SIBE2013

The Second International Conference on Sustainable Infrastructure and Built Environment

Faculty of Civil and Environmental Engineering
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VOLUME IV

"Accelerating Sustainable Infrastructure Developement - Challenges, Opportunities, and Policy Direction"

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Volume IV

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The Second International Conference on Sustainable Infrastructure and Built Environment

Accelerating Sustainable Infrastructure Development – Challenges, Opportunities, and Policy Direction

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PREFACE

Infrastructure provides the basic needs of human beings, and sustainable infrastructure systems are essential for the survival, health, and well-being of a society. The civil, environmental, and ocean engineers are at the epicenter in seeking the means to enhance human life through modernization of infrastructure as evidenced by provision of shelter, water, and transport, amongst others.

The current fast rate of urbanization and industrialization has caused a rise in environmental issues, involving environmental mismanagement, which has been associated with unforeseen global catastrophes. The problems are further aggravated by the impacts of environmental degradation such as soil erosion, hurricanes, sea-level rise, depletion of water resources, etc. These issues have become the current focus of attention and studies of the world's academicians and professionals in infrastructure development. Relevant researches include not only hard infrastructure but also soft infrastructure aspects such as regulation, institution, and policy development framework.

To support economic activities and to offer a better quality of life, developing countries need to accelerate sustainable infrastructure provision. In many developing countries, including Indonesia, lack of infrastructure has been the main obstacle of investment and development activities. Besides limited available fund, the acceleration of sustainable infrastructure development still has to face the challenges of, among others, knowledge, human resources management, best practices, and capacity development. On the other hand, developing countries generally possesses abundant local natural resources, sufficient carrying capacity, and local wisdom.

In order to meet these multifaceted challenges, not only proper planning, design, implementation and verification exercises, but also clear policy and strategy direction of sustainable infrastructure development are required, via an integrated, multidisciplinary and holistic approach.

The global momentum for sustainable development must now lead to practical applications of the engineering and science of sustainability – an optimization – which allows an accelerated infrastructure provision with maximum attention on sustainability aspects.

The conference will provide an opportunity for professionals and researchers to learn, share and exchange the latest development and research in civil engineering and environmental engineering. The scope of the conference will be broad, covering all aspects of civil and environmental engineering practices.

Participants of the conference include researches, academic staffs, students, industries, public and local governments. The keynote presentations during the conference are as follows:

Keynote speakers:

- **Ir. Djoko Kirmanto**
  Minister of Public Works, Indonesia
- **Prof. Tamon Ueda**
  Head of International Committee of Faculty of Engineering, Hokkaido University, Japan
- **Dr. Ir. Bambang Susantono, MSCE., MCP**
  Vice Minister of Communication, Indonesia
- **Prof. Shyh-Jian Hwang**
  National Taiwan University, Taiwan
- **Prof. Ir.Suprihanto Notodarmojo, Ph.D.**
  Dean of the Faculty of Civil and Environment Engineering,InstitutTeknologi Bandung, Indonesia
- **Dr. Ir. Achmad Hermanto Dardak, MSc.**
  Vice Minister of Public Works, Indonesia
- **Dr. Ir. Dedy Supriadi Priatna, M.Sc.**
  Deputy Infrastructure of BAPPENAS
- **Dr. Ir. Lucky Eko Wuryanto, M.Sc.**
  Deputy Infrastructure of Coordinator Ministry for Economic Affair

The objectives of the conference are:

1. To provide a platform for exchange of ideas and information among academics, researchers, consultants, engineers, manufacturers and post graduate scholars in civil and environmental engineering
2. To discuss and evaluate the latest approaches, innovative technologies, policies and new directions in infrastructure development, pollution prevention and eco-friendly technologies adapted to developing countries
3. To promote cooperation and networking amongst practitioners and researchers involved in addressing infrastructure and built environment issues

The oral presentations are subdivided into 8 major sctions as following:

1. Structure and materials
2. Transportation system and engineering
3. Water resources engineering and management
4. Water & waste engineering and management
5. Ocean engineering
6. Construction management
7. Geotechnical engineering
8. Environmental protection and management

There are 131contributors in oral presentation.

