Sustainability Analysis of Domestic Wastewater Treatment Technology Applied on Human Settlement in Swamp Area

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ABSTRACT: Providing wastewater treatment system for human settlement in swamp area are challenging, due to they are related to physical settlement and environmental conditions and other non-physical barriers. Related to those challenging factors maintainingthe sustainability of applied wastewater treatment in swamp settlemens is becoming a big concern and the development of existing wastewater treatment technology to accomplish the challenge in swamp settlement is necessary.Wastewater treatment technologies having been applied in this swamp settlement were analyzed based on sustainability criteria. Those technologies are including tripikon-S, compact biofiltration system, dry and separated toilet with container, floating pods/ garden, and anaerobic baffled reactors. Hhierarchical framework adapted from Analytical Hierarchy Process (AHP) with sustainability criteria is used as the evaluation tools. The criteria used was adapted from the widely used sustainability criteria for sanitation from references, with the elimination of socio-cultural and institution criteria that is considered as site specific criteria. For weighing criteria, the assumption of equally importance of each factor in the same stage on hierarchical structure is used.Several issues were highlighted for existing wastewater treatment applied on human settlement in swamp area, such as durability related to specific environmental condition, requirement and fulfillness in operational and maintenance, treatment efficiency, and cost related issue. Those highlighted issues are becoming the consideration to decide the sustainability criteria accomplishment for each technology.As the result, dry and separated toilet with container consider as the most sustainable system (with score 0.832) and both floating pods/ garden and tripikon-S system are the second highest score (0.666). Based on that result, low-cost concept, that was also related to material selection and environmental analysis, is concluded as a factor that play an important role in achieveing sustainability of technological development of wastewater treatment for human settlement in swamp area.

Keywords: domestic wastewater;swamp area; sustainability criteria;wastewater treatment technology

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1. INTRODUCTION

Swamp, also known as bog, fed, marsh, and wetland, is flat area with soft soil and the soil is permanently condense/ filled by water.Most of the swamp area are continuously or seasonally inundated (Subagyo, 2006; Trettin, 2008; Djonoputro et al., 2010). This area can be either formed as tidal swamp because of the tidal effect near coastal areas, estuaries and other area that affected by tidalwave,or as non-tidal inland swamps in flat areas near to lakes, rivers or other areas with no rainwater runoff. In some of South East Asia country,many swamp area are occupied by people as residential areas. The existence of human settlement in swamp area wasdriven by historical, cultural, and economic reasons (Krausse, 1975 in Navarro, 1994, Djonoputro et al., 2010).

One of the major issue of human settlement in swamp area is insufficient sanitation facilities. Open defecation and overhung toilets without treatment are generally found in swamp area. The impacts from the discharge of domestic wastewater into rivers, lakes, estuaries and the sea is a matter of great concern in most developing countries (Bao et al., 2012). The problem is becoming bigger when the water that directly received wastewater is being used for basic needs such as cooking, washing, bathing and cleaning teeth, or even for drinking water. Several human settlement in swamp area, especially in urban area, are categorized as high densityslum. With the rapid domestic activities of the people in those area, problem of water quality degradation and deposition of domestic wastewater in settlement area are increasing

Providing wastewater treatment system for human settlement in swamp area are challenging. Djonoputro et al (2010) separated two main challenging factors in applying wastewater treatment system in swamp area. The first factor is physical challenge, consist of 1) type of houses, 2) water wave, 3) flood, 4) seasonal water level variation, 5) unstable ground soil, 6) high groundwater level, 7) erossion, 8) land subsidence, 9) corrosive air, 10) irregular shape of settlement, 11) limited land available, and 12) unsufficient access road. The second factor is non-physical challenge that mainly related to the people characteristics, consist of 1) general slums/ squatter characteristics, such as high density, low economical states, illegal settlement, unorganized spreading of settlement, and dirty environment condition, 2) low higiene knowledge of the communities, 3) migrants domination that makes communities with low responsibilities, 4) unpriority area of government to developed and monitored, 5) defecation habbits that difficult to be changed. Some of those non-physical factors were also mention by Katukiza et al (2012)as the challenging aspect for sanitasion facilities application in urban slums, that mostly related to people acceptancemake people want to use and maintain the facilities. Related to those challenging factors, maintain sustainability of the applied wastewater treatment in swamp settlemens is becoming a big concern and the development of existing wastewater treatment technology to accomplished the challenge in swamp settlement is necessary (Navarro, 1994; Djonoputro et al, 2011)

