A review: Domestic wastewater management system in Indonesia

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Abstract. Increasing access to proper sanitation in urban areas in Indonesia has not been accompanied by the availability of a domestic wastewater disposal system that is safe for the environment. The existing domestic wastewater management system is felt to be unable to prevent pollution. Several studies have reported contamination of water bodies in several cities originating from domestic wastewater that has not been appropriately managed. This paper aims to discuss the developments of the domestic wastewater management system in Indonesia by exploring the current conditions and challenges. The service capacity and application of domestic wastewater treatment technology at wastewater treatment plants already operating in Indonesia will be discussed to find out the existing comparisons. Several regulations related to the domestic wastewater management system also be reviewed to find out the policy direction of pollution prevention efforts. From the conditions exposed, it is necessary to evaluate and adjust the existing concepts to the progress of development in the field. More significant effort is needed to find solutions for problems and realize the domestic wastewater management system's implementation to achieve the desired goals.

1. Introduction
The population that continues to escalate creates increasing pressure on the environment [1,2]. Pollutants cause this either in the form of solid waste or domestic wastewater that comes from people's daily activities. Unlike solid waste from households that have generally been treated, domestic wastewater will mostly end up in watercourses leading to rivers or polluting shallow groundwater due to untreated discharges [3]. Although access to proper sanitation in Indonesia's urban areas reached around 73 percent in 2010, this is only based on access to basic sanitation, which does not guarantee the availability of a safe collection and disposal system for domestic wastewater and faeces. Based on existing data, only about one percent of wastewater and four percent of faecal sludge have been collected and treated safely [4].

Organic load from domestic wastewater in big cities in Indonesia is the biggest contributor to river pollution. In the Jakarta area, a load of organic pollutants from domestic wastewater, which contributes to polluting water, is around 70 percent. Those are from office and commercial areas reaching 14 percent. In comparison, industrial wastewater only amounts to around 15 percent [5].
Based on data from the Citarum coordination and management unit program in 2010, domestic wastewater originating from households, offices, the commercials sector, and other public facilities is the largest pollutant of the Citarum River. Organic matter produced by domestic wastewater can reach 60 percent. The remaining 30% comes from industrial wastewater, and 10 percent is wastewater from agriculture and livestock [6]. The large number of irregular urban settlements with sanitation facilities that are not well planned has resulted in pollution of community-owned well water so that it no longer meets the quality standards for consumption. The on-site wastewater management system, which uses a septic tank that is not waterproof and does not meet the requirements, causes seepage to the dug well to cause pollution [7,8].

The problem of domestic wastewater has always been side-lined and has not been prioritized by the government or society. This does not mean that there is no attention or treatment at all, but its management can still be categorized as something that is carried out in an inadequate achievement [9]. Tackling pollution from domestic wastewater in urban areas should have reached the stage to get greater attention because of its increasing volume, while the ability to purify and treat domestic wastewater naturally is increasingly limited [10]. Therefore, efficient management of domestic wastewater from the collection, treatment, to disposal stages with the least possible environmental impact is necessary [11].

2. Regulations related to domestic wastewater

There are several regulations related to domestic wastewater in Indonesia which function to prevent pollution to water body. The regulation also aims to regulate the implementation of activities related to domestic wastewater in the field. According to article 20 paragraph 3 of Law No.32 of 2009 on environmental protection and management, it is stated that everyone is allowed to dispose of waste into environmental media provided that the waste water has met environmental quality standards that have been set and have received a permit from the authorities [12]. In Government Regulation No. 38 of 2011 concerning rivers, in article 20 paragraph 1 letter (b), states that one of the ways to prevent river water pollution is by monitoring the waste water that enters the river [13].