Finally, the organizing committee wishes that the conference is able to provide beneficial scientific information to the participants and other concerned readers

Bandung, November 2013

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Contents

Existing Application of Wastewater Infrastructure for Coastal, River, and Swamp Communities (Review Paper)

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Abstract. Most coastal, river, and swamp communities do not have an adequate wastewater treatment system. Many limitation including physical and non-physical aspect make the application of wastewater infrastructure becomes quite difficult. Decentralized system using simplified sewerage can be applied in stilt house settlement with consideration pipeline's supporting system and required higher but easier maintenance. Communal septic tank, ABR, and AUF can be applied as wastewater treatment system using stake foundation type due to unstable and waterlogged soil inconstruction area. RBC system are less applicable since it can't be submerged constructed and corrosive problem. Three consentric pipe-septic tank system developed as solution for river communities, but the application of those system required understanding of communities and more durable material to maintain its operation. Biofiltration as a compact system also required special materials to be applied in river and need to be constructed well to prevent the system moved by tidal effect. Floating garden/ wetland is other potential system to be applied in coastal, river, and swamp communities. Demand responsive approach (DRA) for floating communities is prospective to find appropriate wastewater treatment system. The sustainable system selected is UDD toilet that is ideal for floating communities but required high attention by the communities in operation and maintenance.

Keywords: *coastal, river, swamp communities; community based development; decentralized system; on-site system; wastewater infrastructure*

1 Introduction

1.1 Coastal, River, and Swamp Communities

Coastal, river, and swamp communities are defined from their housing placement. Those communities are unique because of their unusual living place environment and its forced them to have the special characteristics of living habbits and the housing types (Figure 1). In many Asian country the existence of coastal, river, and swamp communities is still common. For South East Asia countries, estimation number of people living in those area are more than 9 million people in Indonesia, 1.4-2.2 million people in Cambodia, 1-1.5 million people in Lao, and nearly reached 5 million people in Philippines [1].

Figure 1 a) Floating house in river [15] b) Stilt house river settlements, c) Coastal settlements, d) Swamp settlements [1]

The reasons of people living in such kind area are various. Navarro (1994) mention about those several reasons. First reason is based on the roles of the water stream that make those places become a strategic place for trading and fishing activities. For example, river communities along Martapura and Barito river in Kalimantan, Indonesia and in Bangkok city, Thailand while those area famous of trading activities, commonly known as floating market. Next reason is cultural reason. There are *Bugis orang laut* or *Bajaus* people, known as sea-gypsies, that are sprading in some maritime settlement from Burma to Philipphines and some that are nomadic people are scattering over thousands of square miles, from the Sulu Sea to Eastern Indonesia. The third reason is source of livelihood. This reason comes out because the coastal areas are considered among the most productive ecosystems. It makes many communities depended on these areas for their livelihood and as their source of food, water and resources. For example, communities at the northern corner of South Sumatra Province, in Indonesia, lies in the Banyuasin Sembilang mangrove swamps which have been occupied by communities engaged in fishing, agricultural activities, husbandry of forest products, hunting and trade in wildlife and artisan fisheries. Other communities are the one living in the southern provinces of the Philippines, that mainly are fishing villages along seacoasts and on the water itself. Similar with that, in Gameranga, Bangladesh, people occupies a piece of land densely cut by canals and richly dotted with ponds of varying depths and sizes used for rice cultivation, fishing and tapping of date palms.

