchips are higher C/N ratio, longer duration of effectiveness and readily availability at moderate cost (Wang and Chu, 2016). Overall beside treating domestic wastewater, the applied wetland system could support greenery function in riparian area as potential improvement in reducing water run-off, regulating microclimates, treating air-land pollution filtration with variety of plant species and vegetation structures (Philip, 2011).

3.2 Performance of WWTP

The applied wastewater treatment in the study area consist of biological treatment which involves the structured growth system to remove contaminants. In the case of organic pollutants, the biological treatment involves enhanced degradation by transforming organic compounds into innocuous substances. However, inorganic compounds undergo sorption or accumulation onto biological materials (Vijayaraghavan, 2013). According to the composition of wastewater, physical characteristics and social condition in the study area showed vary organic removal and the average water quality at influent and efluent quality can be seen in the Table 2. The primary treatment in both system applied fixed bed biofilm system which could result low organic for treated further in the RBC or constructed wetland system. In the housing area which applied the WWTP of type A could result treated water from WWTP for garden watering and also the groundwater as a source drinking water can be prevented from pollution of individual latrine. Therefore implementation water reuse plant reduce groundwater pollution and further alternatives water source for non potable water demand.

Table 2: *Average water quality in the study area*

Parameter	Type A		Type B		Effluent Standard		
					Ministry of environment and forestry no.68/2016	Local govern-ment	Water reuse agriculture irrigation, EPA, 2004
Capacity (HH)	120		100				
Water quality	influent	effluent	influent	effluent			
TSS (mg/L)	244.5	2	152.5	12.25	30	75	30
BOD (mg/L)	229.5	25.1	190.09	24.4	30	75	30
COD (mg/L)	456	65.1	216.9	64	100	200	40-80
Nitrate(mg/L NO_3)	3.17	2.05	2.32	0.5			

Source: Analysis

In the WWTP of type B, the subsurface constructed wetland or dewatering performance depends on a variety of factors related substrate type, plants type, the maturity of beds, the climatic factors, the sludge characteristic as well as operational factors (hydraulic loading rates, solids loading rates, frequency of beds feeding, etc.) (Kengne, 2011). The effluent quality of type B can meet USEPA standard for water reuse of fish pond or agriculture irrigation that BOD should less than 30 mg/L, turbidity less than 2 NTU and TSS less than 30 mg/L. An approach to water reuse using constructed wetlands could eliminate desinfection by-products from treatment processes (Kracman at al, 2001). However, a major issue and risk with sewage effluent reuse is the potential of sewage-borne pathogens. The direct release of reuse water for the irrigation of agriculture and horticultural crops or recreational areas is viewed as posing potential risks to human health (Bahri et al., 2001; Carr et al., 2004; Kracman et al., 2001). Therefore in the water reuse plant, post treatment can apply sand filtration or desinfection process. Overall these plant decreasing the inflow of organic or nutrient to natural system and can reduce pollutant load to water courses or centralized wastewater treatment plants.

3.3 WWTP Application Criteria

Unsewerage area have pollution risk from existing wastewater infrastructure, water scarcity consideration, poltential of high river water pollution from domestic wastewater, has to improve their wastewater treatment because of difficulty of sewerage system expansion. The communal wastewater system had been applying could be orientated water reuse which need community approaches for its management sustainability. The water reclamation and reuse can return nutrients and water to the land, restore stream flows and bring life back to aquatic ecosystems (Bahri et al., 2001; Carr et al., 2004; Kracman et al., 2001). Therefore the successful water reuse plant application should be supported by understanding of water reuse and recycled water acceptance. For the development and management of improved communal WWTP orientared water reuse, the criteria of site selection should consider some technical and non technical factors as follows :

a. Technical Considerations

1) Serviced area include legal area of urban settlements
2) Serviced area as vulnerable sanitation areas, has sanitation problems or pollution risk from existing wastewater infrastructure.
3) Land availability for the development of communal WWTP.
4) Potential of water reuse.

b. Non-Technical Considerations

1) Willingness of the community as prospective users to participate since the planning, development and management of communal WWTP.
2) Potential of community ability will be developed through the community empowerment organization and those are awareness to operate and maintain the WWTP.
3) The need of community facilitator or assistance for at least one year after the operation of WWTP. Community facilitator or assistance is based on approach need on the activities since the preparatory stage, development stage until the post-construction stage and during the operation of the plant. Community facilitator should know the field condition, skilled and expert in community development are also has high integrity in the sanitation development.
4) Involvement of local government or other institution for educationof community, technical advice and management of WWTP.

Most of low income urban area have no sanitation infrastructure and still have habit to open defecation in the river. Appropriate technologies of wastewater treatment are characterized with concern of optimization energy as a key for low cost operation. According to some application with different capacity of treatment, the criteria of socio economic factor were shown at Table 3. Some barriers or limitation of community participation have also to be considered, may require cross subsidy or local government contribution for WWTP management. For area requirement in each structured media growth treatment system, their comparison can be seen at Table 4. The area requirement for the aerobic system of RBC is more smaller than in the semi aerobic or subsurface constructed wetland system. The treatment train at WWTP of anaerobic and semi aerobic system need larger area, but the system has low cost operation and maintenance. Although area requirements has also been considered in the application of anaerobic and semi aerobic system, include the option of hybrid construction of UASB and fixed bed biofilter and then further treatment by the subsurface flow of constructed wetland.