Based on Government Regulation No. 82 of 2001 concerning water quality management and water pollution control, Article 8 regulates the classification of water quality which is divided into four classes according to the designation of the river. The quality standard criteria of each class become a reference in identifying and preventing pollution that occurs in surface water [14]. For reference, in recognizing and preventing pollution that occurs in shallow groundwater (dug wells), using a different regulation, namely the Minister of Health Regulation No. 32 of 2017 concerning environmental health quality standards and water health requirements for hygiene sanitation, swimming pools, solus per aqua, and public baths. In this regulation, the quality standard used is the part of the water media for sanitation hygiene purposes including physical, biological, and chemical parameters which can be mandatory parameters and additional parameters. The water media for sanitation hygiene purposes includes the use in personal hygiene maintenance such as bathing and toothbrushes, as well as for washing foodstuffs, eating utensils and clothes. In addition, water for sanitation hygiene purposes can be used as raw material for drinking water [15].

| Parameter          | Unit     | Maximum content |
|--------------------|----------|-----------------|
| pH                 |          | 6-9             |
| BOD                | mg/l     | 30              |
| COD                | mg/l     | 100             |
| TSS                | mg/l     | 30              |
| Oil and grease     | mg/l     | 5               |
| Ammonia            | mg/l     | 10              |
| Total coliform     | Amount/100 ml | 3000  |
| Debit              | l/cap/day| 100             |

Table 1. Domestic wastewater quality standards [16]
Flats, lodging, dormitories, health services, educational institutions, offices, commerce, markets, restaurants, meeting halls, recreation arenas, settlements, industry, regional WWTP, settlements WWTP, urban scale WWTP, ports, airports, train stations, terminals, and penitentiary.

The obligation to conduct domestic wastewater management in Indonesia nationally refers to the Regulation of the Minister of Environment and Forestry No.68 of 2016 concerning the quality standards of domestic wastewater. In this regulation which is the implementing regulation of Law No.32 of 2009, it is stated that every business and / or activity that produces domestic wastewater must treat the domestic wastewater it produces before discharging it into the environment. The ministerial regulation also regulates the quality standard value or the limit level or amount of pollutant elements that are allowed to exist in domestic wastewater to be discharged into a water body [16]. The domestic wastewater quality standards can be seen in Table 1.

In the case that the implementation instructions in the field are contained in the Regulation of the Minister of Public Works and Public Housing No. 4 of 2017 concerning the implementation of a domestic wastewater management system. According to the Ministerial Regulation, the type of domestic wastewater management system to be selected in an area must at least be based on factors including population density, groundwater level, slope, soil permeability, and financing capability [17].

3. The Domestic wastewater management system concept

Based on the Regulation of the Minister of Public Works and Public Housing No. 4 of 2017, the Domestic wastewater management system (DWMS) based on the processing site consists of two types of management systems, namely on-site/decentralized system and off-site/centralized system. On-site/decentralized system is a facility and infrastructure for domestic wastewater management where the collection, treatment and disposal of domestic wastewater is carried out at the source (on-site) location. In this system, wastewater disposal is disposed of and treated directly on the spot without going through first distribution.

Based on its capacity, the on-site/decentralized system consists of an individual scale and a communal scale. The on-site/decentralized system for an individual scale is only for one residential unit. The generated domestic wastewater is usually treated using a septic tank and well/infiltration area. The sludge in the septic tank will later be transported by a sludge transporting vehicle on a regular basis every two years or more, and processed at the Faecal Sludge Treatment Plant (FSTP) [17]. For a communal scale, the on-site/decentralized system built is intended for two to ten residential units and / or buildings and / or bathing, washing and toilet facilities (MCK) using a sewerage system. This system is implemented to handle domestic wastewater in areas where it is not possible for residents to build individual septic tanks in their homes. The effluent from the treatment plant can be channelled into infiltration wells or can also be directly discharged into water body (rivers) when the quality standards meet the standards required by applicable regulations [18].

If designed and managed according to standards, an on-site/decentralized system can actually provide a clean and comfortable service as a sewerage system. In an on-site/decentralized system, sewage and domestic wastewater are collected and treated on private property using technology such as a septic tank. In addition, there are small communal facilities, such as a communal septic tank (for 5 to 10 families). Other communal facilities, such as MCK and MCK plus, their own (local) septic tank can also be considered as an on-site/decentralized system on a communal scale [19]. The management system on a communal scale on-site system must pay attention to the strong will (willingness) and ability of the users to operate their own system (user-friendliness) in order to comply with the existing regulations [20].