The previous third reasons mainly comes from communities in rural area. As the last reason, in urban area cases, the coastal, swamps, and riverbank area are perceived as idle lands with limited land use alternatives. This is due to economical problems, while land is more costly, but the demand for low-cost service labour and many opportunities for informal employment and income drive urban migration from marginal rural livelihoods. The result has been sprawling urban slums often situated on land not suitable for habitation. In Jakarta, capital city of Indonesia, urban slums occupied the sloping embankments and terraces along the river, also the coastal marshlands in the northern periphery of the city. Among the sites occupied by the urban poor in Jakarta, marshlands and coastal areas usually provide sites for rentfree accommodations [10] [5]. The similar squatter urban river area also can be found in the eastern suburbs of Bangkok, especially along four major canals in the area, Klong Premprachakorn, Klong Lad Phrao, Klong Bang Sue and Klong Bang Khen. In other place, Sabarmati riverbank squatter settlement in Ahmadabad, India, developed to accomodate the needs of workers in the nearby textile mills. Recently, more than two dozen squatter settlements to be found on the eroding banks of the river and some even on the riverbed itself with a density reaching as high as 2,000 persons per hectare [10].

1.2 Sanitation in Coastal, River, and Swamp Communities

Most coastal, river, and swamp communities in Asia, especially in Indonesia, has sanitation problems mainly caused by the lack of adequate sanitation facilities provided. Main sanitation facilities concerned in this paper are the facilities related on human waste management and disposal. Both in river, coastal, and swamp communities, directly discharged wastewater through open defecation or from a hole in the housing floor and overhung latrine (Figure 2). Overhung latrine is simple superstructures with the toilet seat or floor hole built above the tidal flat, river, canal, lake or swamplands. Defecation takes place directly into the water for transport and eventual dilution, onto the mudflat or the beach to await the tide. In worse conditions, excreta is disposed of into the stagnant waters or simply on the ground underneath the built toilet [10]. In Guayaquil, approximately 83% of the swamps inhabitants use a hole on the floor boards for the family toilet, while the remaining 17% has a separate structure at the back of the house. In Jakarta, most people use latrines, private or communal, with outlets to or built directly into swamps and canals. In Gameranga, Bangladesh, a latrine basically consists of a bamboo construction over a hole or pit in an undergrowth behind a hut. Sometime this type of structure is built over a pond and is covered by old mats [10].

Direct defecation practice enhance the degradation of surface water and/or soil quality in muddy area such as swamp and bay. The nearest communities that got impact of the water quality degradation, especially in river area, are river communities. This due to their sanitation habbits in using river water for most basic needs such as cooking, washing, bathing and cleaning teeth, although do not use for drinking water (Figure 3)[5]. Coastal communities do not use the water in surrounding area as water resources because of the saline water condition, but the use of water for playing and swimming especially by the children are commonly found.

Figure 2 a) Floor hole inside house for domestic wastewater discharge, b) overhung toilet [1]

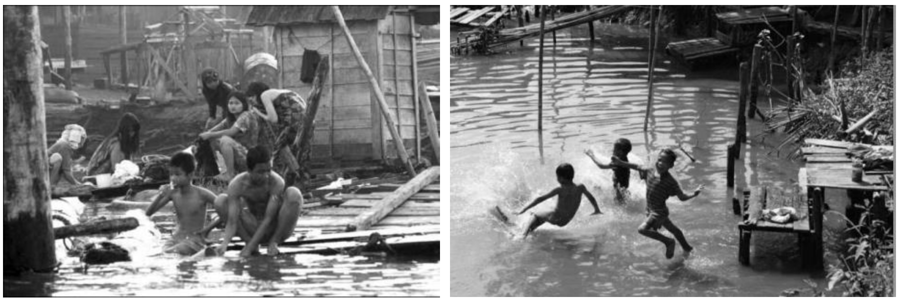

Figure 3 Bathing, washing, and swimming activities of river communities [1]

1.3 Challenge in Providing Wastewater Infrastructure

As mentioned in 1.1, coastal, river, and swamp communities known by its unusual environmental condition of their living area. From the sanitation system providers point of view, this condition make the effort to provide adequate wastewater infrastructure becomes quite challenging. This due to physical and non-physical aspects in applying wastewater infrastructure. Djonoputro et al [6] described those physical and non-physical challenge based on the survey in many coastal, river, and swamp communities in Indonesia. For physical challenge, eleven factors were listed and analyzed which communities affected by each factor (Table 1). Despite the location of the communities, the housing types were also analyzed, including floating house, stilt house, and land-type house. This physical challenge forces limitation in applying several kinds of wastewater treatment system also give some difficulties in constructing of pipelines and planning of maintenance and disposal system.

