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SAFE REUSE OF TREATED WASTEWATER AND SLUDGE IN DECENTRALIZED SYSTEM

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Abstract

The unsafe water and solid reuse from decentralized wastewater treatment plant still occur due to the lack of improved and effective water management. This paper has aims to provide research findings of main management aspect of decentralized wastewater treatment plant with water reuse orientation. The scope of analysis includes wastewater treatment process performance evaluation, health risk, water reuse constraints and community motivation. The decentralized wastewater system had been designed as green technology in some settlements areas, which have low maintenance, low sludge production, and have high potential of water reuse for non potable water demand. According to the treatment schemes for water reuse system, the management is affected by treatment performance, proper maintenance, environmental condition and community motivation. The treated water quality according to water reuse standard of USEPA can be a source for agriculture or non-potable water demand

and reduce contamination of water sources. Achievement of the effective wastewater management system could provide non-potable water source to fulfill 50-65% of clean water demand according water reuse standards. There are some constraints of wastewater reuse that were minimized through some steps to enhance wastewater system towards safe water and solid reuse.

Keywords

Water, Solid, Reuse, Management, Constraints

1. Introduction

The challenge of water resource conservation is increasing as impact of domestic wastewater pollution and high demand of water quantity and quality for domestic, commercial, industrial and agriculture purposes. The domestic wastewater contributes more than 60 % to river pollution (Ministry of Environment and Forestry, 2015), although sanitation access increases which reaches about 60.91% (Ministry of Public Works and Housing, 2018). The degradation of the environment still occur due to the lack of inadequate access to improved sanitation and effective or efficient wastewater infrastructure, beside in Indonesia the main problem of provision of clean water is a limited supply of water (Tony K. Timpua, *et al*, 2018). Mainly in dry season or water scarcity area, unsafe practice of reuse water and sludge from wastewater treatment plant has been growing to meet water demand for watering plant or agricultural irrigation. While some issues of the existing decentralized wastewater treatment as the majority system in Indonesia have designed with water reuse approach but many systems are low sustainability because improper management, low user participation and clean water supply. These conditions could cause a significant impact to water, soil pollution and the increase of water borne diseases.

There is an urgent need to increase wastewater infrastructures development to address the challenges of high population growth and increase water supply from low water quality source. The domestic wastewater as one low quality water sources which can be reused in environmentally for problem water scarcity (Ali, 2018). The water reuse standard could refer to USEPA 2004, and also there is a regulation of the type of treatment of wastewater through secondary treatment, filtration and disinfection. The development of reuse-oriented wastewater treatment facility is part of sustainable development as an alternative water sources. The water reuse effort supports the implementation of Presidential Instruction number 2 of 2008 about Energy and Water Conservation, Regulation number 33 of 2011 about the National Policy on Water Resources Management, state documents "Indonesian Technology Needs Assessment for Adaptation to Climate Change 2011", Regulation of Minister of Environment and Forestry

no. 1 of 2010 about anagement of water polution control, Regulation of Minister of Public Works and housing no. 2 of 2015 about green building.

The decentralized wastewater treatment plant (WWTP) had been applied in public sanitation facility or small sewerage area. Mostly the systems have treatment unit which are not completely removing the organic and nutrient. While some areas had applied small wastewater treatment system which water reuse orientation with community based management, designed more efficient, smarter and enviromentally sustainable. The wastewater treatment with wastewater reuse for agricultural or urban purposes still represent the large reuse volume. While poor management of wastewater treatment, mainly with high accumulation of rubbish or solid present in the treatment plant make poor condition for public health and influence system performance. Beside some small wastewater system face low sustainability because of uncontrolled sewer expansion or high organic wastewater discharge and less maintenance of septage. To support the effectiveness the wastewater treatment management, in this study will describe aspects to improve safe water reuse system that have good impact to community, river, agriculture or environment.

1.1 Green Decentralized Wastewater Infrastructure

The green water infrastructure development have being introducing as a part of improved sanitation consists of technologies and practices that use engineered system or natural systems to enhance contaminant degradation. According The United States Environmental Protection Agency (US EPA, 2015) green infrastructure through natural system or engineered systems can be a cost effective strategy to enhance overall environmental quality and provide utility service. The WWTP orientated green water infrastructure can improve treated wastewater quality for water reuse according to certain purposes. To develop green WWTP with community based management as a majority system in Indonesia should have adaptive and inovative system with consideration of high organic treatment, simplicity, low cost operation and maintenance.

