PERFORMANCE OF COMMUNAL SANITATION FACILITY USING COMBINATION OF BIODIGESTER-BIOFILTER AND WASTE BANK FOR DOMESTIC WASTE TREATMENT

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Abstract

Most of slum settlements in the watershed areas have limited access to proper solid waste and wastewater management. Public sanitation facility is an integrated sanitation option in such area for solid waste treatment and wastewater treatment. The sanitation model has applied through the approach of community development, energy recovery and water reuse for agricultural area. The technology applied are biodigester and biofilter system for organic waste which mixed with black waste water, and waste bank for an organic waste management. The aim of this paper is to study performance and community development process of biodigester- biofilter system and waste bank in public sanitation facility. The study location took place at Lija Village, Megamendung District, Bogor City, West Java, Indonesia. Field research method of performance of domestic waste treatment and community based management were applied. Data analysis done through

quantitative and qualitative descriptive method. The domestic waste treatment system consists of biodigester-biofilter system and waste bank. The main factors that affect the integrated management, is the level of education, awareness of healthy living and a willingness to manage the technology. The domestic waste that is generally vegetables and fruit with a composition of more than 50% mixed with black water in biodigester. The performance of biodigester- biofilter technology showed that BOD of treated water meet water reuse standard and the gas produced of 60-65% methane. Some challenges and obstacles in waste bank practice create fluctuation management condition and need routine monitoring from waste stakeholders to keep the sustainability.

1. Introduction

Indonesia's universal access for settlement sustainability in 2019 is to achieve 100% safe access of sanitation and drinking water. In solid waste management, it was estimated that of the entire wastes generated around 60% - 70% that could be transported to final disposal. The rest would be handled by the community through their self-effort, or spread and systematically disposed all over the city (Damanhuri, Enri (2005).

Concern with waste water management, Indonesia' access to the sanitation reached 76,08 %, consists of 67.2 % safe access and 8.88% basic sanitation in 2016. Most of the population live in unsewered area, rely on onsite individual or communal wastewater treatment plant (WWTP). Increasing population cause environmental problems which indicated by increasing river pollution because of domestic sectors. It is also identified some settlements in watershed areas, waste management and communal wastewater treatment have been implemented, however with improper treatment and without concern environmental standard.

Ciliwung River is an important river for West Java and Jakarta Province, but on all segments have been polluted by domestic waste about 57-58 %, and industrial waste 8.1%-31% as stated by Ministry of Environmental, 2014. The upper Ciliwung watershed is a part of Biosphere Reserve in Cibodas Pangrango Mountain (Megamendung District). The suburban settlements in upper Ciliwung Watershed categorized risk prone of sanitation, high to very high Sanitary and Landscape Agency (2014). The area study located at upper Ciliwung Watershed, mainly Megamendung District, Bogor Regency, West Java, which has some public sanitation

facilities developed by private company or community but has less maintenance and improper treatment.

Along with the national strategies to conserve water resources, waste and wastewater management, as stated in Indonesian Code number 18 in year 2008 concerns Solid Waste Management, Indonesia has to move forward to manage waste in sustainable way and for efficiency of water conservation. Therefore there is a need to develop new strategies for the energy from waste and reclaimed wastewater which can also protect freshwater from wastewater discharge.

Public sanitation facility developed by Research Institute for Housing and Human Settlements (RIHS) is an integrated sanitation option in slum area for solid waste and wastewater treatment applied through the approach of community development, energy recovery and water reuse for agricultural area. In the public sanitation facility, there is a need to improve waste management and wastewater to produce the effluent safely discharge to land/river and also for economic reason. The biodigester-biofilter can be considered a solid waste and wastewater treatment option which have advantages generally associated in small space requirements, energy source, low sludge generation and simplicity of operation and maintenance. The system catagorized as anaerobic digestion that offers the potential for energy recovery and revenue generation. Implementing this technology would allow reductions in greenhouse emissions, utility operational expenditure and dependence on other energy resources (Vincent Vutai et.al (2016).