As the basis of wastewater treatment development, evaluation of existing wastewater treatment technologies should be done. In this paper, hierarchical framework based on Analytical Hierarchy Process (AHP) with sustainability criteria is used to evaluate wastewater treatment technology that has been applied in many settlement in swamp area. The Analytical Hierarchy Process (AHP) is a basic approach to decision making that cope with both the rational and the intuitive to select the best from a number of alternatives evaluates with respect to several criteria (Saaty et al. 1994). AHP isdesigned to structure in a scenario affected by multiple independentfactors. A complex problem can be divided intoseveral sub-problems that are organized according to hierarchicallevels, where each level denotes a set of criteria or attributes relatedto each sub-problem. The top level of the hierarchy denotes the goalof the problem and the intermediate levels denote the factors of therespective upper levels. Meanwhile, the bottom level contains thealternative or actions considered when achieving the goal(Saaty,1980, 2003 in Bottero et al., 2011).

2. METHODOLOGY

2.1Selection of Wastewater Treatment Technology

Wastewater treatment technology evaluated in this paper were limited to several technologies having been applied in swamp settlement, both for stilt houses area and floating houses area. The information of those technological application were collected from literature study, observation, and interview. The list of technology that has been evaluated in this paper, its location and data collection methods is presented in Table 1.

Table 1 Wastewater Treatment Technology Applied in Swamp Settlement

Wastewater Treatment Technology	Application in Swamp Settlement
Tripikon-S	Application on swamp and river settlement in Pontianak-Kalimantan, Yogyakarta, Morodemak, and Palembang (as off-site system).
Biofiltration System	Application on river swamp settlement in Banjarmasin and Palembang, Indonesia
Dry and separated toilet with container	Application on floating houses in Tonle River, Cambodia
Floating pods/ garden	Application on floating houses in Cambodia as primary treatment and on river swamp settlement in Banjarmasin, Indonesia as secondary treatment
Anaerobic Baffled Reactor	Application as communal treatment in Tihik-tihik and Selangan Communities-Kalimantan, Indonesia and Bintan Islands, Indonesia

2.2Criteria Selection

Criteria that has been developed in this paper was based on several sustainability indicators that commonly used in domestic wastewater or the other sanitation fields. From many literatures, main sustainability criteria consists of technological selection/ technical, financial/economical, environmental (including or not including health criteria), socio-cultural, institutional/ organizational (Table 2).

In order to meet the purpose and the condition of evaluation work in this paper, socio-cultural and institutional/organizational criteria were eliminated. This due to the technology that is being evaluated were applied in different places with different culture and institution and generally reviewed as options for common condition of swamp settlement in several places. In term of the weighing criteria, instead using paired comparison judgement with the fundamental scale as suggested in AHP procedure, in this paper, the assumption of equally importance of each factor in the same stage on hierarchical structure is used. Table 3 represented the detail of the criteria and weight that are used and Figure 1 represented the hierarchical structure for the sustainability analysis in this paper.

Table 2 Common Sustainability Indicators for Sanitation

Indicators	Explanation	References

Technical/ Technological	Related to several technical consideration, from construction, operational, and maintenance, also consideration of system endurance/ age. Some included consideration of environmental condition (such as tophography, soil, groundwater)	Mukherjee, 1999; Balkema et al., 2002; Bouabid, 2002; Mara, 2003; Ahmad, 2004; Muga et al., 2008; Lennartsson et al., 2009; Henriques et al, 2010; Setiawati et al., 2013; Zurbrugg, 2013; Seleman et al., 2016
Financial/ Economical	Related to cost, mainly cost of contruction/ capital cost, operational and maintenance, and some give correlation to willingness to pay and ability/ capacity to pay.	
Environmental	Related to pollution risk to the environment. Mostly include the treatment (removal) efficiency and or water stream quality/ carrying capacity. Some mention about several health indicators, and some also mention about sources that required from environmental, including raw materials, energy, and forestry also the reuse potential.	
Socio-cultural	Related to community/ people. Some common indicators are participation and acceptance and several criterias related to community background (such as educational, hygiene). Some literature also consider about conformity, convinience, usability.	
Institutional/ Organizational	Related to management structure, several correlated it to the government and other stakeholders capacity	