The provision of green decentralized wastewater infrastructure could improve environmental quality through treatment of separate wastewater streams with innovative technologies and natural treatment. The green wastewater technology result reusing treated water and reducing energy consumption through the use structured media growth system with further treatment by natural treatment process. There are some technology options for combination of anaerobic-aerobic system to adapt with local ecosystem, such as structured media growth system (submerged biofilter, rotating biological contactor) or semi aquatic plant system (constructed wetland) (Metcalf & Eddy, 2003). It is also important to implement

decentralized wastewater technology have factors of green technology which are directly related to reduced plant footprint, high quality effluent, pathogens removal capacity, avoided use of chemicals for disinfection, reduced sludge production, etc. (Giusy, 2012). The treated water of green WWTP can be a source for agriculture or non-potable water demand which contribute to close the nutrient cycle and reduce contamination of both surface and underground water sources. The generated sludge from decentralized WWTP can be mixed with other organics to be digested or composted for use as fertilizer. The water reuse for agriculture could support closing loop agriculture and promotes recycling of nutrients to grow crops and fruits (Schuen & Parkinson, 2009 in Sharda KC and Hitoshi Shinjo, 2017). Previous researches also show to increase sustainability of the improvement of sanitation facility and its management need to be supported by multi stakeholders.

1.2 Evaluation of Water Reuse System Management

The wastewater treatment with water reuse approach have been developed in some settlements area mainly at water sensitive area according to reuse purpose. The location study was the wastewater treatment system at communal scale at some settlements in West Java Province. The evaluation method with qualitative and quantitative analysis was applied to improve the management of wastewater treatment systems. The research consists of some activities including treatment process monitoring, maintenance problem solving assistance and analysis of perception or motivation of community with concern to public health and environment. Beside the management constraints also was analyzed through technical and social approach including related aspect of operation and maintenance of wastewater system.

2. Result and Discussion

The decentralized domestic wastewater treatment have been developing to accelerate sanitation access and also to promote water reuse practices. The sustainability of wastewater management is essential for public health and wellbeing but many practices of their management have less consideration of appropriate operation, maintenance procedure and water quality. Management of centralized wastewater and sludge in urban areas is generally carried out by under the city government institutions, but mostly decentralized system are by community based management. During dry season or in water shortage area, there are some communities utilize untreated wastewater or effluent from wastewater facilities to spread in garden, park or agricultural land without concern public health and water reuse standard. Beside the result of desludging from wastewater treatment had applied without appropriate way that could threats human health, soil or water pollution by pathogenic content. Therefore the

management of decentralized wastewater treatment system with water reuse target need strict routine evaluation and empowerment from involved institution. While the research findings from some technology applications show some factors of its management will influence their sustainability. To achieve safe reuse of water and sludge from domestic wastewater treatment, wastewater management need to be improved with some following aspects.

2.1 Health Risk of Water and Solid Reuse

Health aspect in the wastewater management with water reuse purpose should be controlled to ensure the user safely and effectively use the system. The issue of poor management of wastewater system could cause health problems, such as cancer of nutrient or heavy metal absorption, diabetes, cerebrovascular and kidney (Kostas Voudouris and Dimitra Voutsas, 2012). Concerning pathogenic bacteria content at domestic wastewater source as shown in Table 1, which related to the content of organic matter in wastewater consists of protein (40-60%), fat (25-50%), fat or oil (10%) and urea. Inorganic matter consist of sand, metal and salts (hardness, chloride, nitrogen, phosphorus in the form of P_2O_5 , and sulfur) in the form of K_2O , carbon and calcium (decomposition of hydrogen sulfide gas, decomposition of methane gas). However, along with the advancement of biotechnology, other types of biological materials emerge, such as surfactants, organic priority pollutants, and volatile organics (Hindarko, S, 2003).

Table 1: Concentration of Microorganism in the Wastewater

Microorganism	Average Concentration (CFU, PFU or cysts/oocysts)
<i>Fecal coliforms</i> /100 L	$10^4 - 10^5$
<i>Enterococi</i> /100 L	$10^4 - 10^5$
<i>Shigella</i> /100 mL	$1 - 10^3$
<i>Salmonella</i> /100 mL	$10^2 - 10^4$
<i>Helminth oval</i> /100 mL	$1 - 10^3$
<i>Enteric virus</i> /100 L	$1 - 5 \times 10^3$
<i>Giardia cysts</i> /100 L	$0.39 - 4.9 \times 10^4$
<i>Cryptosporidium oocysts</i> /100 L	$0.2 - 1.5 \times 10^3$

