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# Biofilter Evaluation in Settlements on Expanded Polystyrene Foam Floating Structure (Case Study: Tambak Lorok Semarang)

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## Abstract

The development of settlement in expanded polystyrene foam (EPS) floating structure must be supported by suitable waste water infrastructure. Capacity factor analysis has been developed as a way to increase waste water technology capacity. This research purpose is to evaluate and increase biofilter capacity factor to meet requirement when a floating settlement is built in Tambak Lorok Semarang. Capacity factor identified from literature, group discussion and inspection data. The community and environment analysis conducted in Tambak Lorok settlement (n = 250). The capacity factor divided into 4 main factors to to evaluate the biofilter. Biofilter must be certified and following its service capability to fulfill the services capacity factor. Sun protector, tidal wave protector, salt water or marine resistant coating and installed only in calm wave area is needed to fulfill its technical capacity factor. Biofilter as low cost technology can fulfill the environmental economy factor needed by the community which has a low willingness to pay (Rp. 1000 / month). The evaluation and model that built in Tambak Lorok can be uses as guidelines for designing biofilter in floating Settlement or building on EPS structure.

**Keywords:** biofilter, capacity factor, floating settlement, EPS

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## 1. Introduction

Floating structures already exist for a long time, but recently building on water has taken flight. Two reasons behind the increased interest in floating structures are the climate change and the lack of available building space. Because of the climate change the earth is warming up. By this warming of the earth sea levels are rising. this climate change results in more severe rainfall and higher river discharges on the one hand, and to longer periods of drought on the other. These phenomena result in water problematic, too much water at one moment and a water shortage at another moment. An answer

to these water problematic is water storage, which could be realized with more surface water. However, space for water conflicts with other interests. Already a shortage of land exists, building ground is scarce and costly and when creating space for water, there will be even less space for building. But, there is a solution to this problem, multiple space usage and more specific building on water [1]. A waste water system is needed when the floating structure is used by human and had toilets.

Tambak Lorok area in Semarang is one of four research study in expanded polystyrene (EPS) floating structure that conducted by join research in Research and Development Body of ministry public works. Tambak Lorok village emerged as a residential area that most people works as a fisherman. Approximately 2,600 fishermen live in the city of Semarang, almost 70% stay in the District North Semarang (1,800 fishermen), especially in Tambak Lorok. in Tambak Lorok Fishermen mostly traditional fishermen with simple equipment. In late 2016, a prototype of floating structure that has functioned as library and community hall builds in Tambak Lorok. The structure also includes one biofilter as domestic waste water treatment. Tambak Lorok community is a typical model of Indonesia coastal community that share same big problems in settlements. The problem of coastal area includes land needs, overlapping of utilization areas, pollution threats, degradation environment, and zoning utilization [2]. Semarang has large rate of land subsidence from 2013-2016 obtained value of 2,07 – 17,04 cm / year, and economic losses resulting from the flood disaster in Semarang city in the residential sector Rp. 545,985 billion and road infrastructure sector of Rp. 70,466 billion. [3].

Capacity factor analysis as model to choosing domestic onsite waste water system is developed by Guruminda [4]. There is 4 main capacity factor include services, social institution, technical, and environmental economy. The sub factor include service capacity, service completeness, pollution load, institution, human resource, design period, topography, distance with water level, water level, community financial capability, and energy availability. The model also can use as a tools to identify what are the technological limitations, so the engineer can do some technology engineering to increase the technology capacity [4].

Polymer bead foaming technology has expanded the market for plastic foams by broadening their applications because of the breakthrough in the production of low-density foamed components with complex geometrical structure. This review presents the recent advances in the processing, sintering behavior and properties of bead foam products, which possess unique advantages such as excellent impact resistance, energy absorption, insulation, heat resistance, and flotation. The key features such as the

mechanical properties of the commercially available bead foams, namely expanded polystyrene and expanded polypropylene (EPP)[5]. The EPS foam had widely use as construction component in Indonesia, several floating structure in lake or sea has been constructed by B Foam, one of leading EPS Foam Construction Component Manufacture in Indonesia. EPS foam has been extensively used in construction, packing materials, marine and automobile due to its appealing features. EPS foam is excellent thermal insulation properties, moisture resistance, effective buffering, good chemical resistance, the convenience of processing, light weight, and low cost. However, EPS foam is extremely flammable and difficult to be flame retarded. A cheap and effective flame retarded EPS system was developed by using a high silica content based fly ash (FA) synergistic with aluminum hydroxide (ATH) in the thermosetting phenolic resin (PF) coating layer [6]. In $700^{o}$ Celcius EPS foam can decompose completely [7].