Table 3 Sustainability Criteria For Wastewater Treatment Applied and Importance Weight Scale

Criteria	Explanation	Weight
Technological Selection		**0.333**
1. System endurance	Durability of wastewater treatment system in responding environmental condition of swamp area	0.167
2. Operational easiness	Easy to operate, do not required special attention, do not required specific skill to operate	0.167
3. Maintenance easiness	Easy to maintain, can be maintained by the communities	0.167
4. Construction easiness	Easy to construct, do not require professional skill, do not more difficult than on land construction	0.167
5. Availability of sparepart	Easy to find materials and spareparts for solving problem or repairing damage	0.167
6. Adaptability	Can be adapted easily in other places	0.167
Financial		**0.333**
1. Investment cost	Cost that is required to construct the wastewater treatment system are considerably low	0.333
2. O&M cost	Cost that are required in operating and maintenance of the system are considerably low	0.333
3. Local development	The possibility of communities to pay the cost requirement (investment and O&M)	0.333
Environmental		**0.333**
1. Not polluting water area	Less potential to spread pollutant in water area due to low removal efficiency and leakage	0.333
2.Efficiency of raw materials	Raw materials are efficiently used in term of system construction and operational and maintenance, minimized waste producing.	0.333
3.Minimization of wastewater	Amount of wastewater is minimized by reducing water use or using water-solid separated system	0.333

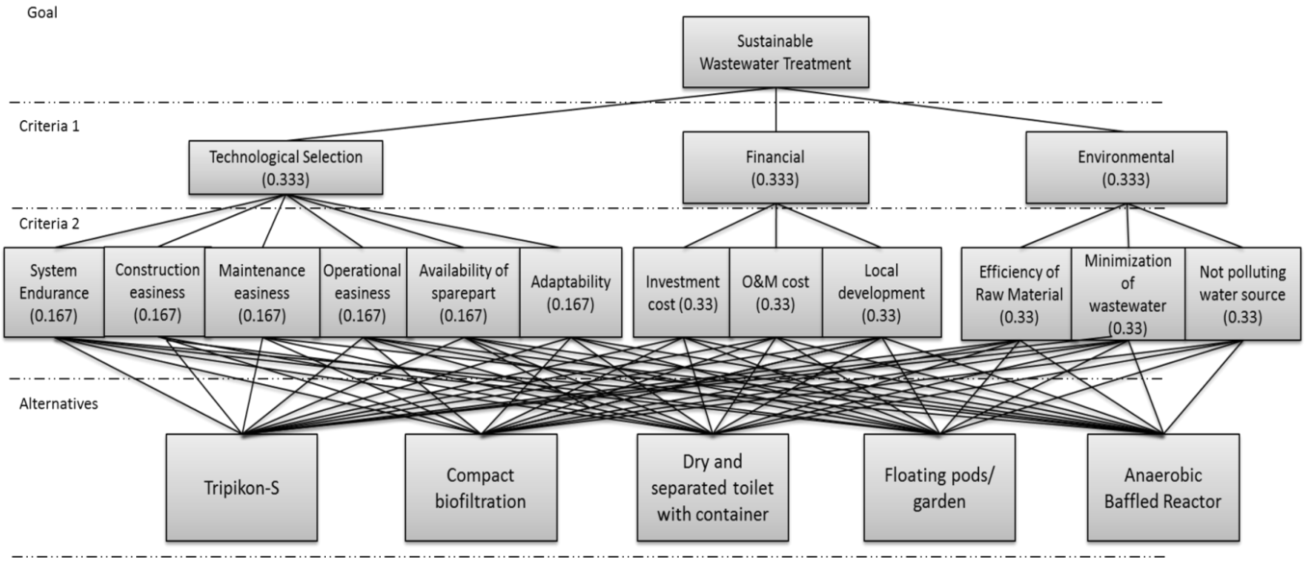

Figure 1 Hierarchy Structure in Reviewing Sustainable Wastewater Treatment Technology

3. RESULTS AND DISCUSSION

3.1Existing Wastewater Treatment System in Swamp Settlement

3.1.1 Tripikon-S System

Tripikon-S (Three consentric pipe-septic) technology (Figure 2) was developed with the consideration of stilt house condition upper the river swamp area. This technology consider as low cost, easy to build, easy finance, and easy replicated wastewater treatment system. This system used vertical flow in a septic container using PVC pipes with three different sizes and build concentrically each other as the place of anaerobic treatment process. Anaerobic treatment process is used by adapting three days detention time of septic tank system.

