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Innovative Solutions for Sewage using Food Chain Reaction (FCR) in Indonesia

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Abstract. Sewage has been a concern of environmental activists in recent years, given the increase in waste generated from offices, hospitals, industry, and households. In this research the focus is to discuss waste generated by households. The sewage treatment system used in most residential areas in Indonesia is still conventional. Conventional sewage treatment systems can be a serious environmental problem if there is no proper design and planning. The method used in this research is a case study of Innovative Solutions for Sewage using Food Chain Reaction (FCR) in one city in Indonesia, Batam. The results of this research explained the development of food chain reactor (FCR) in Batam, reactor configuration, observations from operating sites, plant operating data, aesthetics.

1. Introduction

Sewage is water whose structure changes chemically and biologically because it contains various types of pollutants that affect the balance and environmental ecosystem. [1] Wastewater must be treated properly because it can cause environmental problems including unpleasant odors, degradation of ground and river water quality, and can cause various types of diseases [2] Most of this population is still waiting for an appropriate sanitation system, or aims to improve existing efficiency and improve environmental protection and resource recovery [3] Water is used for a number of purposes such as domestic supply, breeding of aquatic species, industrial supply, power generation, irrigation, navigation, animal supply, natural balance, preservation of water life, dilution and transportation of waste, and recreation. Disposal of liquid waste (collection, treatment and disposal) consists of disposal of waste outside the location and disposal of waste on site [4] In recent years, several new processing systems, known as distributed processing and reuse, have begun to be widely used in several countries, especially in the Netherlands, Germany and Scandinavia. [5] Residential ecological waste treatment is waste dispersion treatment with in situ waste collection, treatment and recycling, treatment is more likely to be based on a centralized and viable economy [6].

The development of a number of different technologies for wastewater treatment has been carried out. One popular one is the use of membrane technology as a phase separation step, such as Membrane Bio-Reactors (MBR). Bio-film technology in wastewater treatment has been used since the 1970s, as a cellular biofilm reactor system (MBBR) or integrated fixed film activated sludge system (IFAS). The biofilm technology discussed in this research is known as the Food Chain Reactor (FCR). This process combines the use of natural plants, such as bulrushes and swamp weeds with IFAS-based processes. Greenhouse design is suitable for accommodating the process because it produces an aesthetic treatment system in a tropical climate [7].

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Several research on wastewater have been discussed in Indonesia such as Planning for Domestic Wastewater Treatment Plants in Rungkut District, Surabaya City. The technology used in this planning is Anaerobic Baffled Reactor (ABR). The planned ABR is designed to be able to serve 100 households with a total length 15.5m, width 2.3 m, and height 2.6 m. The cost required for the construction of ABR is IDR 159,853,000 [8]. Other research Wastewater Treatment Technology with Dyed Biofilm Process described using anaerobic and aerobic submerged biofilter in the total time of one day can reduce the concentration of BOD, COD and Suspended Solids (SS) by more than 90% [9]. Ages Service Installation of Semanggi Wastewater Treatment (IPAL) Based on Performance in Main Reactors explained the main reactor performance shows that the efficiency is low. Development efforts that can be carried out for the main reactor of IPAL-S to remain able to serve residents and customers in the next 20 years are to shorten the time of wastewater in the aeration tank, increase the pump power in the equalization tank so that it can flow according to alternative planning, and replace the pump unit diffusion is in the aeration tank [10].

Batam also has wastewater treatment problems. Emergency problems of Batam City domestic wastewater treatment are divided into two aspects such as technical and non-technical aspects. The technical aspects of Batam City's domestic wastewater management problems are related to inadequate infrastructure (facilities and infrastructure) that can cause pollution. while the non-technical aspects include issues related to funding (budget), management institutions, community participation and the absence of relevant local regulations. The development of wastewater facilities and infrastructure in Batam City considers several local characteristics, both service level, type and number of services. Criteria used in determining the priority stages of sanitation development in Batam City include data on current and future conditions, central business district (CBD) area based on RTRW, priorities based on risk levels 3 and 4 and groundwater conditions, service level sanitation (wastewater), population density, and regional classification (urban or rural).