Research institute of Human Settlements also functions as inspection body for domestic waste water in Indonesia following the 17020 standards. Generally, inspection involves direct determination of the conformity with specific or general requirements of unique – often complex or critical – products or small series of products, whereas product certification primarily involves indirect determination of the conformance of products manufactured in long series to specific requirements[8]. Based on the certification data in July 2018, only two bio filter household scale or non-communal manufacture that certified pass the standards and requirements. One of the requirements that must fulfill is the domestic waste water standard P.68/Menlhk-Setjen/2016. The two manufacture is PT. Rototama Berlian Plast which have certificates for biotaff capacity 5-6 people, and PT. Mega fiber Indonesia which have certificates for biotrop capacity 8-12 people. Both of the biotaff and biotrop is categorized as biofilter. Biofilter is one of biological treatment for domestic waste water. Based on inspection result, biotaff can reduce BOD from 265,3 mg/lt in the inlet to 19 mg/liter in the outlet.

Biological treatment is ecologically pure and less expensive compared to other methods. However, to find the optimal solutions of design and technological problems we have to clearly imagine mechanisms and stages of a complex biological process. There is three biological processes that can be represented, The first stage is characterized by a considerable withdrawal of pollutants during the time filling in wastewater. Second stage continues the process of adsorption of organic pollution and starts the mechanism of active oxidation of exoenzymes which gives off the activated sludge in the processing of biomass. This stage is characterized by a decrease in oxygen consumption and the water gradually accumulates dissolved oxygen. The third stage of endogenous power the oxidation is carried by and enzymes inside the cells [9]. Bio filtration is

an efficient biotechnological process also used for waste gas abatement in various industrial processes. It offers low operating and capital costs and produces minimal secondary waste streams [10].

## 2. Methodology

The research begin by identify capacity factor related in designing biofilter on floating EPS foam structure. Literature study, biofilter inspection data, and several group discussions conducted to determine possible capacity factor. Group discussion participant include researcher, engineer and expert from research institute of human settlements, research institute of water resource, research institute of technology implementation policy, research institute of road and bridge, and B-Foam an EPS foam manufacture company. After identify capacity factor, the community and environment assessment in 2015-2016 with proportional random sampling 250 respondents in case study Tambak Lorok area. Community assessment conducted using questioners and interview; the environment assessment conducted using observation and measurement of primary data. The community social an economics assessment conducted by research institute of technology implementation policy, the technical and environment assessment conducted by research institute of human settlement, and the physical construction of full scale floating structure with biofilter as waste water treatment managed by the research institute of road and bridge. The full scale project is used as feedback for the future planning and analysis. The data collected than been evaluated and analyzed using capacity factor analysis that has been developed by Guruminda [4]. The capacity factor divide into 4 main criteria and 12 sub criteria for evaluated and analyzed the community data and the technology. The final purpose of the evaluation is to give recommendation and guidelines when an onsite biofilter waste water system is needed to support floating settlements on EPS structure. The complete methodology flow chart can be seen in Figure 1.

## 3. Result and Discussion

### 3.1. General assessment

The majority of Tambak Lorok people work as fishermen (37%) and traders (28%). Monthly Income of population, higher than 3 million rupiah (15,1%), 2 – 3 million rupiah (19%), 1 – 2 million rupiah (37,7%) and below 1 million rupiah (13,9%). Due to the land