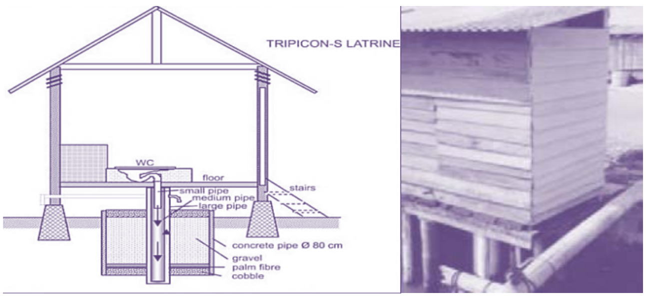

Figure 2 Tripikon-S System (Saraswati et al., 2009)

Tripikon-S system has been applied and piloted in many places, includingriver swamp area in Pontianak and Banjarmasin (data from Civil Engineering Traditional Technology Laboratory, Gajah Mada University and interview), riverbank area in Yogyakarta (Wijaya et al., 2010), coastal area in Morodemak (Saraswati et al., 2009), swamp area in Palembang (data from observation and interview). Several information about removal capacity Tripikon-S has been reported. The field application of Tripikon-S in Pontianak achieved 95% of organic removal as $KMnO_4$, and in Banjarmasin achieved 83% of organic removal as $KMnO_4$. Both with influent 1000mg/L organic concentration as $KMnO_4$and reached the optimal condition afer 3-4 months usage. Saraswati et al. (2009) reported Tripikon-S can remove 40% organic as $BOD_5$and 44.5% organic as $KMnO_4$ after five years used (without maintenance) with the initial concentration 334.7 mg/L BOD5 and 3,177 mg/L $KMnO_4$. Beside field application, laboratory works of Tripikon-S has also been established. In Selintung et al. (2011), outdoor Tripikon-S system, designed for six person with three days detention time, was analyzed for ten days. It achieved 20.86% organic matter removal as $KMnO_4$, 35.03 % BOD_5removal, and 23.92 % COD removal (influent concentration : organic matter as $KMnO_4$ = 179 mg/L; BOD_5 = 362 mg/L, COD = 533 mg/L. In Putri et al. (2015) optimization of Tripikon-S system, using artificial domestic wastewater, showed the removal works efficiently in 1-2 days, and by using continuous procedure, 58% COD removal achieved (Initial COD = 1,500 mg/L) with 48 hours hydraulic retention time (HRT) and 50% COD removal achieved (Initial COD = 2,000 mg/L) with 48 HRT. In order to reach higher removal efficiency, several development of Tripikon-S system has been established. Saraswati et al. (2009) combined Tripikon-S system with gravel filter and Putri et al. (2015) design Tripikon-S with additional bioball in the large pipe and design Tripikon-S with additional venturi-shaped chamber. Both gave promising increasement of organic removal efficiency.

The problems in application of Tripikon-S system are mainly related todurability and maintenance. Five Tripikon-S system applied in Morodemak region in 2003 (Saraswati et al., 2009). Two was built in wet area (river swamp) with the system directly attached below the toilet facilities, three others was built in land/ dry area, with separated system from toilet, connect by the pipeline and using the concrete as replacement of the biggest pipe. From two wet type of Tripikon S, one of them completely can not be used since the big damage that is caused by the boat crash. Another one are still being used by people even has some leakage problem in the bottom. From three land type Tripikon-S, one is still being used by the people without any problem, another one still can be used, but is not being used anymore because of toilet replacement, and another one can not be operated since the elevation change that make the wastewater can not flow well.

3.1.2 Compact Biofiltration System

Compact biofiltration system that was mentioned in this paper is fabricated fiber tank with several compartment that facilitate different treatment process, which are includes the suspended and attached microorganism process. The biofiltration system made the possibility to facilitate both anaerobic and aerobic process in one system (Sumidjan, 2012). This treatment system was claimed as complete treatment system that made the requirement of additional infiltration area is neglected. Since the system is fabricated and produce as compact product, the reparation work and the sparepart can only provided by specific company. Biofiltration system is not considered as cheap wastewater treatment system, but it consider as easy built.