Table 1 Physical challenging factors and communities affected

CHALLENGE	Coastal & estuaries	River	Swamp
Water wave	Floating, Stilt, Land-type	Floating, Stilt	
Flood	Stilt, Land-type	Stilt, Land-type	Stilt, Land-type
Seasonal water level variation	Stilt, Land-type	Floating, Stilt, Land-type	Stilt, Land-type
Unstable ground soil	Floating, Stilt, Land-type	Floating, Stilt	Stilt, Land-type
High Groundwater level	Land-type	Land-type	Stilt, Land-type
Erossion	Stilt, Land-type	Stilt, Land-type	
Land subsidence	Land-type		
Corrosive air	Floating, Stilt, Land-type		
Limited land area	Stilt, Land-type	Floating, Stilt, Land-type	
Irregular settlement area and slums	Floating, Stilt, Land-type	Floating, Stilt, Land-type	Stilt, Land-type
Unsufficient access road	Floating, Stilt, Land-type	Floating, Stilt, Land-type	Stilt, Land-type

[Floating] = Floating house [Stilt] = Stilt house [Land-type] = Land-type house

Non-physical challenge were listing based on the communities characteristics, which are 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. This non-physical factors were also mention by Katukiza et al [9] in describing the challenging aspecrs in sanitarion facilities application in urban slums especially to make people accept and use the facilities.

2 Applied Domestic Wastewater Infrastructure in Coastal, River, and Swamp Communities

Several application of domestic wastewater infrastructures in some coastal, river, and swamp communities were developed by government, research organizations, and non-government organizations (NGOs). For this section, the infrastructure that has been reviewed mainly are the current application in Indonesia. Those domestic wastewater infrastructures divided into some decentralized application and on-site application.

2.1 Decentralized Domestic Wastewater Infrastructure

Decentralized domestic wastewater infrastructure is considered to be a sustainable wastewater infrastructure in developing countries. System that consist of simplified sewerage and wastewater treatment system for a group of houses considered to be more effective, do not need high cost and central maintenance like in centralized system, but also reduce the pollution potency from on-site application, especially to be applied in high density area. Decentralized system also provides privacy requirement of the communities better that communal toilet system, since it mainly consist of housing connection for private toilet.

2.1.1 Simplified Sewerage System

Simplified sewerage system has been practically developed in some coastal, river, and swamp area with stilt construction (Figure 1). Unlike pipeline system in land area that are burried in soil, the simplified sewerage system in stilt settlements are applied as hanging construction with some support materials. Consideration to decide the support material is one of the important issue in applying simplified sewerage system in stilt house settlement due to an effect of water wave and water quality in surrounding settlement area. Djonoputro et al [5] evaluate system using wood as supporting material. It was easily broken due to strong water wave, and quickly obsolete because it submerged in the water. Other support material by using wire found in Tihik-tihik and Selangan coastal area, Bontang city. It was easily corroded as the effect of saline water and it influence to the air in surrounded area. Once the support material broken, breakages of the pipe, especially in pipe joint could be often ocurs, even since the pipes are not burried, leakage problem and repairment of the system can be done easier than in land area.

Figure 1 a) Simplified sewerage system in Tihik-tihik and Selangan coastal settlement, Bontang City [4], b) simplified sewerage in Bintan island, Riau [17]

Djonoputro et al [5] suggested to use concrete construction as supporting materials even it will make the construction becomes more difficult and require higher cost. Pipeline mostly places below or in the edge of access road and the edge of house, since it was difficult to aply below the housing construction. Manhole using concrete materials applied every certain distance for monitoring and solid settlement. Wastewater Treatment System

Some wastewater treatment system was constructed as communal wastewater treatment system. Mostly were directly adapt from decentralized wastewater treatment system on land area with some changes in foundation to support construction.