The further treatment by subsurface constructed wetland is important to be considered because of water conservation in Ciliwung Watershed. Besides that, the small waste bank had been operated for inorganic waste management in the public sanitation facility. Therefore integrated waste management could be an option for waste management in conservation area which involved community development. Motivational factors of community to recycle waste, reuse water and wastewater are opportunities to conserve the natural environment, possibilities to manage in-situ water sources, minimization of infrastructure costs, including total treatment and discharge costs, reduction and elimination of discharges of waste (treated or untreated) into receiving environment (Vigneswaran, S, Sundaravadivel, M, 2004).

2. Material and Method

The model of integrated solid waste and wastewater treatment using Biodigester and Biofilter at communal scale. The model had been applied at Lija Village, Megamendung District, Bogor City, West Java.

The selected location was considered based on the recomendation from local government, risk prone of sanitation condition, community readiness for management, and a part of Cibodas biosphere reserve area.

Field research method of performance of domestic waste treatment and community based management were applied. Data analysis done through quantitative and qualitative descriptive method. The water analysis from composite sampling done in the field for physical parameter and the laboratory for chemical parameter. The performance of this integrated technology done through composite sampling for twice a year since 2014. During management by community, technical and non-technical facilitation done by RIHS through Focus Group Discussion (FGD), Community Education and Sosialization for sustainability of the system. While for waste bank management, community approach done gradually through regular discussion, field study to other location, expert involvement for technical skills and good management.

3. Result and Discussion

3.1 Characteristic of Area Study

The upper watershed Ciliwung has a hilly and highlands topography, which is geographically located at 6 ° 02 '- 6 ° 35'-107 ° 55'LS 00'BT. Ciliwung River is one of the national strategic rivers, which are important water source for West Java and Jakarta City. Most of the Ciliwung watershed, about 72 % is built area. Upper zone has areas ± 15,065 Ha, located in altitude 333-3,002 meters above sea level. Land use is dominated by farm and settlement. In development blueprint 2011 of Ministry of Environmental, it was targeted that segment I of Ciliwung watershed has a water class 1, which COD loading is 693.79 ton/day and BOD loading is 2,727.86 tons/day.

The selected site for waste and wastewater management is in Lija Village, Sukaresmi Subdistrict, Megamendung District, Bogor City, and West Java. Most of the community in the study area use individual pit latrines and public sanitation without wastewater treatment. Those sanitation facilities may cause human and ecological health impacts associated with microbiological and chemical contamination of groundwater. The pit latrines generally lack a physical barrier, between stored excreta and soil and/or groundwater Graham, P, Jay and

Polizzotto, L, Matthew (2013). While in the study area, more than 50% of wastewater dispose directly to the land and drainage, whilst in some area solid waste dispose to land and open burning. The proper handling of solid waste and wastewater need to be introduced and applied based community empowerment. For inorganic waste, there is routine private collection by truck to transport to the city. The public sanitation facility also have been built by community and private company but without clean water sources and proper treatment of wastewater.
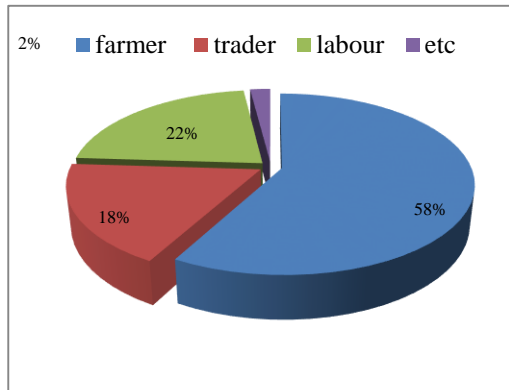

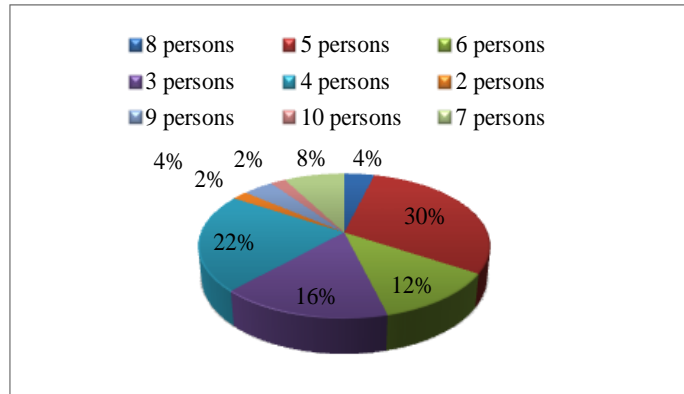**Figure 1a :** *Community occupation*

Figure 1.b. : *The number of occupant per house*

According to field and social identification in area study, most resident occupation is farmer (58%) and the rest are labor, private employees and trader (Figure 1a). It is directly proportional to the amount of agricultural land that dominate this area. The largest number of family members is 8 persons, while the smallest is 2 persons, the average number of occupant per house is 5 (Figure 2). Number of occupant per house shows the characteristics of the population in rural areas where family members in each house tend to be high.