Note: CFU (Colony Forming Unit), PFU (Plaque Forming Unit)

Source: NRC, 1998, Maier et al., 2000, EPA 2004

To minimize pathogenic content of wastewater, the treatment in some location applied separated stream between black water and grey water. Therefore the wastewater treatment with the separation of wastewater source will be more less maintenance and safe than mixed wastewater. Most of the applied treatment system with wastewater separation had developed for water reuse to supply agricultural area, river or lake water quality improvement, public need or fishery. Some areas had applied also treated wastewater for groundwater recharge, that could

be a viable option for addition source to reduce water demand and enhanced water reuse (S. Packialakshmi, 2015). Therefore reuse water can restore nutrients and water to soil, renew the river flow and restore the life of aquatic ecosystems. Nonetheless, the main problem and risk of wastewater reuse is the pathogenic potential of wastewater which has life time according to Table 2. Reducing potential health risk from the wastewater treatment system could take some attention and management as follows:

- Reuse planning is the key to ensure public health and environmental protection. The selection of appropriate wastewater treatment system with reuse intended should be based on community acceptance, physic consideration, social and culture condition. Most of secondary wastewater treatment had been applied by natural treatment or wetland system therefore the management should maintain vegetation diversity, human contact and minimize mosquito breeding.

Table 2: Life Time of Pathogenic Organisms

Type of Pathogen	Time to Hold (Survive) (Day)			
	Feses and Septage	Wastewater & Clean Water	Soil	Plant
1.Virus <i>Enterovirus</i>	<100 (<20)	<120 (<50)	<100 (<30)	<60(<15)
2.Bacteria <i>Fecal coliforms</i>	<90(<50)	<60(<30)	<70(<20)	<30(<15)
<i>Salmonella sp.</i>	<60(<30)	<60(<30)	<70(<20)	<30(<15)
<i>Shigella sp.</i>	<30(<10)	<30(<10)	-	<10(<5)
<i>Vibrio cholera</i>	<30(<5)	<30(<10)	<20(<10)	<5(<2)
3.Protozoa <i>Entamoeba</i>	<30(<15)	<30(<15)	<20(<10)	<10(<2)
<i>Hystolytica cyst</i>				
4.Helminth egg <i>Ascaris lumbricoides</i>	some months	some months	some months	<60(<30)

Source: NRC, 1998, Maier et al., 2000, EPA 2004

- The wastewater treatment with water reuse purposes should be monitored routinely for the system performance according to the guideline at Table 3. While in the decentralized system with community based management, there are some limitations for routine monitoring. Many decentralized systems, the monitoring system done by community and involved institution but no routine monitoring. This study evaluated the performance system of water reuse system at seven settlement areas. The average result of water quality for 3-5 years of monitoring of green decentralized WWTP can be seen at Figure 1. The parameter of Biochemical Organic Demand (BOD) shows concentration fluctuation but some systems have meet effluent BOD less than 30 mg/L as water reuse standard for agricultural irrigation (Figure 1). The wastewater treatment system had

applied biofilter anaerobic, followed by subsurface constructed wetland and granular filtration. The effluent of WWTP normally applied for agricultural irrigation except in the urban area which had been applied for housing park or garden. In the figure 1, the effluent standard of Coliform total has target to reach less than 3000 /100 ml, but at location -3 and 7 can not meet Coliform standard because some maintenance procedure still need assistance and less participation of community.