2.1.1.1 Septic Tank, Anaerobic Baffled Reactor (ABR) and Anaerobic Upflow Filter (AUF)

Septic tank application can be found in many coastal, river, and swamp area as individual and communal wastewater treatment, but in apllying it, infiltration area that is required becomes the problem since no adequate area condition for infiltration can be found in coastal, river, and swamp area. Communal baffled septic tank and anaerobic baffled reactor (ABR), that includes settled compartment followed by several baffled reactor to give higher contact time in order make higher efficiency then become a better treatment system option to be applied in coastal, river, and swamp area. Anaerobic upflow filter (AUF) which is ABR system but including anaerobic filter media became another option. In applying its construction, stakes are required as the foundation to handle water wave and unstable soil condition. By the evaluation in Djonoputro et al [5][6], problem in applying both septic tanks, ABR, and AUF system in coastal, river, and swamp area are due to basic maintenance (desludging) problem and higher cost of construction, also damaged by tidal wave.

2.1.1.2 Rotating Biological Contactor (RBC) System

Rotating biological contactor (RBC) is one of the aerobic wastewater treatment using aerobic fixed film system. RBC itself is the attachment media for aerobic microorganisms. RBC is commonly used as communal wastewater treatment system since it required less area with quite high efficiency than other biological treatment system. The problem to apply RBC in coastal, river, and swamp area is the placement, since it can’t be costructed as submerge system so will need special area in housing settlement. Because of the corrosive material used in RBC, it is also suggested not to be used in coastal area [6].

2.2 On-site Wastewater Treatment System

Besides decentralized wastewater infrastructure, some wastewater treatment system has been applied or piloted as on site treatment in coastal, river, and swamp area, including three concentric pipe-septic tank system, biofiltration, and floating garden/wetland system.

2.2.1.1 Three Concentric Pipe-Septic Tank System

Three concentric pipe-septic tank system was developed by Civil Engineering Laboratorium, Gajah Mada University to solve sanitation problem in river communities. The system developed known as Tripikon-S (Figure 2a), which is modified septic tank by using vertical flow and pipe as construction materials. This technology consider as low cost, easy to build, easy finance, and easy replicated wastewater treatment system. The material used is the PVC pipes with three different sizes and build concentrically each other as the place of anaerobic treatment process. In its development, the pipe filled by gravel as filter applied after effluent pipe to replace infiltration area requirement [13][11][16]. Tripikon-S system has been applied and piloted in many places, such as riverbank area in Yogyakarta, swamp area in Palembang, also swamp area in Pontianak, Kalimantan. Tripikon-S can remove 40% organic as BOD5 in septic pipe and 91.6% can be achived in gravel filter, with total BOD5 removal about 95% [13] but in evaluation by Djonoputro et al [6], Tripikon-S without gravel filter can achieve 75% BOD5 removal. Modification of Tripikon-S system was also constructed in Muhammadiyah University, Yogyakarta, with the name T-Pikon H (Figure 2d) which is use horizontal system to reduce the height of the treatment system, so the system can be applied in floating house [6]. But the use and further research about T-Pikon H is still rarely found. Durability of material used in both Tripikon-S and T-Pikon H, communities understanding and ability to operate, maintain, and modified while the condition change could be the application problem, since in Saraswati et al [13] from five system applied, only one that still work adequately after six years, two can not be operated since the flow condition change and replacement of system, two others have problem with material breakage.

2.2.1.2 Biofiltration System

Biofiltration process includes microorganisms attached to the contacted media and wastewater flowing through those materials to be treated. The biofiltration system made the possibility to facilitate both anaerobic and aerobic process in one system. This treatment system mainly is fabricates packed system using fiberglass materials and claimed that it can be used without any additional infiltration area. Biofiltration system has been tested in Tanjung Pagar, Banjarmasin, followed by floating wetland as complimentary system (Figure 2 b and c). Whole of the system called

BIOSANTER [15]. Biofiltration itself without floating garden could remove organic content for about 40-46%. Problem appear in the strength of materials. The use of biofiltration system in river effected by tidal wave required special materials (heavy duty) and the installation need to be construct with the supporting construction, unless it will always move and make the system easily broken. The pther effect of moved biofiltration while its directly connected into the containment system also make the problem in pipe connection and joint [5].