Community perception about treatment of sanitation are shown in Figure 2 and 3. Figure 2a shows that most resident (80%) stated that to treat waste correctly by separating organic and inorganic waste. But they don't understand how to treat waste after it separated. The observation of community motivation concern with water reuse shows that people prefer to use recycled wastewater for flushing toilet, watering plants and doing the laundry (Figure 2 b). Some of them (about 10%) will use recycled wastewater for farm irrigation, and they don't prefer to use it for bath. Figure 3 shows that about 56% of the community treat their black water with latrine and 36% of them dispose black water directly to open channel. This condition causes a high risk disease exposure and land or river pollution.

The centralized wastewater treatment in this upper watershed Ciliwung are not suitable, since the centralized treatment in rural areas need high construction, maintenance, and

management costs. Therefore, decentralized sewage treatment processes with high treatment efficiency, low investment costs and easy operation and management are in urgent demand for rural domestic sewage treatment (Shen, Dong Sheng et.al 2013). Technology option for integrated solid waste and wastewater in the study location could applied appropriate technology with anaerobic system for organic removal and attached growth or vegetated land system for nutrient removal.
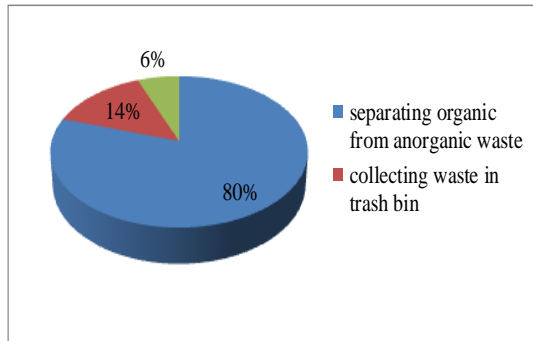

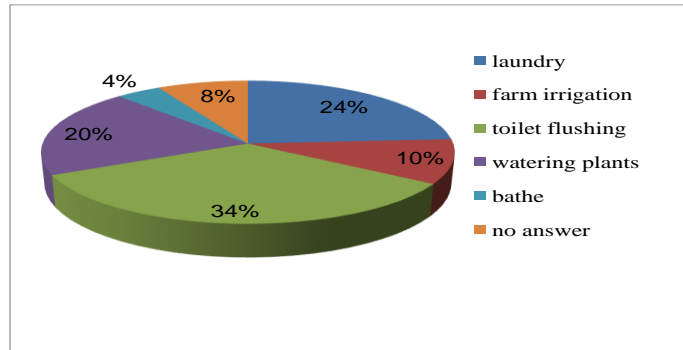**Figure 2 a:** *Perception of community for treating waste and*

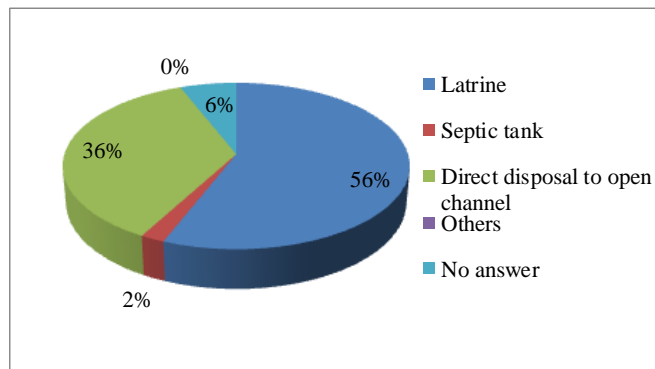**Figure 2 b:** *Perception of community water reuse purposes*