2. Methodology

In this research the method used is a case study approach, taking into account the focus of research is to answer the question "how" and "why". Case studies focus on specific cases in depth to identify social relations, processes and categories to be identified. Research Case studies consist of detailed investigations, often data collected over periods of time, specific phenomena and contexts whose purpose is to provide context analysis and processes related to theoretical problems that are happening. [11]. The case study design consists of five components such as research questions, prepositions if, unit analysis, logic that links data with analysis, criteria for interpretation findings. The fourth and fifth components are of concern because they relate to planning data analysis. This analysis consists of examining, classifying, tabulating, testing, or rearranging two quantitative and qualitative evidence to deal with the initial propositions of the study [12]. Data collection conducted in this research refers to indicators, such as by collecting related data contained in the domain of food chain reactor (FCR), reactor configuration, observations from operating sites, plant operating data, aesthetics through documents, archival records, direct observations, and physical devices.

Domestic wastewater management technology in large urban areas implemented in Indonesia is decentralized wastewater treatment system (DEWATS) through the sanimas program (sanitation based Public) [13]. The main several purpose of the construction of a wastewater treatment plant in Batam is to protect the reservoir from domestic waste and also the quality of coastal waters, maintain raw water quality, improve the aesthetics of the environment so that it can invite investment from tourism because of the environment, drainage and clean waters, and wastewater treatment can produce fertilizer to green the city of Batam. This study aims to explain the development of food chain reactor (FCR) based on reactor configuration, observations from operating sites, plant operating data, aesthetics.

3. Results and Discussion

3.1. Development of Food Chain Reactor (FCR) in Batam

Food Chain Reactor (FCR) is the process of combining the use of natural plants such as bulrushes, marsh weeds with Integrated Fixed film Activated Sludge (IFAS) based processes. Greenhouses are usually used to accommodate the process, resulting in an aesthetic maintenance system. For warmer climates, shaded structures are used [14]. Design changes in wastewater treatment plant technology in Batam that previously used the Conventional Active Sludge (CAS) system to the Organica Food Chain Reactor (FCR) valid from 2014 to 2021. The parties involved in this project are Batam Indonesia Free Zone Authority (BIFZA) or BP Batam as an owner, Sunjin Eng & Arch, and Hansol EME. The scope of work consists of wastewater management installation (capacity of 20,000 m3/sec), monitoring and automation system, 5 pumping stations, 114.35 km of disposal lines, composting and utility facilities, and commissioning and training.

