Conference Paper

The Ecosystem Approach for Improved Sanitation in Specific Urban Areas

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Abstract

The acceleration of improved sanitation access in specific urban areas can reduce water-borne diseases and the degradation of water resources. In this paper, the development of technology of wastewater infrastructure in some specific urban regions with an ecosystem approach will be analyzed based on some practical research. The ecosystem approach is analyzed with integrated biophysical and social factors for improved wastewater system; it includes the tidal area, coastal area, and urban water sensitive area. The system of wastewater treatment has certain design criteria to be adapted for specific areas and upgrading the treatment process based on the ecosystem characteristic, community awareness of sanitation and some best practices. The design criteria of wastewater treatment consider the process of environment approach, pollutant transformation target, and the configuration of the processing unit. The option of treatment technology at an individual, communal or settlement scale depends on biophysical factors in each area. This condition can achieve 80-95 % organic removal, 30-70 % nutrient removal by biofilm absorption or phytofiltration. Challenges and social constraints at each selected technology development have an influence on the sustainability of infrastructure in achieving health requirements and the standard of effluent for watercourse or water reuse.

Keywords: specific area, ecosystem, wastewater, technology

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1. Introduction

The domestic wastewater infrastructure in a dense urban settlement in specific is usually in poor conditions. These conditions cause a significant impact to access clean water due to high water pollution and the increase of water-borne diseases. The sustainability of wastewater management is essential for public health and people's well-being, but many practices are not considered appropriate technical options for wastewater treatment. Meanwhile, the involved stakeholders or the community mostly have low attention and different perception of safe wastewater access. The important issue of poor sanitation is linked to health problems, such as cancer, nutrient or heavy metal absorption, diabetes, cerebrovascular and kidney problems [1]. The prevalence of worms and stunting among children under two years old has increased from 2010 to 2013. It is predicted that up to 50% of malnutrition is related to repeated diarrhea or intestinal infection due to poor sanitation [2]. Prevalence of worm infection for all ages was between 40% and 60% in the year of 2006, which was also found especially in conditions of poor sanitation and lack of personal hygiene [3].

Universal access to drinking water and sanitation, as stated in the National Development Plan of 2015-2019, should give access to everyone who lives in urban and rural areas to reliable drinking water and sanitation up to 100 % in 2019. This target is in line with the Sustainable Development Goals (SDGs) of 2030, which includes goal number 3 about health and well being, goal number 6 about improved water and sanitation, and goal number 11 about sustainable cities and communities. The improvement of wastewater treatment must be well anticipated to solve existing sanitation practices in specific areas, mainly for the protection of water sources and reducing the spread of diseases caused by a water-related pathogen. The specific areas have physical characteristics, such as unstable soil conditions, soft soil, erosion and land degradation, tidal influences or coastal areas [4]. Other characteristics in some specific areas are the condition of irregular settlements, limited land availability and inadequate road access. The types of challenging areas include communities living along riverbanks, living above rivers and above coastlines and estuaries [5] as well as in swamp areas, areas with high groundwater levels, and in areas which flood on a predictable and seasonal basis. The dense settlements built on water sensitive areas, such as watershed area or water crisis aquifer, are considered as highly vulnerable to contamination from human activities, potential problems caused by current sanitation and hygiene practices. Most existing condition of onsite sanitation applied pit latrine, which can influence groundwater with bacterial contamination [6] states that safe groundwater from bacterial contamination on horizontal distance of $>$ 5.5 m and vertical distance of $\geq 3 - 4.5$ m from latrine bottom to groundwater table in wet and dry conditions, but bacterial contamination of E.Coli, Coliform total, and anaerobic bacteria were influenced by soil saturation and groundwater velocity. It is estimated that in 1999 to 2100, sea level rise has been about 1.4 to 5.8 m and will affect sanitation practices in communities living along coastlines. This settlement is affected by the tidal flood which has hit several coastal areas in Indonesia and caused by sea water tides. On the other hand exploitation of groundwater use has led to land subsidence [7].

Communities in specific environments demand improved water infrastructure, which could be applied by the ecosystem approach considering the biophysical landscape and also improving the function of the ecosystem. An ecosystem, in general, an integrated strategy of land, water, and living creatures, to achieve conservation and sustainable use [8]. The importance of changes in wastewater management could improve well-being, including the impact on diarrhea incidence. The research indicated a household with unimproved drinking water source is about 12 percent, and unimproved sanitation is approximately 23–27 percent more likely to suffer from diarrhea [9]. The concept of resource recovery or water reuse for improved sanitation should be introduced in a specific area. Some researchers in [10] study community acceptance of resource recovery in the Brisbin's karst area which community acceptance about 61 % to use human manure as fertilizer and 62% to use urine as fertilizer.