Figure 3: *Existing Condition of Wastewater Treatment Facilities*

3.2 Waste Characteristic in Study Area

In the study area, the local government have been introduced waste minimization and recycling/reuse policies to reduce the amount of waste generated. The composting at final processing site in Bogor City has used as an alternative waste management practices because a large fraction of organic waste. While solid waste generation rates and composition vary from settlements area depending on the economic situation, activities structure, community awareness and life style. The solid waste handling in the study area, and the general characteristic have been conducted in Lija Village through ground checked with solid waste surveys to determine composition and waste practices based on sampling standard method (Darwati, 2013). The waste

characteristic and practices in study area as shown in Table 1. The amount organic and anorganic waste almost have almost same composition, and anorganic waste is dominated by plastic waste. This condition requires treatment for waste that generated to reduce impact to environment. Moreover, the large amount of plastic waste and community awareness has a potency for development of waste banks in this area.

Table 1: *Household Solid Waste Characteristic and Practices in Study Area*

No.	Characteristics	%	No	Waste Practices	%
1.	Organic	51.20	1	Composting	0
2.	Anorganic		2	Incineration	0
	- Plastic	32.31	3	Open burning	34
	- Paper	6.09	4	On site - land disposal	40
	- Metal	0.9	5	Plastic collection by private truck	26
	- Glass	1.2	6	Transported to landfill	0
	- Etc	8.3			

3.3 Performance of Prototype of Biodigester and Biofilter System

According to site characteristic and community empowerment process, the public sanitation facility was developed in granted land from Lija Village's leader. The green technology for sanitation improvement could be developed in this dense settlement area because related to reduce 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). The biofilter system could improve treatment perfomance can improve effort to waste water recycling and environment quality. The implementation should consider the land availability, community acceptance, operation and maintenance (Darwati and Hastuti, 2017). The green management which developed in the public sanitation at Lija Village as shown in the figure 4.
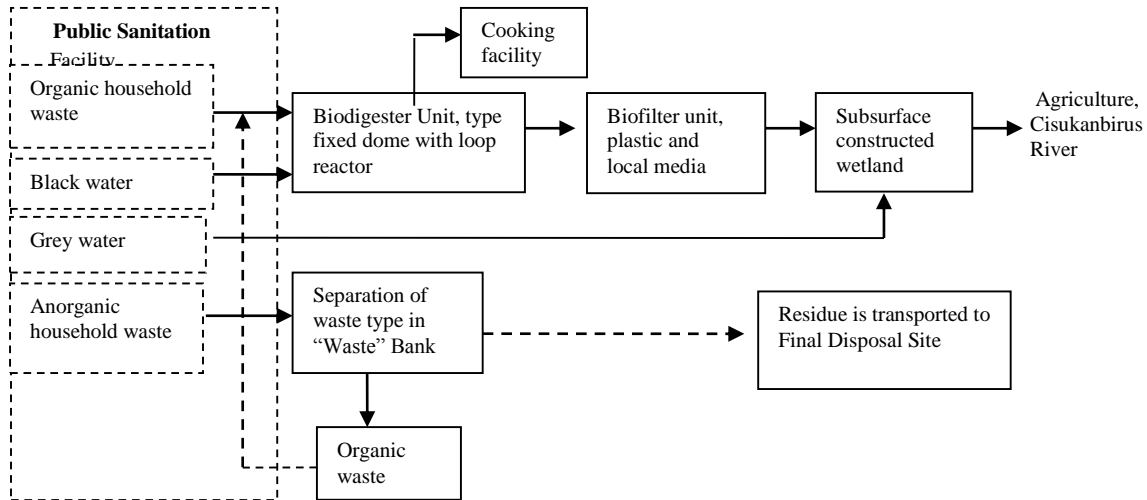
Figure 4: *Treatment Scheme of Household Waste and Wastewater at Public Sanitation*

The technology of Biodigester –Biofilter was developed since the year 2013 at public sanitation facility for service area of 50 households. The biodigester system applied mixed plug flow loop reactor system with hydraulic retention time of 40 days. The influent of this system planned from black water of 100 persons and organic solid waste of maximum of 85 kg/day. The reactor was completed by modification baffled and self-mixing of the sludge. The future development trend of longitudinal inner components is organic integration of the components within the multi group, in order to optimize the flow field and reduce the intermediate product inhibition (Abdelgadir, Awad et. al.2014).