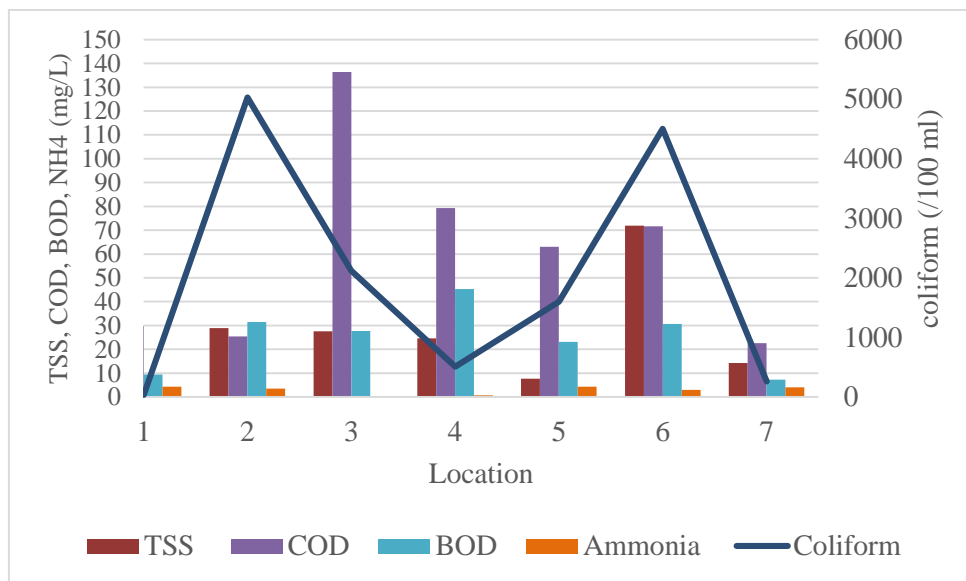


Figure 1: Treatment Performance in Average at 8 Locations of WWTP with Water Reuse approach (note : location 1: Cimanggung- Sumedang Regency, 2: Wangisagara-Bandung Regency, 3: Megamendung-Bogor City, 4: Batujaya-Karawang Regency, 5: Cingised-Bandung City, 6: Muarabaru-Jakarta City, 7: Pulogebang-Jakarta City)

- Community attention to treated wastewater reuse mostly related to pathogenic organisms contained in wastewater. Pathogens that still survive in wastewater and in various environmental conditions vary greatly. Access to health hazards from wastewater reuse and transportation routes from direct contact to food or water, such as use for tourism. Other aspects of indirect pathogen contamination during wastewater reuse for non potable purposes, such as on crops or fish contamination, soil or groundwater pollution (Nusa Idaman Said, 2017).
- Some studies observed disinfection with UV can achieve 2,5-log to 5,7 -log fecal Coliform reduction. The organic loading and pra treatment system will influence the suspended and dissolved solid content and the biofilm growing on UV bulb which influence the disinfection rate (Meagam *et al*, 2019). Treated wastewater with disinfection of UV radiant energy of 49500 mWs/cm² need disinfection time of 30 seconds, 70 seconds, 300 seconds, 600 seconds, respectively for removal of *Klebsiela*,

Enterococci, Escherichia Coli, Coliform (Badea Cristinel, Zagan Remus, Tăbăcaru Lucian, Axinte Eugen, and Nedelcu Dumitru, 2011).

Table 3: Guideline for Wastewater Reuse

Level of Treatment	Reuse Purpose	Quality of Reuse Water	Monitoring Schedule	Safety Distance
Secondary treatment, tertier treatment and disinfection	-Public usage -Irrigation/food crops agriculture -Recreation -Lake recharge	pH = 6-9 BOD ₅ ≤ 10 mg/L Turbidity ≤ 2 NTU E.coli = none Res.Cl ₂ ≥ 1 mg/L	pH-every week BOD-every week TSS-every time E.Coli-everyday Res.Cl ₂ - continue	distance 15 m from water resource
Secondary treatment and disinfection	- Irrigation of non food crops agriculture - Landscape Irrigation - Construction works - Habitat	pH = 6-9 BOD ₅ = 30 mg/L TSS = 30 mg/L Turbidity ≤ 2 NTU E.coli = 200/100 ml Res.Cl ₂ ≥ 1 mg/L	pH-every week BOD-every week TSS-every time E.Coli-everyday Res.Cl ₂ .continue	- Distance 30 m from area that accessed by community - Distance 90 m from drinking water source

Source : Metcalf and Eddy, 2003

2.2 Minimize Water Reuse Constraints

Some application of decentralized wastewater treatment with reuse orientation stay in the local watershed and could provide the benefits of water reuse and community development. The principle of wastewater treatment is an effort to reduce the levels of hazardous substances contained in wastewater to meet the standard. The process of wastewater treatment at study area apply an inherent growth system or biofilter that carried out under anaerobic, aerobic or combination anaerobic - aerobic conditions. In some areas apply hybrid system of Anaerobic Baffled Reactor (ABR) and biofilter system, which wastewater treatment can combine the advantages of each system (Feng et al., 2008, Liu, 2010). The application of water reuse in wastewater treatment system requires a level of treatment until it reaches a certain level of quality in accordance with reuse purposes. Study area in Bandung City, wastewater treatment develops anaerobic and aerobic biofilter system followed by hybrid constructed subsurface wetland and granular filtration. Anaerobic decomposition produces less sludge, only 5% of organic carbon while in aerobic processes about 50% of organic carbon is converted into biomass. The activity of aerobic microorganisms contain oxygen and air to decompose the complex organic substance into carbon dioxide, water and ammonium. Then the ammonium will be converted to nitrate and H₂S will be oxidized to sulfate. Nutrient reduction in wastewater can occur at subsurface constructed wetland, through filtration mechanism, absorption by microorganisms and absorption by plant roots. While most wastewater

treatments at study areas apply anaerobic biofilter, subsurface constructed wetland and/or granular filtration.