In this paper, the development of technology and management of wastewater infrastructure in some specific urban areas with an ecosystem approach will be analyzed based on some practical researches that have been done by Research Center for Housing and Settlement, Ministry of Public Works. Sustainable wastewater management can support the application of wastewater treatment plant (WWTP) to be effective to treat certain biological and natural pollutants, thereby making an impact on the function of ecosystem improvement and increasing the community's health. Besides, a non-physical approach is very important to increase sanitation awareness and safe technology concern with community-based management. Thus, people can have access to reliable domestic sanitation facilities and water supplies.

2. Method

The study of the ecosystem approach for sanitation improvement in specific urban areas took place at dense settlements above the river, tidal area and water sensitive area, such as watershed area and groundwater scarcity area. Some small field application was developed for individual and communal wastewater treatment with the specific integrated ecosystem. It included a community approach increasing sanitation awareness about technology management, waste impact, health, and environmental conservation. The data collection is done through field analysis of wastewater management for one to three years at some dense settlement of the coastal area in Indramayu City and Cirebon City, floating settlement in Banjarmasin City and Citarum's watershed settlement (Figure 1). The analysis of wastewater management considered biofiltration technology options, the biophysical landscape, improving its ecosystem and building local capabilities in a specific ecosystem. To examine the study area, DPSIR (Driving forces, Pressure, State, Impacts, Response) method is applied to link Driving forces; (sanitation activity) through

Pressure (waste water), State (biophysics) and Impacts (on ecosystem and human health) and Response (target, options, application). The community approach to analyze public perception and motivation were identified through intensive small group discussion and structured observation, both physical and non-physical aspects to support the technology implementation and management.

Figure 1: Some specific areas at coastal area, floating and watershed settlement.

3. Result and Discussion

The challenge of water resource in urban areas is increasing as an impact of wastewater pollution and high demand of water quantity and quality for domestic, commercial or industrial purposes. Sanitation problems have polluted water sources in settlement areas, which includes coastal communities, floating settlement above river or tidal mudflats/ dry tidal area, water sensitive area or watershed area. The sanitation infrastructure in specific urban areas should be planned to improve the specific ecosystem or water sensitive area which consider the biophysical landscape, improving its ecosystem and also building local capabilities. The ecosystem approach will support and change environment for better community health, fewer infections of water borne disease. In the research area, most sewage is discharged untreated into surface and groundwater systems that resulting in great sea, river, swamp pollution and pollution of valuable resources. Cultural eutrophication arising from anthropogenic activities is particularly evident in floating settlement areas above rivers or lake with limited water exchange. Therefore it needs specific concern for the development of improved sanitation at some dense settlement of coastal area, floating settlement and watershed area. Wastewater infrastructure management in specific areas with an ecosystem approach characterized by maximizing the removal wastewater pollutant by key ecosystems, the protection of the environment sustainable use of resources, the practicality of operation and maintenance and the fulfillment of effluent standard and vector disease requirements. The improved sanitation with the ecosystem approach should have factors such as follows:

1. Integrated water and waste management to increase clean water supply and provide the waste treatment system have high organic removal efficiency, simplicity, low-cost, low capital and maintenance costs and low land requirements. The option of treatment technology at individual, communal or settlement scale depend on biophysical factors at each areas and should achieve 80 -95 % organic removal, 30-70 % nutrient removal by biofilm adsorption or phytofiltration.

2. The design criteria of wastewater treatment considers process environment approach, pollutant transformation target and process unit configuration. Enhancing the buffering capacity of ecosystem wetlands for the removal organic, nutrients and pathogens and other pollutants.

Table 1: Analysis of sanitation activities in urban specific area.