Sumidjan (2012) applied biofiltration system with floating wetland/ garden as additinal treatment (called BIOSANTER) in the river swamp settlement in Banjarmasin (Figure 3). The biofilter tank was directly put down above the swamp soil, connected to hanging toilet by PVC pipe. Damage of the tank found after several months. It is analyzed as the impact that received related to the tank movement as the effect of tidal wave. In order to sove the problem, special materials (*heavy duty*)was used, but it affects the cost of the system.Problem of the application of fiberglass biofiltration system was also found in the application in Palembang (Putri et al., 2014). Biofiltration tank found floating freely as the effect of tidal wave, loose from its pipe connection. The consideration about problem of pipe connection and joint as the movement of the tank was also considered in Djonoputro et al. (2010).

Figure 3 Application Compact Biofiltration System in Banjarmasin (Sumidjan, 2012)

3.1.3Dry and Separated Toilet with Container

Dry and separated toilet (Figure 4) is one of the sanitation options for urban slum (Katukiza et al., 2011) and from the difficult environmental condition for construction such as in swamp area, it can be one of the best solution.Navarro (1994) mentioned that for houses that are built on areas with high groundwater level and those submerged in water, the most ideal means is to collect the human waste and transport it to another site for treatment or disposal.But, still from Navarro (1994), the wastehandling requirement of this system make this technology not easily adaptable by many communities. Putri (2015) also mentioned about people rejection to use dry toilet in human swamp settlement of Palembang city and Banyuasin county. It can conclude that the biggest consideration of the application of dry and separated toilet with container is related to people acceptance, both acceptance to use the dry toilet system and to contribute in wastehandling such as replace and collect the waste container.

Figure 4a) Dry and separated toilet with container; b) Waste collection station; c) Urine container; d) Composting site (Brown, 2010; Sayre et al., 2011)

Brown (2010) and Sayre et al. (2011) applied the dry and separated toilet system (Urine

Diversion Dehydrating/ Dry Toilet – UDDT) as community based project which was including capacity development and empowerment of the community in floating communities Tonle Sap Lake, Cambodia. Community is involved in designing toilet from the beginning also contribute in trial phase. It leads the people acceptance and people agree to operate and maintain the toilet system, including replace bucket and collect used bucket in waste collection station. This UDDT application consider as a low-cost wastewater treatment system since it utilized the used stuff that can easily found, such as bucket and jerrican. Other consideration while its product will be further used as fertilizer is to make sure the stabilization process was complete, so the product do not contain any harmful/ pathogen microorganisms.

3.1.4 Floating Pods/ Garden

Floating pods/ garden (Figure 5) is the modification of wetland system as wastewater treatment technology. Chakraborty et al. (2012) developed floating pods system for Tonle Sap Floating Communities in Cambodia by widely-used tarpauline with water bottle sewn into the edge, 235 L capacity for single pod and 470 L for double pod, and using water hyacinth (*Eichhornia crassipes*) for plant to do the treatment. It was applied by using rope to connect the system to the house. Two floating pods was applied by simply added tap water and water hyacinth, then put sewage (35 L/ day) for one of floating pods and feces (500 g/day) for other.The system can eliminate coliform bacteria from 65,000 cfu/100 ml as the input, to 10,000 cfu/100 ml as the output. Several issues that appeared in floating pods application by Chakraborty et al (2012) are the smell, animals such as mice that disturb the treatment area, durability or tarpauline especially in the edge area related to sun exposure, and stability/ flexibility issue.

Figure 5 Floating Pods/Garden (Sumidjan, 2012; Chakraborty dkk., 2012)

Sumidjan (2012) and Brown (2010) were also applying floating garden, but the aim of the application is quite different from Chakraborty et al. (2012). Sumidjan (2012) add the floating garden by using PVC pipe as floating material and nets, added coconut fiber as growth media of the plantation, and do not use specific type of plant. Floating garden received effluent water from biofiltration by PVC pipe with capillary hole to growth the plant. In this work, the floating garden is used mainly as added value for the whole treatment plant, mainly to esthetic value and to gave people understanding that the treated wastewater could be a functional resources. A bit similar in Brown (2010), the floating garden was becoming added value for people also designed to use the stabilized wastewater from UDDT after several months process.