Table 4: *The Pathogenic Organisms at Sewage Sludge of WWTP System with Anaerobic Biofilter*

Parameter	Sludge without Treatment	Stabilized sludge-1	Stabilized sludge-2	EPA Standard
E.coli (MPN/g)	1,5x 10000	110-150	150-200	< 100 MPN/g
Fecal Coliform (MPN/g)	4,6x 100000	27000	19500	< 1000 MPN/g
Salmonella (MPN/g)	93	150	23	< 100 MPN/g
Helminth egg (egg/100 ml)	3090	0,24	0,475	1 viable egg/100 ml
Shigella (CFU/g)	<30	<30	0	< 3 CFU/100 ml

Source: Analysis

The suspended or floating solid or material generation from decentralized WWTP, mainly at primary treatment unit need routine maintenance which also include sludge, rubbish, grease or soil. This primary treatment unit removes approximately 50-65 % of the suspended solid and 30-40 % of the BOD from wastewater. The primary sludge removed from this process contains a high amount of organic matter that is highly degradable. While the sewage/secondary sludge quantity and quality at treatment unit determined by wastewater characteristic, quality of treatment and communal facilities connected to the sewer system. This secondary sludge is consisting of nearly 90% organic matter and is composed of approximately 2-4% solids (Berhanrd Mayr, 2005). During the biological treatment under anaerobic biofilter remove BOD ammonia, and suspended solid. Recently most of the sludge from decentralized treatment is cleaned on site and discharge directly to a river or spreading to the agricultural land. The presence of pathogenic organism on sewage sludge at average from treatment process unit in study areas shown in Table 4. The sludge from unit of anaerobic biofilter without further treatment has high content of pathogen bacterial or vermi egg compared to stabilized sludge-1 (treatment sludge by anaerobic and solar drying) and stabilized sludge-2 (treatment sludge by anaerobic and lime addition). Therefore to safe sludge reuse from decentralized WWTP should develop septage treatment and disposal such as land application, treatment at wastewater treatment plants, and treatment at independent septage treatment plants.

The evaluation of some system with water reuse purposes were found constraints that summarized at Table 5. Completion of each constraints is generally carried out after technical

agencies assistance but some community can handle the problems independently. Technical constraints that occur during the maintenance phase are not routinely carried out, such as drainage or cleaning of solid waste that enters the treatment unit. While the non-technical constraints include the disposition of solid waste in sewerage or pra treatment unit, low participation at maintenance and financing. Therefore efficient wastewater treatment is important to prevent pathogen spreading from water body or agriculture as recipients of effluent of wastewater treatment plant (Abidelfata, 2016). A change toward more sustainable management can be introduced through multi stakeholder involvement to assistance and monitor the water reuse system. Some efforts had been done to support sustainability appropriate to local ecosystem through cooperation with some institution to assistance the community during maintenance phase.

Table 5: *The Constraints of Treated Water Solid Reuse at Decentralized WWTP*

No	Location of WWTP	Main Treatment Process	Reuse Purpose	Maintenance Problem	Main Constraints
1	Cimanggung, Sumedang Regency	<ul style="list-style-type: none"> - Anaerobic Biofilter - Constructed wetland 	Agricultural irrigation during paddy field growth	No routine cleaning of grease, solid waste, sand, soil	<ul style="list-style-type: none"> - application of unstable effluent water quality make empty rice granule - less mature of biological solid can cause pathogen risk such egg worm, coliform, etc. - community acceptance of agricultural products
2	Wangisagara, Bandung Regency	<ul style="list-style-type: none"> - Anaerobic Baffled Reactor - Vermi biofilter - Subsurface constructed wetland 	River water quality improvement	<ul style="list-style-type: none"> - flooding to public sanitation facility. - limited clean water supply 	<ul style="list-style-type: none"> - low access to safe sanitation still cause high water pollution - eutrophication due to nutrients N, P
3	Megamendung, Bogor Regency	<ul style="list-style-type: none"> - Biodigester combine organic waste - Anaerobic biofilter - constructed wetland 	Garden irrigation	livestock disturbance to treatment unit	<ul style="list-style-type: none"> - problems with organic pollutant, heavy metal, pathogen, nitrate - public acceptance, aesthetic, virus transmission and other phatogens