The biofilter is designed with capacity $5m^3$, consist of two systems, fixed bed system and vegetated system. In the fixed bed use structural plastic, wood and coconut shell media for bacterial growth media, with detention time of 14 hours. The effluent of these system flows to vegetated system or subsurface constructed wetland then treated water discharged to the agricultural area. The capacity of subsurface constructed wetland about of 16 m^2

At the beginning of operation the cattle entrails is used as the seeding for digestion process. Methane gas generated from digester is used for cooking purposes. Based on (Rianawati, Elisabeth et.al, 2018), study comparisan of household and communal digesters reduced over 29% for COD concentrations, between 68%-85% for TS concentration and between 82%-92% for VS concentration. The effluent of biodigester flows to biofilter containing contaminant passes over the biomass growing in a biofilm on media, nutrient diffuse into the biofilm and area metabolized by the immobilized microorganisms.

The biofilter system applied fixed-growth systems through structural plastic and natural media, which the substrates must diffuse through the biofilm layers to become available, thus the transport of substrate from the bulk liquid through the stagnant boundary layer and into the biofilm through the process of diffusion (Water Environment Federation, 2010). The biofilter media is to provide a high specific surface area for the growth of biomass in a compact volume. A plastic media system using small shape like stone for biofilm carrier elements. A plastic small cylindrical media and local media such as bamboo cut, coconut shell, and bottle plastic cut are also developed which is packed by fish net. Plastic waste biofilter processing system is very effective to decrease BOD 84.85%, less effective to decrease COD 31.73% but effective enough to decrease ammonia 50.60%. (Putu Sri Juniarta et .al, 2018). According to the plug flow kinetics, the designed biofilter could produce effluent less than 50 mg/L of BOD and 200 mg/L of COD.

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The final treatment was enhanced by subsurface constructed wetland (SSCW) for reduction of nutrient, color or trace element. Constructed wetlands provide an alternative method of either treating or polishing the landfill leachate, which is inexpensive, simple to operate, and has potential to remove not only organic carbon and nitrogen compounds, but xenobiotic and heavy metals as well (Wojciechowska, Ewa, et. al.2010).

The operation of the system through community organization has been running since the year of 2013 which the final effluent for agricultural purposes and the overflow to Cisukanbirus River. The sustainability of technology management influenced by community participation and operation or maintenance procedure applied. Mixing of black water and solid waste has ratio of organic and water of 2-3:1 and achieve of C / N ratio more than 30. For some observations of

technology performance according to the Table 2, the methane gas about 60-65 % for cooking of 2-3 hours/day at two houses and the final effluent of from subsurface constructed wetland can reach water reuse standard BOD ≤ 30 mg/L, TSS ≤ 30 mg/L (Brix, H. H, 1994). The rate of degradation in the subsubsurface constructed wetland is influenced by solar radiation, temperature, rainfall and humidity. Beside that decomposition of organic matter in tropical area was 57% faster than in the sub-tropical regions Irvindiaty, Diana, et.al (2013). The sludge (septage and slurry) generated from biodigester and biofilter units also had applied in the constructed wetland and also as fertilizer by farmer in palawija area. After two years of operation of this system was evaluated for the technology audit components, they are techno ware, human ware and info ware as shown in Figure 5.
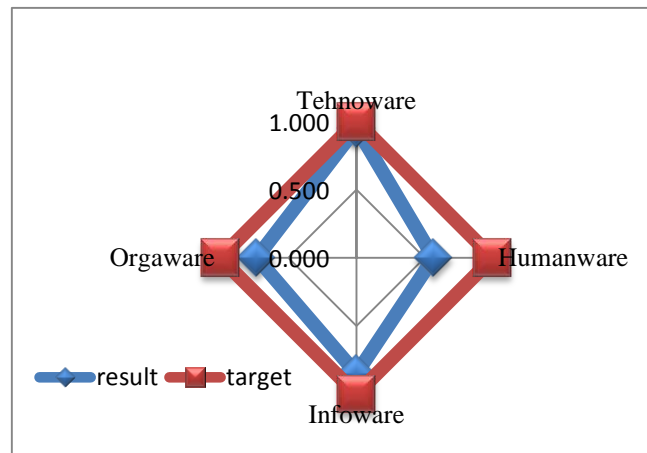