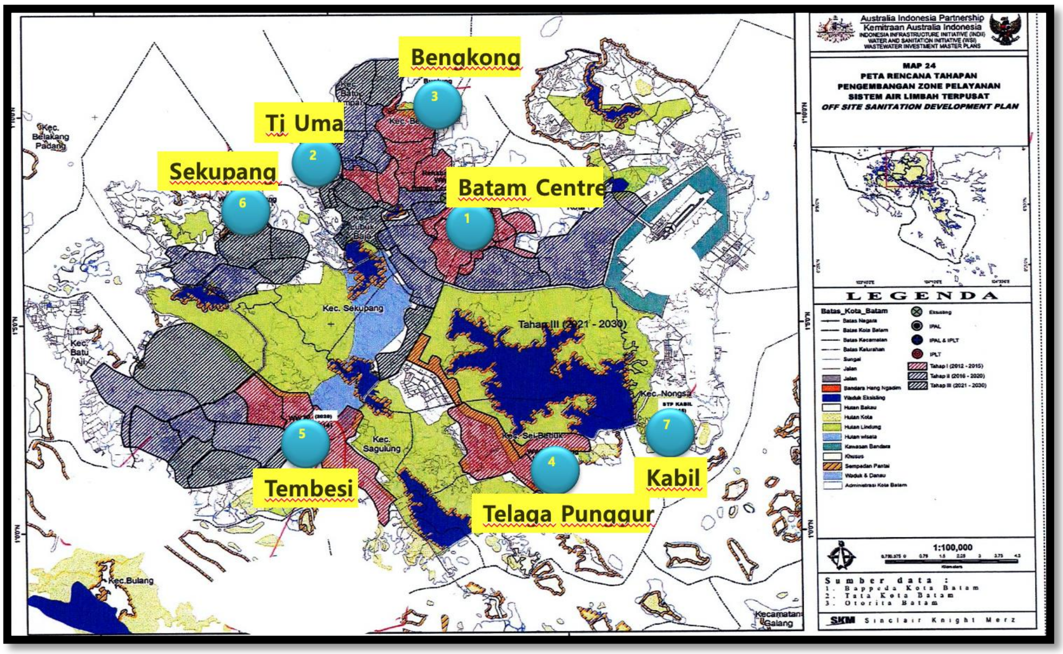

Figure 1. The Masterplan of Sewerage System in Batam
Source: Hansol EME

Wastewater treatment plants were built at 7 locations in Batam which began at the Batam Center. Fieldwork has begun in 2017, physical progress in the field up to March 2019 is 36%. The main pipe installation has been installed along 27.68 m (66% of the planned 41.82 m) and secondary pipes have been installed along 48.77 m (67.26% of the planned 72.52 m), covering 20 points of residential area. The pipeline connection to residential area is still not workable, because it cannot be done in parallel with the main and secondary pipe installations, planned to begin April 2019. The construction of wastewater treatment plants has reached 17%, the final target in 2019 is 80%. Construction of sewer pipe x3 has reached 49%, construction of Pump Station x5 has reached 45% and the loan agreement has been extended to 30 June 2021 for anticipating delays in construction work. The building construction of wastewater treatment plant in Batam Centre reached 95% in July 2020.


Figure 2. WWTP Batam Centre in July 2020
Source: Hansol EME

3.2. Reactor Configuration

The Food Chain Reactor (FCR) process is configured for a multi-stage cascade process. Biological processes take place in a series of cascade reactors, with standard initial treatment, and phase separation (through Organica Disc Filter or Secondary Clarification) and final instigation at the end (if necessary). When water flows from one reactor zone to another, various ecologists will grow and adapt to these conditions at each stage. This configuration causes a "food chain effect" because higher organisms are predators of simpler organisms. The result is increased efficiency and durability of disposal, using less energy and sludge.

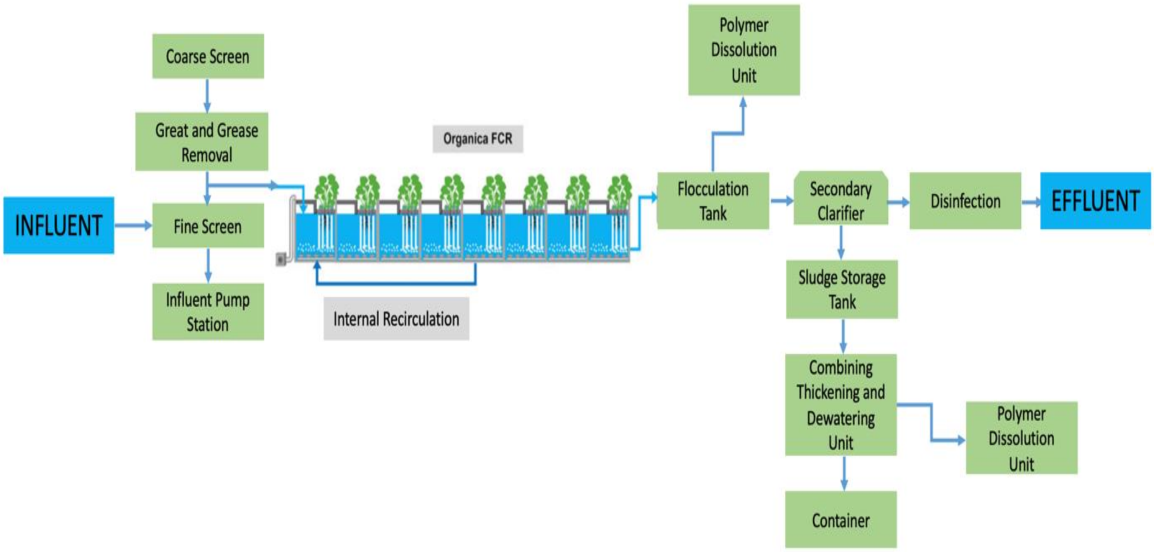

Figure 3. FCR Process Scheme in Batam

3.3. Observations from Operating Sites

The FCR multi-stage cascade provides a number of operational benefits. The control process in the FCR system depends on several parameters such as the flow rate of wastewater, incoming pH, COD, BOD, ammonia, density and types of microorganisms and species, and DO levels at each phase of the FCR reactor, especially in reactors 3 and 5 [15].