2.2.1.3 Floating Garden/ Wetland

Floating garden/ wetland is considered to be low-cost technology by adapting the wetland process with floating agent such as plastic bottle or PVC frame to make it float on the surface water. Local materials can be used as supporting material for floating garden/ wetland . The efficiency achieved of system is around 77% BOD5 removal (Figure 2c) [15] and can stabilized faeces with degradation of E.coli until about 88% CFU/100mL (Figure 2e) [3].

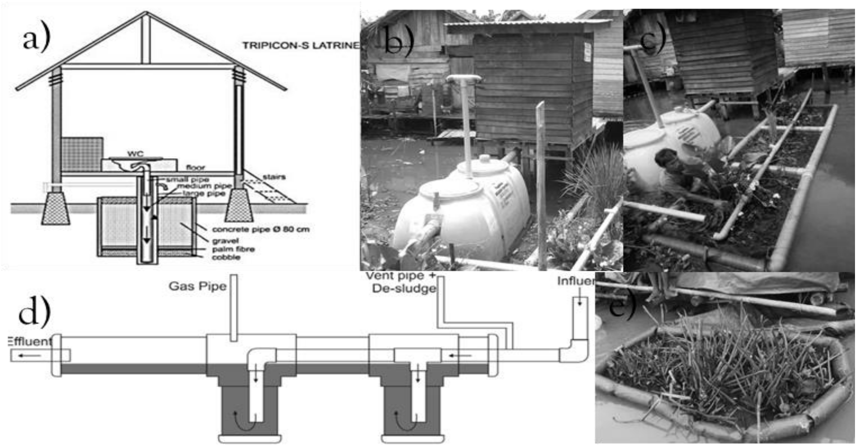

Figure 2 a) Tripikon-S [13], b) Biofiltration [15], c) Floating garden after biofiltration [15], d) T-Pikon H [6], e) Floating pods (wetland) [3]

3 Sustainable Wastewater Infrastructure Development for Floating Communities

A sustainable sanitation system can be achieved while systems fulfilled criteria of technically feasible, acceptable to the users, affordable and contribute to health improvement and environmental protection [9]. By highlighting the acceptable to the users factor, approach methods based on community based development were rapidly developed, known as demand responsive approach that developed by

World Bank with Participatory Hygiene and Sanitation Transformation (SARAR-PHAST) methodology to promote improved hygienic practices inthe community and encourages communities to take direct control of their water provision and sanitation-related services as the method foundation [7].
In the case of coastal, river, and swamp communities, this approach was applied by non-government organizations (NGOs) in floating communities in Tonle Sap Lake [2],[12],[8] and in coastal flooded zones, Philippines [14].

Engineers Without Borders (EWB) and Live & Learn (LL) have been collaborating on the Tonle Sap sanitation project since 2008 up until 2013 focus on Phat Sanday villages which consists of floating house communities. Several works including development of some pilot technologies achieved in this work. The communities were involved in concept and planning, design, and execution. Several focus group discussion and workshop has been hold in concept and planning stage, while community has been consulted throughout the design process and their feedback feed back into the design developed by the engineers in the design stage, and two members of the community has been employed on a part-time basis to help with execution of the project. Their assistance has enabled improved community feedback on the project and allowed to access local skills and labour during construction phase of the project [2].

3.1 Development of Toilet Design

First technology development that has been achived was development of floating toilet. This contained of Urine Diversion Desiccation (UDD) toilet . The latrine constructed using locally available materials. Latrines contained of three holes, a straight hole for faeces, and large pan area, and hole for wash-water. Additional of ash to increase pH of faeces collection are required in UDD toilet. Faeces were collected in 20L bucket while urine collection using storage container (jerry can), and wash-water directy discharge into water area [2]. Similar toilet design also been achieved by Lien Aid NGOs [12] in general communities for Tonle Sap lake, and Sayre et al [14] for flooded coastal communities with stilt house in Philippines by adapted ecosan toilet system.