3.1.5 Anaerobic Baffled Reactor (ABR)

ABR (Figure 6) is animprovedseptictankbecauseof theseriesof bafflesunderwhichthewastewaterisforcedtoflow.Theincreasedcontacttimewiththeactivebiomass(sludge)results inimprovedtreatment (Tilley et al., 2008).Organic removal as BOD maybereducedbyupto90%, a lot higher compared wit aconventional septictank (around 50-60% removal). Sludge is accumulating especially in the first treatment chamber, it make desludgingisrequiredevery2to3 years. Infiltration process is still required as secondary treatment from ABR effluent.

ABR system can be applied as individual and communal wastewater treatment, but mostly used as communal wastewater treatment, one of the consideration is related to cost, since the cost could be considerably lower if it applied to provide higher number of people. The system was widely used, including in several swamp area in Sumatera and Kalimantan area. Djonoputro et al., 2011 mentioned about the difficulties to construct the ABR system and other concrete big tank in swamp and water environment. Beside the difficulties, the cost (ABR is classified as moderate cost) can be significantly higher than its construction in land area. The additional cost is related to the additional structure required, such as piling foundation, and also related to drying effort and other additional engineering work during the installation.Putri et al. (2015) also mention another issue related the concrete ABR tank in Palembang area, which are the cracking of the tank and/ or the movement of the treatment system related to soil condition in swamp that can make the wastewater flow changed.

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Figure 6 ABR Followed by Filtration in Tihik-tihik and Selangan Coastal Communities

3.2 Sustainability Analysis

From the review of existing wastewater treatment technology that has been written in previous sub-chapter, the information that is collected is further used to fill the rate of accomplishment for each sustainability criteria Summary of the sustainability analysis of wastewater treatment technologies is represented in Table 4.

From the sustainabilty analysis result, the highest score of technologies were reached by dry and separated toilet with container (0.832), while both floating pods/ garden and tripikon-S system got the second place (0.666). Those three technologies has some simililarity in their concept and consideration factor of technology establishment. Those similar concepts are low-cost, using widely-used material, and the technology concept was developed with the purpose to deal with swamp/ water condition of environment.

Table 4 Summary Sustainability Analysis of Wastewater TreatmentTechnology

	Tripikon-S	Compact Biofiltration	Dry separated toilet with containment	Floating pods/ garden	ABR
Technological Selection					
1. System Endurance	X	X	√	√	√
2. Operational Easiness	√	√	X	X	√
3. Maintenance Easiness	X	X	X	X	X
4. Construction Easiness	√	√	√	√	X
5. Availability of Sparepart	√	X	√	√	√
6. Adaptability	√	√	X	√	√
Financial					
1. Investment cost	√	X	√	√	X
2. O&M cost	√	√	√	√	√
3. Local Development	√	X	√	√	X
Environmental					
1. Efficiency of raw material	√	X	√	√	X
2. Minimization of wastewater	X	X	√	X	X
3. Not polluting water source	X	√	√	X	√
Score	0.666	0.389	0.832	0.666	0.444

The other two treatment technologies, which are ABR and biofilter are the treatment technologies that designed to fulfill general condition of the human settlement, mostly for land area, and in order to fulfill swamp area condition, additional constructional tools or structure were used. The consideration of low-cost and widely-used material is partly fulfilled by the general condition of ABR application, but especially for cost, it is not accomplished anymore related to additional cost that is required for swam area. While the biofiltration system, since it fabricated technology, did not consider as low-cost technology.

Low-cost was also mentioned in Navarro (1994) as the key of applying wastewater in coastal area, that in some points has similar characteristic with swamp, and it mentioned that low-cost can be achieved by analyze the environment condition, community structure, and available services such as water supply, collection of waste water and solid waste.In the larger feasibility framework, Navarro (1994) described that wastewater technology is feasible to be applied in coastal area while it isfeasiblein areas with adverse ground conditions, specifically impermeable and unstable soils with high ground water; feasible in high density areas; requires minimum water; and does notrequire large equipment for waste collection and transportation.