Table 1. Annual Average Performance Data Design FCR in Batam

Influent Wastewater			Effluent water requirements		
Parameter Name	Average	Unit	Parameter Name	Average	Unit
COD	230	mg/L	COD	<40	mg/L
BOD_5	190	mg/L	BOD_5	<20	mg/L
TSS	210	mg/L	TSS	<20	mg/L
TKN	45	mg/L	TKN	<40	mg/L
TP	12	mg/L	TP	<15	mg/L
NH_4^+-N	28	mg/L			
Oil & Grease	10	mg/L			

Source: Organica Company

Significant advantages of the FCR system are Biomass growth in six reactors (two anoxic zone and four aerobic zone) independently, Biomass diversity increases with natural plant interactions, high sludge retention time (SRT), as a result of predator and higher SRT effects, lower biomass yields, low Mixed Liquor Suspended Solids (MLSS) causes the alpha factor in the aeration system to increase, the less odor aerosol, Return Activated Sludge (RAS) system is not required [16] [17]. The concentration of suspended solids in FCR reactor is 200-300 mg/L therefore the oxygen transfer efficiency (alpha-factor) in the Organica FCR reactor is extremely high (0.90 - 0.95). Relative energy consumption in Organica FCR compared to other technologies in the graphic below:

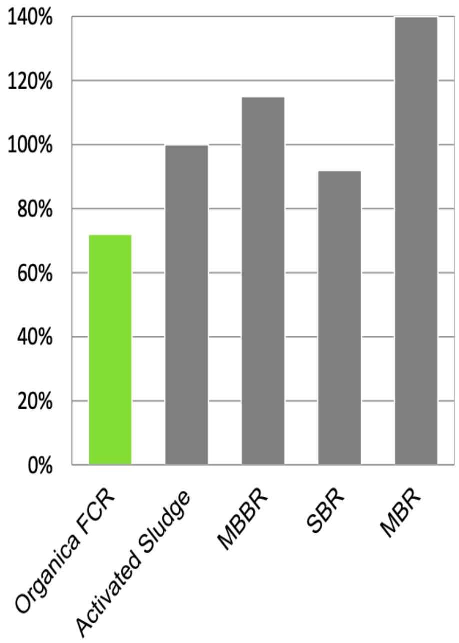

Figure 4. Relative energy consumption
Source: Organica Company

3.4. Plant Operating Data

This system is basically the same for other wastewater treatment technologies. The difference consists of adding a few plants to the tank so that the roots create a home for bacteria and the complete food chain is in the reactor. As a natural root that does not take too long to drop from the tank, the creator invented an artificial root system. With this discovery, bacterial population density increased by four. That means better plant size efficiency can be reduced [18]. There are six FCRs for plant growth space with a volume of 278 m^2 and a height of 5 m, a plant rack size of 13.3 m^2 with an average capacity of

10,000 m^3/d. This process that distinguishes conventional wastewater treatment in Batam City. Wastewater treatment flow with FCR is household wastewater that flows through pipes installed directly into houses then accommodated and treated at the pumping station hence waste treated in a WWTP building. The end result of the waste can be processed into fertilizer or thrown into the sea in clean conditions.