Development of UDD toilet and ecosan toilet were equipped with the existence of waste management places as the place to put full bucket to be further stabilized. In Phat Sanday communities this waste management center was developed in one large flat floating construction and stabilization occured in the bucket. Urine management was developed by let the urine stabilized naturally in storage and use it for watering or direct discharge to surrounding water surface area.

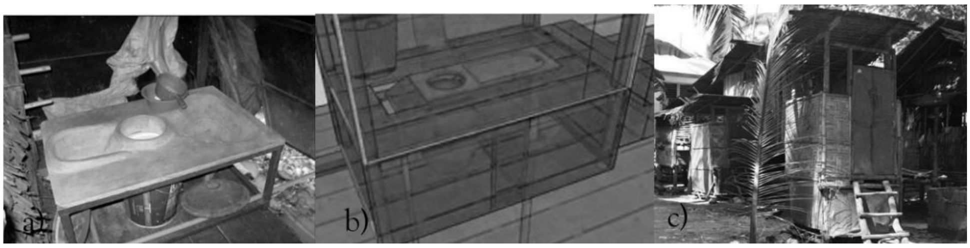

Figure 3 a) UDD toilet [2], b) general design UDD toilet [12], c) Ecosan toilet in coastal area [14]

Navarro [10] mention about the UDD toilet type or other kinds toilet that includes storage system and using nightsoil collection practise to other place for stabilization process is quite ideal to be applied in coastal and waterfront communities. But the main limitation in applying this system is depend on the acceptance of the communities about wastehandling as main requirement of operation and maintenance. To operate UDD toilet adequately, commitment of the communities is one of the main requrement since this wastewater system required exact procedure to operate the toilet and need to be maintain frequently by the communities itself.

3.2 Other Wastewater Treatment System Development

Work in Phat Sanday communities were continued to apply to other wastewater treatment system than has been considered also by the communities. First development is floating garden [2]. It was built with the consideration that the community lacks access to land for most of the year, which reduces opportunities for growing vegetables and supplementing diet of fish and rice. Floating garden was developed using the stabilized faeces from wastewater management station. The other wastewater treatment system developed is floating biodigester which is considered become the side source of energy for rural communities. This two wastewater treatment system development are still in prototype and testing stage [8].

4 Conclusions

Decentralized system can be applied well in coastal, river, and swamp area that consist of stilt settlements by applying simplified sewerage system using adequate support materials. Septic tank with several compartment or baffle, such as Anaerobic Baffled Reactor and Anaerobic Upflow Reactor considerably applicable as decentralized wastewater treatment system in coastal, river, and swamp area by considering stake foundation to prevent breakage due to waterlogged and unstable soil also tidal/ water wave. Rotating biological contactor is less applicable since it can't be constructed as submerged system and corrosive material that included in system. Three consentric pipe-septic tank system consider applicable as on site wastewater treatment, the efficiency of the system better enhance by adding gravel filter after the septic process to remove higher organic loasing. Biofiltration as compact fabricated system is also applicable by support foundation to prevent movement of system. Filter or floating garden better to be applied after biofiltration to reach adequate treatment efficiency. Both three consentric pipe-septic tank system and biofiltration required more durable material to be long-lasting used in area affected by tidal wave. Floating garden/ wetland considerably as potential wastewater treatment system applied in coastal, river, and swamp communities, as main or additional treatment system. Appropriate technology achieved by demand responsive analysis in the case of Phat Sanday floating communities in Cambodia come out with urine diversion dessication (UDD) toilet. UDD toilet consider as ideal system for coastal, river, and swamp communities, but the attention of communities in operating and maintain system are highly required especially the acceptance of wastehandling practise. Other potential wastewater treatment selected by demand responsive analysis are floating garden due to additional land for vegetation growth and floating biodigester due to its energy source potential.

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