Table 3: *WWTP application criteria*

System Type	Design Capacity (HH)	Flow system	Community income in the serviced area (Rp/month)**	Participation level, retribution (Rp/month) *5)	chalenging area
Type of A	50	gravitation	1,000,000- 2,500,000	High 10,000	*1
	100	gravitation	1,000,000- 2,000,000	High-medium 7,000	*2
	110	gravitation	1,000,000-1,500,000	medium 6,000	*3
	80	pumping	1,000,000- 2,500,000	High 10,000	*4 flat, low
Type of B	50	gravitation	750,000-1,500,000	medium 1000-2000	
	100	gravitation	750,000-1,500,000	medium 1000-2000	

Description:

* 1,2,3: Based on experience at Kricak Kidul Location (service area of 65 of HH, capacity of 70 HH, the cost of operation and maintenance is Rp 408,000/month + allowance) and Karangwaru Location (service area of 81 of HH, capacity of 120 of HH, the cost of operation and maintenance is Rp 605,000/month), Yogyakarta City.
* 4: Based on experience in Landungsari Location, Pekalongan City (service area of 36 of HH, capacity of 80 of HH, the cost of operation and maintenance is Rp 375,000 / month + allowance).
* 5: Calculation of the cost of operation and maintenance is not considered a substitute for appropriate equipment investment costs lifespan of each piece of equipment: motors, gearboxes, bearings and chains. Regarding the cost of dewatering sludge, normally has to be considered, for example in Kricak Kidul Location, operation team received a fee of Rp 150,000 (of dues residents) who worked on sludge dewatering. At Karangwaru location and Sukunan location has already sludge treatment system and a straw processing is done by mutual cooperation.

** 1 $ about Rp.13,000

Table 4: *Area requirement for WWTP (m^2)*

Capacity service area (HH)	Anaerobic system		Semi aerobic system (constructed wetland)		Aerobic system (RBC)
	*1	*2	*3	*4	*5
50	80	23	29	42	25
100	100	34	44	61	38
150	150		63		55

Description:
* 1: Information of Local Goverment of Yogyakarta City.
* 2: data from the anaerobic biofilter system (Pusat Penelitan dan Pengembangan Permukiman, 2013)
* 3: data from the communal WWTP Sukunan Location, Yogyakarta City: land requirement RBC 3-Dimensional Lattice is 38% of the same function Aeration Contact (Pusteklim, 2014)
* 4: data from constructed wetlands (Pusat Penelitan dan Pengembangan Permukiman, 2013)
* 5: data from the communal WWTP Karangwaru Location , Yogyakarta City (capacity 120 HH, 44,3 m^2), Landungsari Location, Pekalongan City (capacity 80 HH, 32,8 m^2 besides pumping chamber). There is also an extreme case: Kricak Kidul Location , Yogyakarta City (capacity 70 HH, 12,3 m^2) (Pusat Penelitan dan Pengembangan Permukiman, 2014)

3.4 Operation and Maintenance

The wastewater treatment applied anaerobic aerobic structured media growth system could become reliable option for communal waste water treatment improvement in urban areas. This treatment would increase healthy condition and decreasing the inflow of organic or nutrient to natural systems, resulting in better water quality for reuse water, such as fish pond (Pusat Penelitian dan Pengembangan Permukiman, 2013). The sustainability of these technologies depend on the management of various operational and maintenance elements. There are some limitation of each technology application that have to be considered and require well trained people. According to Table 5, some major elements should be considered in operation and maintenance procedure. For operational and maintenance costs, the mechanical systems using RBC more costly than the subsurface wetland system. But in the wetland system, semiaquatic plant maintenance require an external attention from climate or animal. The both operation system has to maintain the biological growth become attached to the surface of the media and form a slime bio mass over the entire surface area of the media. Most of community as operator of theses system aware the treatment is appropriate for their area and also give benefits for water reuse and also esthetical landscape of wetland system. Moreover implementation of these systems should consider potential flooding or other disaster therefore buffer area or protection area are important. The both system will still further improvement for low cost or simplicity of operation and also define for long performance capabilities and operational problem.

Table 5: *Operational and Maintenance of Communal WWTP*

System Type	Description
Type of A	Cleaning from grease /solid waste at periodic time
	Desludging of 6 – 12 months, maximum of sludge desludging is 1/3 -1/2 of sludge volume
	Maintenance of RBC machine (lube/oil)
	Media replacement on the an aerobic filter tank every 20 years
	Spraying RBC film on the disc if it is full
	Electricity consumption about Rp 350,000-Rp.500,000 per month
Type of B	Cleaning from grease /solid waste before at periodic time
	Seeding using facultative bacteria and an aerobic bacteria at the first operation
	Desludging of 10 of years, maximum of desludging is 1/3 -1/2 of sludge volume
	Replacement of constructed wetland media every 20-25 years
	Maintenance of the constructed wetland plants regularly

4. Conclusion

The development of communal wastewater treatment with structured media growth system could improve treatment performance that give more benefits for community health, the effort towards recycle orientated community and environment quality. The applied communal wastewater treatment system should consider physical condition of serviced area, land availability, community acceptance and skill, simplicity of operation and maintenance and potential water reuse development. The communal wastewater treatment system applied the treatment train of plug flow system/anaerobic baffled reactor (ABR), submerged media growth system and rotating biological contactor (RBC) system has low area requirement and has to concern optimization energy. The communal wastewater treatment system applied the treatment train of hybrid upflow anaerobic sludge blanket - submerged media growth system and hybrid sub surface of constructed wetland has low cost operation and maintenance and very depend on community participation. Both of the system have many advantages and could consider as improvement or upgrading of the anaerobic communal wastewater treatment system. The sustainability of these technologies depend on the management of various operational and maintenance element. The evaluation of performance show these systems can meet effluent standard but associated water reuse practices at settlement area should include evaluation of health risk and require additional treatment for high quality reclaimed water.

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