Table 5: The constraints of treated water solid reuse at decentralized WWTP(continue)

No	Location of WWTP	Main Treatment Process	Reuse Purpose	Maintenance Problem	Main Constraints
4	Batujaya, Karawang Regency	-Biodigester -Anaerobic biofilter -Semi-aerobic biofilter	Recharge lake/river for recreation, fishery, increase water quality	-No routine cleaning of grease, solid waste, sand, soil -limited clean water supply - high user of sanitation facility	- problems with high water demand for agriculture, no spread evenly - Public health concerns, especially regarding the transmission of pathogens
5	Cingised, Bandung City	- Anaerobic-aerobic biofilter - Constructed wetland - Granular filtration	Public water usage: fire hydrant	- no routine cleaning of grease and sand - filter maintenance	- Public health concerns, especially regarding the transmission of pathogens through aerosols - Effect of water quality, crust problems, corrosion
6	Muara baru, Jakarta City	- Anaerobic-aerobic biofilter - rotational biological contactor - Constructed wetland - Granular filtration	Public water usage: fire hydrant	- no routine cleaning of rubbish - filter maintenance - Flooding from drainage	- Public health concerns, especially regarding the transmission of pathogens through aerosols - Effect of water quality, crust problems, corrosion
7	Pulo Gebang, Jakarta City	-Anaerobic-aerobic biofilter -Granular filtration	Garden, housing watering, housing park	- Bacterial maintenance - filter maintenance	Public health concerns, especially regarding the transmission of pathogens through aerosols

Source: analysis

2.3 Increase Motivation Community

The application of wastewater treatment orientated water reuse give new knowledge and experience for community and local government. It may be difficult to introduce, change perception of non-standard sanitation solutions. Water reuse can increase the value of water resources and reduce environmental degradation. The sustainability of water reuse management should be supported by communities in serviced area and related stakeholder. Community motivation factors had been studied at management of water reuse in some settlements area (Vigneswaran, 2004), which have benefits as follows :

- community motivation for water and solid reuse from WWTP as opportunities to increase limited water resources and benefits for managing local water sources

- prevention of excessive changes from other uses, including the natural environment. For example, the aquifer injection from treated wastewater can increase the aquifer capacity and reduce sea water intrusion
- minimize water supply infrastructure costs
- reducing and eliminating wastewater contaminants

The application of green infrastructure or water reuse effort from wastewater treatment plant could have some barriers of non-technical aspect which influence the management. Therefore community approach through small groups or intensive meeting and supported by related institution are important to increase awareness and acceptance for green wastewater infrastructure management and the need to improve environmental quality. At settlement area, non potable water demand can achieve about 65 % of total water demand while many areas often have limited water supply from municipal water works or groundwater well. Most community at study area of green WWTP for first three months of operation can not trust in quality, planner or managers. After community assistance and some small workshop, there is an increase of awareness of water crisis, willingness to reuse water for garden, landscape or agricultural irrigation or public water demand such as for cleaning or washing. However, water pollution from poor management lacks effectively remove certain pathogens or chemicals which will impact to human health.

3. Conclusion

The process of wastewater treatment with water reuse orientation has important effect to health risk, the reuse constraints need to be minimized and community need to be motivated. The sustainability of wastewater management should have high consideration of appropriate operation, maintenance procedure and treated water quality. A change toward more sustainable management can be introduced through multi stakeholder involvement to assist and monitor the water reuse system. The effectiveness of management decentralized wastewater treatment for safe water and solid reuse are influenced by some aspects, as follows:

- Proper maintenance to have stable process and consistency treatment performance can achieve water reuse standard and health risk reduction.
- Evaluation of each constraints of water reuse practices in location study need routine technical unit or research institute assistance. The non-technical constraints that occur during the maintenance phase are mainly caused by low community and manager awareness and motivation.
- The sustainability of water reuse management should be supported by communities in serviced area. Therefore increase community motivation could support water reuse

effort from decentralized wastewater treatment plant can meet about 50-65% of non potable water demand.

Developing of decentralized WWTP with water reuse orientation need future research, mainly focus on microorganisms recommended for monitoring, constraints management, and effluent standard for water reuse which suitable with Indonesia condition and according to variation of water reuse purposes. The water reuse research at decentralized scale should also consider some limitations such as community acceptance and fluctuation of wastewater quality that may contain high organic or household industrial wastewater.

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