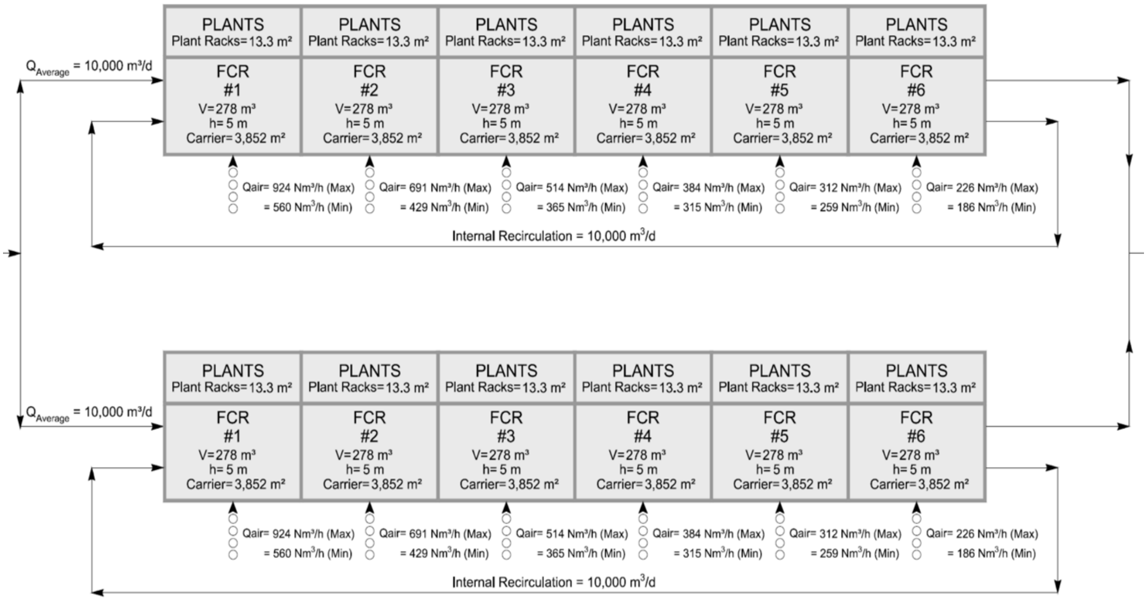

Figure 5. Internal Recycling in Batam
Source: Organica Company

Aquatic plant data operating systems are important from a technological perspective in providing ideal fixed film substrates, factories uniquely enhance aesthetics with a little extra care, patented woven fabric media provides a place for organisms to flourish, root systems provide ideal habitats for organisms to live. Once formed in the root zone, species develop not only in the waste stream, but also benefit from a symbiotic relation with plant roots. This is the basic unit of organic solution. The condition is to increase the consumption of contaminants by thousands of species of organisms that live in the root zone and engineering media. Fibrous aeration is the traditional fine bubble aeration used for the aerobic phase.

3.5. Aesthetics
An attractive architectural solution that allows seamless integration into urban landscapes that greatly facilitates water reuse. Various capacities can be applied depending on the needs and available footprint. The wastewater treatment in Batam City is located near the sea so that the WWTP building can be a good view with buildings for the city landscape. The Organica treatment plant is a sustainable solution for sewerage in urban areas with increasingly limited land. FCR can be placed inside a greenhouse structure, or equipped with a protective structure. The selection is generally based on the minimum temperature. The FCR design structure in Batam is based on a minimum temperature of 26 degrees Celsius with a maximum temperature of 30 degrees Celsius with a location around the sea. The end result is a wastewater treatment plant that resembles a garden or greenhouse facility, with low odor emissions and a very aesthetic appearance.

Figure 6. WWTP Design in Batam
Source: Hansol EME

4. Conclusion
The wastewater treatment plant using bio-film technology provides a number of advantages associated with footprints and biomass inventory. The combination of natural plants and IFAS results in an improved process to a facility that saves operational costs. Natural plants provide nutrients, organic acids, and enzymes that create diverse biology in plant roots and IFAS modules. Saving energy demand and sludge removal are two other major benefits of this process. Broader and more complex ecology is able to break down various pollutants that emerge such as drugs and other xenobiotics with higher efficiency resulting in cleaner water. Complex life systems collaboration, small footprints, proximity to wastewater sources all contribute to significant energy savings. Smart process control enables flexible and highly automated low-cost operations. The plant is designed for trouble-free maintenance and management. Some of the advantages of the FCR described previously are very suitable to be applied in Indonesia to deal with and manage wastewater, especially household waste.

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