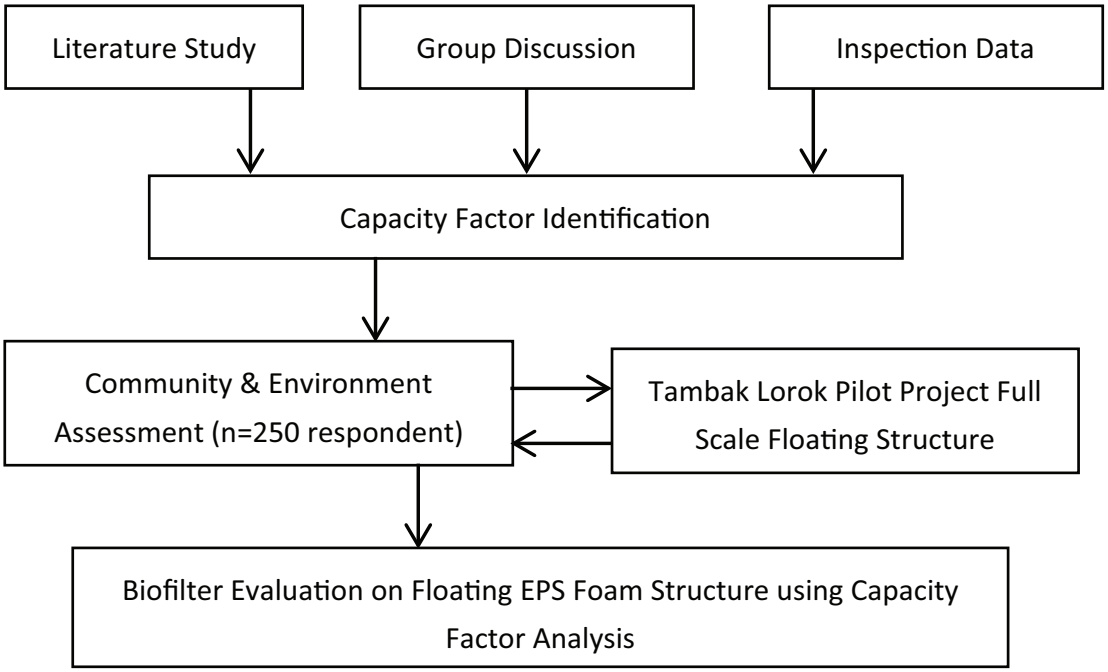


**Figure** 1: Methodology flow chart.

subsidence the community shares in average 20% of monthly expenditure to renovation and soil replacement. For household sanitation 30-60% of residents have latrines and septic tanks that also need to be renovated. The majority of population that stays near the sea chooses to throw the waste water direct to sea instead using septic tanks. The settlement concept from conventional structure to floating structure is necessary in the future to minimize cost impact of land subsidence. An onsite waste water treatment biofilter is necessary to prevent the sea polluted from human feces. A guideline must be built to prevent any technical issue that can make the infrastructure not working properly.

## 3.2. Full scale model floating biofilter in Tambak Lorok

A full scale model floating biofilter is built in Tambak Lorok in late 2016. These models function as library and community hall that have toilets and waste water system. There are several option to install biofilter on a floating EPS foam structure, the biofilter can be adjusted with some additional structure to the main structure, which in Tambak Lorok the biofilter is connected with metal structure, and second option the biofilter is floated with different EPS foam structure and connected to the toilet on main structure with flexible pipe. The second option is more expensive and harder in technique due to the secondary EPS foam floating structure must be anchored to the bottom sea. The main structure area of pontoon 13.8 x 9.8 x 1.2 m has buoyance 840 kg /$m^3$ that can hold up

to 136.322 kg of weight. The design and placing of upper structure, wall, construction and location of biofilter is very important to make the pontoon is stable and have same level. In the case of Tambak Lorok the pontoon is a little shallow due to pontoon and the building not symmetrical weight. The full Scale model can be seen in **Figure 2.**

**Figure** 2: Biofilter installed on side the main Tambak Lorok library floating structure.

Based on group discussion related in other four floating project, it is not recommended to have a biofilter in floating environment that have very high tidal wave, and possibility to be dumped off. A very high tidal wave risking the EPS foam to be cracking, and a reduced water level can make the floating structure dumped and cracked due to unbalanced weight force. Further calculations on the strength of fiber and EPS foam against ocean waves and some testing's must be conducted. A iron structure to hold the biofilter is very weak again salted water and corrosion, therefore an salt water resistant coating needed to prevent corrosion. Several months visual observation in Tambak Lorok, shows the plastic material in biofilter still in good shape. A further material testing is required to see the biofilter property change due to sun exposure, tidal wave, and saltwater. A sun cover is added in the top of biofilter in Tambak Lorok to prevent ultra violet (UV) exposure and increase the lifetime. To ensure there is no back flow to the biofilter, the effluent output biofilter must be placed higher than the sea water level; a 10 cm higher is designed in the floating project.

### 3.3. Services capacity factor analysis

Service capacity, service completeness, and pollution load for designing floating biofilter is based from the number of household and the uses of clean water in a household. The number of household data can be collected from the official demography data that regularly collected by the local government. The latest demography data show that in 970 poor households have dependents of ≤3 family is 595 household, dependent 4-7 is 358 House Hold, and dependent ≥8 is 16 House Hold. From the data the average household in Tambak Lorok is 4-5 people and only 1.65% that have more than 8 people in household. When tambak lorok become a floating settlement, A certified of 4-6 people capacity biofilter is recommended to ensure the biofilter fulfill the quality standard for domestic waste water system. One of certified biofilter is biotaff that produced by PT. Rototama Berlian Plast. The biofilter that build by Rototama is not need secondary treatment that is hardly to build and costly. Based the inspection procedure, a certified domestic waste water treatment biofilter must compliance with standard design of BOD removal, Hydraulic retention time, hydraulic loading, organic loading, and full fill the effluent domestic waste water standard.