Off-site/centralized system is a sewerage system for channelling household wastewater that is channelled out of the yard of each house to the sewage collection channel, and then channelled centrally through the piping network to the Wastewater treatment plant (WWTP) before being discharged to the receiving water body [21]. Off-site/centralized systems are generally managed by local government or official private bodies, which collect, distribute, and process black water and gray water at once. This system is considered to have been applied to cities with population densities
greater than 300 capita/hectare. In fact, in accordance with the development and population growth that continues to increase, urban areas are felt to be no longer suitable for implementing the on-site/decentralized system [19]. Based on the scope of service, the off-site/centralized system consists of three types of capacity, namely urban scale, settlement scale, and certain area scale. Coverage for urban scale services is intended for urban and/or regional coverage with a minimum service of 20,000 (twenty thousand) peoples. Settlement scale services are designated for the scope of settlements with services from 50 (fifty) to 20,000 (twenty thousand) peoples. Meanwhile, the scope of certain area scale services is devoted to services in commercial areas and apartment areas [17].

Settlement scale off site system is an “intermediate system” from individual or communal on-site system to an urban scale off site system. This system must be integrated in a comprehensive sanitation plan, where when the urban scale off site system (centralized system) has been built, the individual scale and communal scale systems will be connected to the urban pipeline network system, to be processed in the centralized-WWTP. The function of a settlement scale sanitation system can be maintained if it is technically and economically unsuitable to be integrated with the urban system. This system can be maintained if it is located in an area that is relatively far from the urban pipeline system, or is topographically under the urban system, so that although pumping can be used, it is not economically feasible [22].

4. The Development of domestic wastewater management systems in Indonesia

The history of centralized wastewater management system in the world began when countries in Europe carried out the construction of sewerage systems on a large scale in the 1850’s [23]. Edwin Chadwick was one of the figures who initiated the use of a sewerage system in the form of a piping system. He and a few of the Engineers who supported him, introduced the Small-Bore Sewer as a novelty in sewerage systems in England [24]. Chadwick is also known as someone who put forward the concept of separated sewer in the mid-19th century through the expression “rain will flow into rivers and domestic wastewater will flow to the ground” which has become a very influential concept until today [25].

In America, the method of collecting public wastewater began to be replaced by sewerage system technology in the late nineteenth and early twentieth centuries. Previously, most urban communities in America used cesspoll or pit latrine as a facility for collecting domestic wastewater. The facility often leaks and pollutes the surrounding soil, and requires periodic emptying or requires a new hole to be dug if it is full [26]. Not too different from what happened in Europe and America, the sewerage system in Japan was built in 1884 in the Kanda area, Tokyo. Initially, this system only aimed to drain rainwater which would be discharged directly into the river, without being accompanied by a function to drain domestic wastewater. It was only in 1913 that Tokyo began planning a sewer system for wastewater complete with domestic wastewater treatment facilities. Until 1922, the Mikawashima domestic-WWTP finally started to operate treating domestic wastewater by using Trickling Filter technology [27].

Historically, the development of domestic wastewater management in Indonesia began in 1969 through the Kampong improvement program (KIP) in Jakarta, which was the first urban slum settlement sanitation quality improvement project in the world. In 1974, the World Bank provided a soft loan scheme to the Indonesian government, which then responded by establishing KIP as a national policy in 1979. The government focused KIP activities on developing local sanitation facilities (on-site system) and rehabilitating centralized systems (off-site system). Through the Integrated urban infrastructure development program (UIDP), a number of off-site system sanitation facility pilot projects such as the Sewerage treatment plant (IPLT) or sewerage systems have begun to be built in several cities such as Medan, Prapat, Jakarta, Bandung, Cirebon, Yogyakarta, Denpasar, Banjarmasin and Balikpapan [28].