Figure 5: *Evaluation of Technology Components*

Evaluation result of techno ware and info ware aspects show that system that applied in study area has an ideal condition, which its values approaches to 1, while the humanware aspect only has value 0.6. This indicates that it needs more endorsement to increase capability of human resources to maintain a good operational. While water quality from treated water was observed regularly, to monitor the performance of system. The observation results during twice a year of effluent monitoring are shown in Table 2. The quality of effluent from this system appropriate with quality standards for wastewater issued by Ministry of Environmental and Forestry of Indonesia. No 68 year 2016 about Domestic Waste Water Quality Standard

The community also had applied the effluent for agriculture irrigation which meet water reuse standard according USEPA, 2004 .The applied effluent to the agricultural land also can be considered as artificial recharge as an additional sources of recharged water. In this context,

recharge of groundwater using treated domestic effluent is a viable option that reduces the demand for freshwater and enhancing the waste water reuse (Packialakshmi, et all, 2015).

Table 2: *Average of Treated Water Quality from Biodigester-Biofilter Unit*

Parameter	Unit	2014		2015		2016	Regulation of Minsitry Environmental and Forestry No.68/2016	USEPA Standard (2004) water reuse – agricultural purposes
		I	II	I	II	I		
T	°C	28	28	27	28	24		
pH	-	7,03	7,00	7,16	7,01	7,04	6-9	
TSS	mg/L	34	30	22	20	18	30	≤ 30
COD	mg/L	86,23	56,19	72,7	80,52	112	100	
BOD	mg/L	43,22	36,54	28,2	24,13	22,6	30	≤ 30

3.4 Community Approach for Waste and Wastewater Management

Community approach and empowerment in Lija Village is conducted in collaboration of RIHS with facilitator from Green NGO and Sanitary and Landscaping Division of Bogor Government. Survey of locations, problems identification and land preparation is involving community leaders and people in the service area. One of community leader has granted his land for sanitation model development. Before develop the sanitation model, the community was given an explanation on how to live healthy, knowledge of drinking water technology, simple practice of water quality monitoring, waste and wastewater treatment, and at the end is achieved an agreement of management for sanitation facility. That community meeting was conducted regularly in small (5 participants) or large groups (more than 50 participants). The participants come from community, key persons, local government and researchers. For two year community approach, the process has several steps to achieve some outputs as shown in Table 3.

The process of FGD (Focus Group Discussion), education, and socialization managed by social team, facilitator and local government. In addition it also conducted intensive assistance by facilitator in small groups to increase the level of awareness and understanding of healthy living and preparing sanitation management. During the process of community facilitation, we found some conflicts and proposed waste or water infrastructure that to be solved to support or influence the sustainability of planned public sanitation. According to participation method of quick success,

the provision the important of community demand for other infrastructure was developed to increase the willingness of community for management of waste and wastewater technology.

Table 3: *Community Approach Steps for Waste and Wastewater Management*

Step	Topic	Participants	Output
FGD I.	Sanitation problem identification, social mapping	Comunity, key persons, neighborhood assosiation	Increase knowledge of healthy sanitation, awarness healthy life and sanitation problem mapping
FGD II	Solution for sanitation problem	Comunity, key persons, neighbourhood assosiation prospective manager	Community skill, agreement of technology management
FGD III	Community organization	Community, key persons, neighborhood assosiation prospective manager	Description of task of community organization
Socialization	Agreement of FGD result	Community representative/ neighborhood assosiation / prospective manager	Community organization
Education-1	Organization	Technology manager	Knowledge of organization of sanitation group
Education-2	Administration	Technology manager	Understanding of administration material
Education-4	Waste and wastewater treatment technology	Technology manager	Understanding of operational and maintenance
Socialization	Agreement of mechanisme of sanitation management	Community representative/ neighborhood assosiation / manager	- Willingnes to manage technology - Communiy participation

3.5 Waste Banks Management

Waste Bank is an alternative solution to increase public interest in sorting out of waste, between organic and inorganic waste. In the study area, the waste bank manage by housewives group. During management of this technology, community perception about treatment of waste (80 % of residents in the serviced area) stated that to treat waste correctly by separating organic and inorganic waste.