Settlement Location	Pressure (Sanitation activities)	State (Existing condition)	Impact (Ecosystem, human health)	Responses (improved wastewater technology)
Tidal area, coastal area	Direct untreated wastewater disposal, unmanaged solidwaste practices	Unhealthy settlement environment, spread of diseases caused water related phatogen	- sea biota degradation - increase worm inspection caused polluted water or soil	Applied technology with static-mobilized biofilter adaptive to tidal condition (tide, wind,stability system),integrated water supply system
Floating settlement above river	- river water for direct clean water use (bathing, cleaning) - detergent contamination - plastic waste disposal	- high concentration nitrogen, organic - alteration river class	- degradation river quality - low community awareness - fish life standard disturbance	Applied technology for two to ten household with floating biofilter –wetland system
Water sensitif and Watershed area	Forest clearing, unmanaged pit latrines, open defecation	- Clean water and soil pollution - Helminthes infections	spread of diseases caused water related phatogen	Resources recovery or water reuse (improved latrine, composting toilet, biofilter, phytotreatment, etc)

3. Reducing potential health risks by macrophyte diversity and natural disinfection processes by granular or slow sand filtration, incorporating lagoons, shallow-water wetlands and subsurface-flow wetlands. Subsurface flow wetland designed to minimise mosquito breeding, and also surface flow wetlands, by increasing macroinvertebrate predators.

4. Wastewater management in water sensitive areas includes water scarcity area or watershed area which needs to consider treatment and reuse systems. Treated water from communal wastewater treatment can become an alternative of raw water source for urban water demand. Reducing the risk in the water sensitive area through removing the source of contamination or reducing the level of contaminants, increasing the time for water to travel from the source to the receptor, minimizing man–made pathway [11].

According to the analysis of DPSIR in some specific areas at Table 1, the areas were identified mainly in low-income urban areas which have poor sanitation condition such as limited clean water source, low supply from the local water company or high domestic wastewater pollution. Most public perception, motivation about sanitation identified through intensive small group discussion, that indicated still profound knowledge of healthy environment and impact of wastewater discharge [12]. The knowledge of poor sanitation impact introduced to intensive small community discussion includes the importance of handwashing, open defecation free or wastewater technology maintenance. The effect of tropical climate to water or soil contaminated by wastewater in some specific areas could increase the development of parasite or vector-borne disease, which also discussed by [13] that sanitation factor has significant impact worm infection. Therefore, it is important that the design criteria of wastewater treatment consider the process of environment approach, pollutant transformation target, and process unit configuration. Response to this sanitation problem and decentralized treatment application may lead to an effective reduction or organic, nutrient or bacteria thus could contribute to watercourses quality improvement and a healthy settlement environment.

The provision of individual or communal toilets should meet technical requirements and socio-cultural acceptability of installation and maintenance of the wastewater treatment facility (Figure 2). The option of improved technology at an individual, communal or settlement scale depend on biophysical factors at each area and shall achieve 80 -95 % organic removal, 30-70 % nutrient removal, among others process by biofilm absorption or phytofiltration. In the case sanitation improvement in high-density low-income urban areas at floating settlement above a river or tidal mudflats, should consider

Table 2: Small scale of wastewater treatment with biofiltration system in specific areas.

Design of BOD effluent: < 30 mg/L, TSS < 30 mg/L				
Tidal settlement area	**Parameters**	**Specification**	**Parameters**	**Specification**
	1. Anaerobic Biofilter System		**2.Wetland and granular filtration System**	
	Capacity (communal treatment)	10-50 Household	Target effluent	BOD effluent: < 10-30 mg/L
	Specific surface area	Fish net media 60 m^2/m^3, coconut shell 100m^2/m^3	Wetland media	gravel:5-8 mm, gravel:2-3 mm
	Detention time	10 - 24 hours	Detention time	2.2 days
	Required volume	4-11 m^3	Required area	0.2- 0.5 m2
	Structural Stability	Shape, size, equipment, wind	Slow sand filtration	Velocity: 1 m3/m2/day Area: 20 m2
Floating settlement area	**1. Anaerobic-Semi aerobic system**		**2. Floating wetland system**	
	Capacity (individual treatment)	1-2 household	Target effluent	BOD effluent: < 30 mg/L
	Specific surface area	plastic media 150 -200 m^2/m^3	Wetland media	foam, wood
	Detention time	8-16 hours	Detention time	16-24 hours
	Required volume	0.8-1.2 m^3/capita	Required area	0.1-0.25 m^2/capita
	Tank material	PE, FRP, PVC	Material	PE, FRP, fish net
	Structural Stability	Wind, water current, wave	Structural Stability	Wind, water current, wave
Watershed settlement area	**1. Hybrid Biofilter system**		**2. Wetland and granular filtration system**	
	Capacity (communal treatment)	30-100 household	Target effluent	BOD effluent: < 10-30 mg/L water reuse for irrigation, fishery
	Specific surface area	Plastic media, 150 -300 m^2/m^3	Wetland media	Gravel, woodchip, sand
	Detention time	9-33 hours	Detention time	1-2 days
	Required volume	8 - 15 m^3	Required area	0.25-0.7 m^2/capita
	Tank material	FRP, concrete	Material	Brick masonry, concrete
	Structural stability	High groundwater table, seasonal flooding	granular filtration	Further treatment by gravel and sand filtration for fishery