After the reformation, the development of efforts to improve sanitation facilities, especially wastewater in Indonesia, began to be carried out again, to be precise since 2000 when Bappenas carried out several initiatives to reform policies related to the water supply and sanitation sector. These reforms are in line with decentralization, which delegates responsibility for sanitation to local governments in each region. Economically, the impact of poor sanitation in Indonesia is important,
where from the results of a study conducted by the World Bank, it was found that Indonesia was estimated to have lost Rp. 56 trillion (USD 6.3 billion) in 2007 due to poor hygiene and sanitation, or the equivalent of around 2.3 percent of Indonesia's Gross Domestic Product (GDP) [4].

![Diagram](image)

**Figure 1.** The history of the sanitation sector development in Indonesia [4]

Although there is increasing awareness of sanitation issues, the service area of domestic wastewater management in Indonesia is still very low. As an illustration, between 1970 and 2000, the Government of Indonesia spent only around IDR 200 / capita / year on the sanitation sector (USD 0.021 / person / year at the current exchange rate). Prior to 1980, only four cities had centralized sewerage system, which were actually facilities that were already under construction during the Dutch colonial period. As of 2012, the number of cities that have been served by sewerage facilities for centralized domestic wastewater systems is still 12 cities. Of these (twelve cities), most of the services also only serve a small part of the area of these cities, and the processing capacity available at the centralized-WWTP, is still not used optimally (less than 70 percent). In Jakarta, as the nation's capital and largest city in Indonesia, in 2012 it only had off-site system services for about two percent of the total population. In 2019, the coverage of increased services would be 12.37 percent with a focus on expanding the connection area to commercial areas such as hotels, apartments, and offices in the central business district. Based on the data, only the cities of Balikpapan and Yogyakarta can maximize the use of processing from their WWTPs to reach more than 90 percent [4,29,30].

Problems related to centralized system sanitation facilities that already exist in 12 cities arise from a mismatch between demand and supply. In 2012, the number of house connections that had been installed was still less than 200,000 HC with the rate of added connections which was still very low. Well-functioning centralized-WWTP accounts for less than 50 percent and sludge collection efficiency in some cities is only 30 percent. Regarding sustainability, only the sewerage systems in Bandung and Jakarta can operate with sufficient income to meet the operational and maintenance costs of the existing systems, while other cities still need subsidies from the government [4].

Domestic wastewater management through the Decentralized wastewater treatment system (DEWATS) or known as the communal-WWTP, is considered well accepted by the community. This
is proven by the number of DEWATS that have been built in Indonesia. However, many DEWATS facilities are not functioning properly due to reduced utilization of the facilities after several years of operation. The processing system in the communal-WWTP in DEWATS is not able to produce the quality of effluent that is up to the standard, coupled with the lack of capacity of managers from the community to handle technical problems. Implementation of community support for DEWATS also often stops at the planning and implementation stages of development. Community participation will decrease or even no longer exist at the operational and maintenance stages, so that the sustainability of the DEWATS and communal-WWTP programs often experiences a number of problems. The sustainability of DEWATS requires special attention because the revenue generated from user or customer charges is usually insufficient to pay for various operational and maintenance costs. Furthermore, DEWATS cannot meet the enormous need to treat more domestic wastewater and sludge [4,31].

5. The Domestic wastewater treatment technology in Indonesia

The choice of domestic wastewater treatment technology really depends on the characteristics of the domestic wastewater to be treated. Many failures occur in the operation of WWTP due to errors in the application of the technology used. Domestic wastewater treatment in general aims to reduce organic matter, suspended solids, pathogens and phosphates [32], so that they do not pollute water body and have a negative impact on public health. Wastewater treatment can be broadly divided into solid-liquid separation, colloidal compound separation, and dissolved pollutant compound removal. Meanwhile, the type of process wastewater treatment can be grouped into physical processing, chemical processing, physio-chemical processing, and biological processing [33].