The participation of community depends on the socialization of organizer and the availability of goods to change the waste. Because most of the community come to waste bank are low income people, the waste bank organizer keep of bottled drinking water, food or other goods for change the saving waste. Ideally the concept of waste bank is that the residents collected recyclable materials and it will be collected and transported to waste bank as recycling station. For some houses, the waste should be picked up by organizer because unawareness or inert activity of community. The recyclable materials will be weighted and bought by the Waste Bank that has functions as neighborhoods dealer. The members of The Waste Bank who deposit the recyclable waste will get the book 'savings', include the amount and type of waste deposited. It will be put

into savings that can be debited by the members of Waste Bank. The model adopted from activities of waste management in IWM Mulyoagung Village Site (Darwati,2013) can be seen at Figure 7 below.
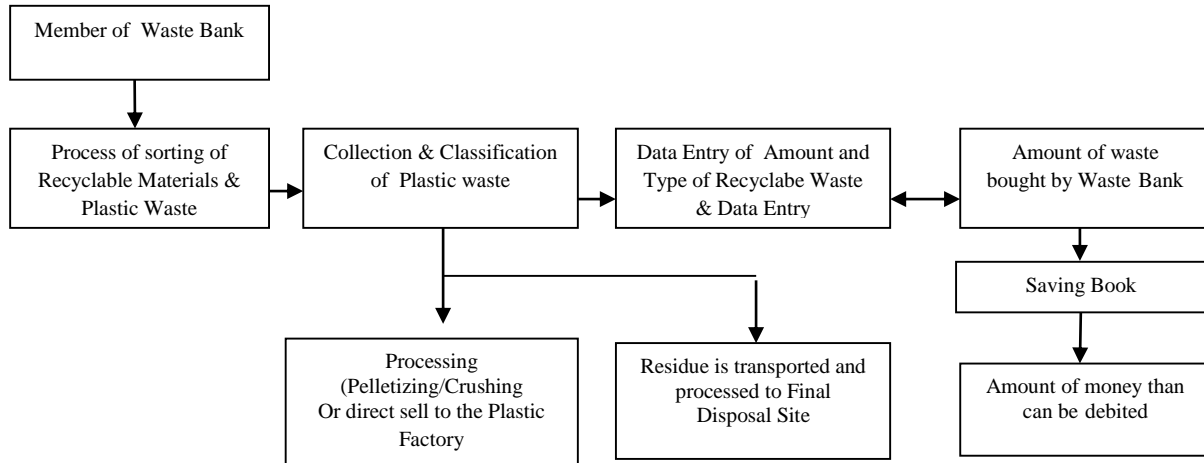

Figure 7: *Concept of Waste Banks in Study Area*

Waste bank has been operation in two years and we found some challenges and obstacles in practice. Fluctuation condition always happens of waste banks management in encouraging residents to participate. The socialization or assistance from facilitator or local government for community approach needs continuous activity. Therefore the community approach through improvement of awareness, sanitation education and facilitation during operational or maintenance process are important which could help to keep sustain of the technology and environmental conservation .

4. Conclusion

The technology of biodigester-biofilter system for organic solid waste and wastewater management at communal scale could be an integrated technology option for improvement public sanitation in dense settlement area. The further treatment had applied subsurface wetland system to achieve water reuse standard for agriculture. The domestic waste that is generally vegetables and fruit with a composition of more than 50% mixed with black water in biodigester. The performance of biodigester- biofilter technology showed that the average BOD less than 30 mg/L of treated water meet water reuse standard and the gas produced of 60-65 % methane.

Community motivation factors to recycle waste, reuse water are opportunities to conserve the settlement environment and possibilities to manage in-situ water sources. During management

of this technology, community perception about treatment of waste (80 % of residents in the serviced area) stated that to treat waste correctly by separating organic and inorganic waste.

The main factors that affect the integrated management, is the level of education, awareness of healthy living and a willingness to manage the technology. The process of community approach for management of the waste will influence the sustainability of operation and maintenance. The operation of waste bank for inorganic waste need high awareness of the community to save the waste, and this becomes problems. The education and facilitation during operational or maintenance process need longer time, therefore routine monitoring from concerned stakeholders could help to keep sustain of the technology and environmental conservation.

Acknowledgment

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