### 3.4. Social institution capacity factor analysis

Tambak Lorok, have RT, RW and kelurahan as the official government institution. There is some joint business group in the area. Tambak Lorok is near Semarang city that have lots of engineer and expert that can operate advance waste water technology. Biofilter is a simple technology that is almost free maintenance and not needed any social institution and high of human resource capacity. Therefore, installing a single household biofilter will not have potential problem in social and institution capacity factor.

### 3.5. Technical capacity factor analysis

The common biofilter have technical capacity sub factor as design period, topography, distance with water level, water level depth [4]. The community wants the design period as long as possible. A common biofilter is installed in the ground and have little environmental exposure. Environmental Exposure such as to UV radiation, moisture, alkaline, and saline environments on Fiber-Reinforced Plastic (FRP) materials have effects to create Changes in strength, viscoelastic response polymer surface, and

thermal properties [11]. Exposure from UV can be prevented by covering biofilter with sun protector. Exposure from salt or sea water can be prevented by adding biofilter with salt water or marine resistant coating or paint. Exposure from the tidal wave force can be reduced by adding wave barrier in the biofilter. The floating biofilter is limited only in calm wave sea. Some area of Tambak Lorok near the coast have much calm wave than the area near the sea. This mean not all area in Tambak Lorok is recommended to use floating biofilter, only area with calm wave and fixed water depth is recommended.

## 3.6. Environment economy capacity factor analysis

Community's willingness to maintain infrastructure, facilities and infrastructure environment, can be shown through their willingness in paying for that service given (Willingness To Pay). When viewed on the desired contribution rate graph, average is at the number Rp. 1,000,- / month for each service. Tambak Lorok have good electricity grid, that majority of the area is covered by electricity from state electricity company. Biofilter as low cost technology is almost maintenance free and have need of sludge removal maintenance every 5-10 years. The sludge removal can be conducted by the community itself or sludge Removal Company. Floating biofilter will have maintenance cost lower than the common biofilter due to it is not affected by the land subsidence. A certified biofilter will have quality assurance meet the minimum 30 mg/liter BOD domestic waste effluent standar P.68/Menlhk-Setjen/2016.

## 3.7. Design criteria recommendation of floating biofilter with EPS Foam in Tambak Lorok settlement

Based on the capacity factor analysis, design criteria for biofilter in Tambak Lorok can be described. A biofilter must be certified and following its service capability to fulfill the services capacity factor criteria. A biotaff biofilter manufactured by Rototama berlian plast in one of recommended type of biofilter for use in Tambak Lorok settlement. The biofilter is recommended covered by sun protector, tidal wave protector, salt water or marine resistant coating and installed only in calm wave area to fulfill its technical capacity factor criteria. The floating biofilter is suitable with social institution and environment economy capacity factor that identified in Tambak Lorok communities.

Based on feedback in full scale prototype, several calculation and analysis must be included in planning, included a weight balance calculation or dynamic analysis that can be conducted by manual calculation or software instrument to ensure the balance of

pontoon, buoyance and weight analysis or static analysis based on Archimedes law, to ensure the pontoon not drowning. The positioning of effluent biofilter pipe is important to prevent back flow. Tidal wave strength analysis and flexural strength is required to ensure EPS pontoon or floating structure meet standard of stability requirement.

A biofilter capacity of 5 people have an weight around 50 kg. When it's on operation, 80-90% of the biofilter volume will be filled with water. The 10-20 % of the biofilter volume that not filled with water and the 10 cm extra height that not submerge in the water, make an extra weight that must be considered in the stability calculation. Since the EPS system is very weak with fire, an additional fire coating in biofilter can be considered. Due to the fresh water difficulty in coastal area, there is high possibility that community will flush the toilet with salt water or brackish water. When sea wave is higher than the biofilter effluent pipe, there is possibility of salt water intrusion into the biofilter. A further research on impact of salt water in biofilter efficiency is suggested. Some Research in using algae spirogyra for treatment in saline water [12], salt tolerant plant [13], and secondary constructed wetland with halophytic plants [1] can be considered to increase biofilter technical capacity again saline water.

## 4. Conclusion

Tambak Lorok community have low economic capacity factor that can use a low cost biofilter technology as an option. When biofilter is used on EPS floating structure, a technical modification and calculation is needed to increase its technical capacity factor. A certified bio filter with sun protector, tidal wave protector and water or marine resistant coating is recommended to use in residential building EPS floating structure. A metal connector to the main structure is recommended to maintain the stability of hydraulic flow. Biofilter weight must be considered in the pontoon stability calculation. The evaluation and the system that built in Tambak Lorok library floating structure can be used as guidelines and examples in designing onsite waste water system in floating building or settlements on EPS structure.

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