From the result, accompanied by the comparison with feasibility criteria by Navarro (1994), this analysis can be generally described some essential factors that can increased sustainability potential in developing wastewater treatment technology for application on human settlement in swamp area. The keyconsideration is about providing low-cost technology, while to achieve that, the consideration of specific environmental condition and availability of resources

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(especially related to building material) are important.Socio-cultural and institutional factors also should not be forgotten in order to select and develop technology for each specific human settlement in swamp area.

CONCLUSIONS

Several issues were highlighted for existing wastewater treatment applied on human settlement in swamp area, such as durability related to specific environmental condition,requirement and fulfillness in operational and maintenance, treatment efficiency, and cost related issue. Those highlighted issues are becoming the consideration to decide the sustainability criteria accomplishment for each technology.

Dry and separated toilet with container consider as the most sustainable system (with score 0.832) and both floating pods/ garden and tripikon-S system are the second highest score (0.666).Based on that result, low-cost concept, that was also related to material selection and environmental analysis, isconcluded as a factor that play an important role in achieveing sustainability of technological development of wastewater treatment for human settlement in swamp area.

REFERENCES

Ahmad, T.T. (2004). *A Classification Tool for Selecting Sanitation Service Optionsin Lower-Income Communities*. Master Thesis, University of Virginia, Virginia

Balkema, A.J., Preisig, H.A., Otterpohl, R., Lambert, F.J.D. (2002). Indicators For The Sustainability Assessment of Wastewater Treatment Systems, *Urban Water*, 4, pp. 153-161

Bao, P.N., Aramaki, T., Hanaki, K.(2013). Assessment of Stakeholders' Preferences Towards Sustainable Sanitation Scenarios, *Water and Environmental Journal*,27, pp. 58-70.

Bottero, M., Comino, E., Riggio, V. (2011). Application of the Analytic Hierarchy Process and the Analytic Network Processfor the assessment of different wastewater treatment systems, *Environmental Modelling & Software*, 26,pp. 1211-1224

Bouabid, M.A. (2004).*Requirements Analysis for Sustainable Sanitation Systems In Low-Income Countries*,Master Thesis, University of Virginia, Virginia

Brown, M., (2010).Sanitation on Floating Communities in Cambodia.Report for the Ministry of Rural Development,*Live&Learn Environmental Education Cambodia Engineers Without Borders Australia.*

Chakraborty, I., Jennings, W., Khon, P., Hand, T. (2012). *Floating Treatment Pods for Lake Communities*.International Faecal Sludge Management Conference, 30 October, Durban, South Africa.

Djonoputro, E.R., Blackett, I., Rosenboom, J..&Weitz, A. (2010), Understanding SanitationOptions in ChallengingEnvironments, *Waterlines*, 29, no. 3, pp. 186-203.

Djonoputro, E. R. Blackett, I.Weitz, A., Lambertus, A., Siregar, R., Arianto, I., Supangkat, J. (2011). *Opsi Sanitasi yang Terjangkau Untuk Daerah Spesifik*, Water and Sanitation Program-

East Asia & the Pacific (WSP-EAP), Indonesia.

Henriques, J.J., Louis, G.E. (2011), A Decision Model for Selecting Sustainable Drinking Water Supply and Greywater Reuse Systems for Developing Communities with A Case Study in Cimahi, Indonesia, *Journal of environmental management*, 92, no. 1, pp. 214-222.

Katukiza, A.Y., Ronteltap, A., Niwagaba, C.B., Foppen, J.W.A., Kansiime, F. & Lens, P.N.L. (2012).Research Review Paper - Sustainable sanitation technology options for urban slums, *Biotechnology Advance*, 30, pp. 964-978.

Lennartson, M., Kvarnstorm, E., Lundberg, T., Buenfil, J., Sawyer, R. (2009), *Comparing Sanitation Systems Using Sustainability Criteria*, Stockholm Environment Institute, EcoSanRes Series, Stockholm, Sweden

Mara, D. (2003). *Domestic Wastewater Treatment in Developing Countries*, Earthscan, London, United Kingdom

Muga, H.E., Mihelcic, J.R.(2008). Sustainability of Wastewater Treatment Technologies, *Journal of Environmental Management*, 88, pp. 437–447

Mukherjee, N. (1999). Measuring Sustainability — Recent Lessons From Indonesia, *Waterlines*,18, no.1, pp. 13-16

Navarro, R.G. (1994). *Improving Sanitation in Coastal Communities with Special Reference to Puerto Princesa, Palawan Province, Philippines*, Ph.DThesis, McGill University,Montreal, Canada.