Source: analysis Note: BOD: Biochemical Oxygen Demand, TSS: Total Suspended Solid

with treatment tank has floating ability and structural stability both internal or external caused of the tide, wind, water current, etc. The appropriate technology for floating settlement according to Table 2, had been planned and applied in Banjarmasin City with biofilm system as a combination of biological, chemical and physical processes, followed by a natural and ecological method of wastewater treatment. The main wastewater treatment of floating system is anaerobic-semi aerobic biofilter system then further treatment had developed floating wetland. Local government also had developed some communal sanitation built on more stable ground, but the system shall also be adapted with routine flood and has routine desludging or debris collection. In this way, the biofilm system at reactor predicted grows anaerobic, and semi-aerobic created by natural mixing caused float structure. The initial operation uses night soil for seeding to form a microbial attachment. The formation of a biofilm is on two different biofilter media that can adsorb organic compounds over the media. According to Rao, Senthilkumar, Byrne, and Feroz [13], the duration of this adherence phase will depend on several factors: the nature of the support, the surface charge, the nature and the concentration of the feed, etc. The initial surface colonization occurs at the cavities in the inert material, which has a surface roughness favorable for this development. The effluent of this system in a floating settlement - Banjarmasin City for observation one year has the average of BOD less than 30 mg/L from individual treatment applied for 30 households.

Figure 2: Routine maintenance of biofilter and surface/subsurface constructed wetland in floating settlement, coastal areas and watershed area.

In the coastal area, water-related problems recognized significantly at low-income housing that their poor sanitation may increase the organic pollution to the coastal ecosystem. Reducing the impact of settlement activities on coastal ecosystem function depend on various factors, including the provision of safe water sources and improved sanitation. In Eretan Village, Indramayu City, implementation this wastewater treatment by biofilm system above the river still face problems related community sanitation behavior, process disturbance of flooding from the land area, seawater intrusion and further would influence process in biofilter or wetland system. The coastal area revitalization in Surabaya, communal treatment is becoming one of the efforts and the community involvement is strongly recommended to maintain the sustainability of the operation of facilities [14]. In Kesenden Area, Cirebon City, most of the low-income community have limited clean water source, and some of them have use water from municipal wastewater pond for public purposes. The applied biofilm system in this study area uses local media for media growth such as coconut shell cut, woodchips and old net fish.

Meanwhile, the various used natural plant-like materials, woodchips, are the most popular and considered to be attractive in practical application due to their lower cost, higher C/N ratio, longer duration of effectiveness and ready availability at a moderate cost, as explained at [15]. A small quantity of the effluent from urban oxidation pond in local water company area flow to water reuse plant with capacity of 20 m3/day with a hydraulic loading rate of 0.86 m3/m2/d. The constructed wetland at Kesenden Area consists of two series units horizontal and vertical flow of subsurface constructed wetland, designed for the hydraulic loading rate of 0,86 m3/m2/day and the capacity 20 m3/d has been applied to treat effluent from anaerobic wastewater treatment. The effluent from hybrid wetland flowed to slow sand filtration and carbon filtration designed to remove soluble organic or bacteria. In the hybrid wetland, local hydrophyta were chosen to plant in wetland medium (sand, gravel) which have proved an ability to remove organic, nitrogen and phosphor such as *Typa angustifolia*, *Typa latifolia*, *Canna edulis*, *Cyperus alternifolius*, and *Cyperus papyrus*. Application of this reuse concept may enhance the quality of treated wastewater because the high temperature could accelerate the reaction rate and oxygenation process.