Putri, D.W., Apriadi, D.P., Soewondo, P. , Effendi, A.J., Setiadi, T. (2014).*Physical Analysis of Wastewater System Application Failure in River Swamp Area (Case Study in Seberang Ulu I District, Palembang City, Indonesia)*, 11th International Symposium on Southeast Asian Water Environment, 26 – 29 Nov, Bangkok, Thailand

Putri, D.W., Marlisa D.F., Kusumaningayu, D.A., Soewondo, P. , Effendi, A.J, Setiadi, T. (2015).*Organic Substance Removal Using Modified Tripikon-S System*, The 5th Environmental Technology and Management Conference, 23 – 24 November, Bandung, Indonesia.

Putri, P.S. (2015). *Penentuan Kriteria Kapasitas Masyarakat Kawasan Permukiman Spesifik dalam Mendukung Keberlanjutan Pengelolaan Fasilitas Sanitasi Rumah Tangga (Studi Kasus : Masyarakat Kawasan Sungai/ Rawa dan Pesisir, Provinsi Sumatera Selatan, Master Thesis*, Institut Teknologi Bandung, Bandung, Indonesia

Saaty, T.L., Vargas, L.G. (1994). *Decision Making in Economic, Political, Social, and Technological Environments with the Analytic Hierarchy Process*, RWS Publications, Pittsburg, USA

Saraswati, S.P., Nizam, Darmanto (2009). *Design and Reviewing the Work of a Rural Sanitation – Tripicon System : An Application in Coastal Area*. International Conference on Sustainable Development for Water and Wastewater Treatment, MUWAREC YK09-Muslim Water Researches Cooperation, Yogyakarta, Indonesia.

Sayre, E.V., Sayre, J.C. (2011). Sanitation Solutions for Flooded Zones: The WAND Foundation Experience. *Special Publication by the: Water, Agroforestry, Nutrition and Development*

Foundation (WAND), Inc.

Seleman, A., Bhat, M.G. (2016). Multi-criteria assessment of sanitation technologies in rural Tanzania:Implications for program implementation, health and socio-economicimprovements, *Technology in Society*, 46,pp. 70-79

Selintung M., Malamassam, M. R. (2011). Pengolahan Air Limbah Rumah Tangga Pada Lahan Sempit, *Prosiding Hasil Penelitian Fakultas Teknik*, 5, TS-7, pp. 1-6

Setiawati, E., Notodarmodjo, S., Soewondo, P., Effendi, A.J, Otok, B.W. (2012). Structural Equation Modelling and Analytical Hierarchy Process For Sustainable Wastewater Infrastructure of Jakarta, *International Journal of Academic Research*, 4, pp. 287-291

Subagyo, H. (2006). Chapter 1 – Klasifikasi dan Penyebaran Lahan Rawa. In : *Karakteristik dan Pengelolaan Lahan Rawa*, Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian, Bogor, Indonesia

Sumidjan, I. Y. (2012). *Efisiensi Sistem Biosanter dalam Pengendalian Pencemaran Kawasan Permukiman di Sekitar Bantaran Sungai*. Pusat Penelitian dan Pengembangan Permukiman, Indonesia

Tilley, E., Luthi, C, Morel, A., Zurbrug, C., Schertenleib, R. (2014), *Compendium of Sanitation Systems and Technologies*, Swiss Federal Institute of Aquatic Science and Technology;Water Supply and Sanitation Collaborative Council, Dübendorf, Switzerland; Geneva,Switzerland

Trettin, C. (2008), Swamps, *Encyclopedia of Ecology*, pp. 3446–3449

Wijaya, A.W., Dewi, N.P. (2010). *Tripikon-S as A Appropriate Technology for Sustainable Sanitation Along Riverbank Area at Tropical Developing Country.*International Conference on Sustainable Future for Human Security,Kyoto, Japan.

Zurbrügg, C. (2013).*Assessment methods for waste management decision support in developing countries.*Ph.D.Thesis -UniversitàdegliStudi di Brescia