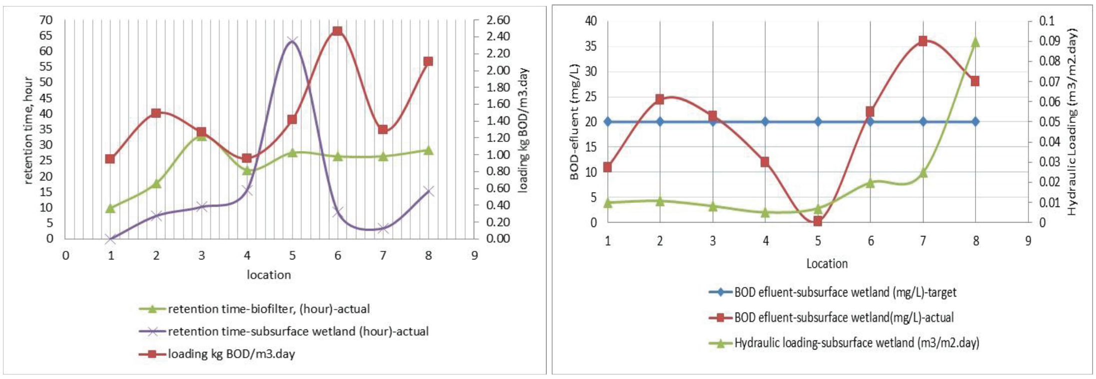

Figure 3: The effluent BOD and detention time actual of communal treatment.

As the population grows in Citarum watershed communities, the clean water demand is increasing, and the ability to sustain a healthy environment is becoming difficult. The predominant wastewater technology in Citarum watershed settlement is the pit latrine or septic tank. Especially at Citarum oxbow settlement, the cultural eutrophication arising from these anthropogenic activities. This area needs for effective, affordable treatment technologies, with ecosystem approach can develop a reuse system including a shallow sewer system connected to the communal anaerobic treatment system and wetland system built on the riverside. The cost of a decentralized system with simplified sewer systems is lower than both conventional sewer systems and septic tank-based systems, comprising septic tanks, ventilated improved pit latrines, urine diversion dry toilets, and pour-flush pit latrines, according to [16]. Groundwater crisis associated with sanitation development, so that the wastewater treatment system should consider multiple processing stages which can consist of biofilm systems, subsurface constructed wetlands then inducted to groundwater through a shaft of granular filtration. The applied research on developing and community facilitating at eight locations with integrated, effective domestic wastewater treatment and drinking water supply have significant benefits to provide options for better technology than conventional system [17]. Mostly the affluent target of wastewater treatment is for agricultural irrigation and river water quality improvement to achieve about BOD effluent is below 30 mg/L. In Figure 3, there is fluctuation of effluent quality and detention time of application of biofilter and wetland system for two years observation. The applied system are considered as ways to improving water course quality, water reuse practice and effective degradation through highly promising hybrid wastewater treatment systems, including up flow anaerobic sludge blanket (UASB), fixed bed biofilm system or ecological system (subsurface flow constructed wetland, surface flow constructed wetland or pond). Hybrid treatment could be the choice as a modified design to have effective degradation or to have a high rate anaerobic system and is considered more stable for the treatment of soluble or partially soluble wastewater [18]. The hybrid treatment system ensures no public nuisance but also become river greenery or settlement landscape. Therefore, it is also to ensure the flexibility, the safety and the ease of operation and maintenance.

4. Conclusion

Wastewater infrastructure management, applied through ecosystem approach in urban specific areas, is characterized by maximizing the removal of wastewater pollutant by key ecosystems, sustainable use of resources, the practicality of operation and maintenance and the fulfillment of effluent standard and vector disease requirements. The sanitation infrastructure in specific urban areas should be developed to improve specific ecosystem or water sensitive areas, which consider the biophysical landscape, improving its ecosystem and also building local capabilities. The implementation of wastewater infrastructure in some specific areas should concern, such as follows:

1. Tidal settlement areas, integrated water management to increase clean water supply and provide the waste treatment system. Enhancing the buffering capacity

of ecosystem wetlands for the removal of organic, nutrients, pathogens, and other pollutants.

2. Floating settlements, wastewater treatment system has floating ability and structural stability. The further treatment could develop floating wetland.

3. Water sensitive areas, such as watershed area. The applied systems are ways to improve the quality of water course, water reuse practice and effective degradation through hybrid wastewater treatment systems. In the wastewater treatment system should concern with enhancing macrophyte diversity and natural disinfection processes by subsurface-flow wetlands granular or slow sand filtration.

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