The wastewater treatment is an effort to remove existing pollutants to meet requirement of quality standard values as of the Regulation of the Minister of Environment and Forestry No.68 of 2016. In accordance with existing culture in Indonesia, most of the people are still reluctant and feel uncomfortable to consume wastewater origin as clean water. Regardless, the wastewater has been processed which meet quality standards requirement was usually discharged directly to the receiving water body. Relate to that fact, wastewater treatment technology used generally prioritizes process at the primary treatment and secondary treatment stages. Meanwhile, tertiary treatment and advanced treatment is carried out if the existing treatment is not meeting yet the quality standard requirements, or is intended to recycle wastewater for clean water supply needs [19,33]. The complete flow of wastewater treatment process at centralized-WWTP can be seen in Figure 2.

| City      | Systems / technology applied                                      | Performance (m³/day) | Capacity used (m³/day) | House connections (HC) |
|-----------|------------------------------------------------------------------|----------------------|------------------------|------------------------|
| Medan     | Upflow Anaerobic Sludge Blanket (UASB)                           | 10,000               | 5,650 (56%)            | 12,370                 |
| Prapat    | Aerated Lagoon                                                   | 2,000                | 115 (6%)               | 253                    |
| DKI Jakarta | Moving Bed Biofilm Reaktor (MBBR)                           | 42,000               | 5,195 (12.37%)         | 2,703                  |
| Bandung   | Anaerobic, Facultative and Maturation Pond                        | 243,000 Installed 80,835 | 49,769 (20%)          | 99,538                 |
| Cirebon   | Anaerobic, Facultative and Maturation Pond                        | 24,566 Installed 20,547 | 9,667 (39%)           | 13,165, waiting list 14,585 |
| Yogyakarta | Aerated Lagoon                                                   | 15,500               | 14,260 (92%)           | 23,500                 |
| Surakarta | Aerobic, Facultative and Biofilter                               | 9,504 m³/day         | 6,325 (67%)           | 11,978                 |
| Bali      | Aerated Lagoon                                                   | 51,000 m³/day        | 35,000 (68.6%)        | 10,290, with target 15,000 |
| Batam     | Oxidation Ditch                                                  | 2,852 m³/day        | 150 (5%)               | 300                    |
| Banjarmasin | Rotating Biological Contactor (RBC)                           | 12,000 m³/day        | 3,480 (29%)           | 7,049                  |
| Balikpapan | Extended Aeration                                               | 800 m³/day          | 800 (100%)            | 1,452                  |
| Tangerang | Oxidation Ditch                                                  | 2,700 m³/day        | 600 (22%)             | 1,200                  |
There are several options of technology systems for secondary domestic wastewater which is frequently chosen to be applied to WWTP in Indonesia include:

1. Biofilter/Anaerobic Filter is a biofilm system installed in a watertight tub made of concrete, fiberglass, PVC or plastic which functioned to hold and treat wastewater. In this tub or tank, the microbial culture process either anaerobic or combination which attached to a filter made from porous material. This filter aim to reduce non-settleable dissolved solids and organic matter. Wastewater usually flows through the filter from the bottom up (up-flow), contact with the biomass in the filter and then anaerobic degradation occurs [19,35]. Anaerobic filter have several advantages include minimal land requirement, can be used for household scale, relatively low cost and easy to operate. The drawbacks require mechanical device, filter media cleaning and clogged filters proning [36].

2. Anaerobic Baffled Reactor (ABR) is a technology innovation from a septic tank development in form of a mud blanket system with clogged flow / plug flow or a bulkheaded septic tank. ABR has a similar design and application to the UASB but does not require a special granule formation for its operation [37]. Rows of bulkhead walls of ABR force wastewater to flow through it. The processing became better due to increasment contact time with sludge (active biomass) at a reactor bottom. However, the sludge in each compartment will be different depending on a specific environment and compounds or substances that are degraded. The ABR is specifically designed to make wastewater flow fluctuate up and down since entering a reactor until going out through an outlet [19,38,39].

3. Pond and Lagoon. Wastewater pond is also known as stabilization or oxidation pond. The lagoon itself is a natural pool, which generally is a large, shallow and not too deep ground pool. The difference between a lagoon and a pond is in an aeration process carried out. The oxygen supply are usually carried out mechanically (artificial aeration) due to a large area factor, while in a pond are usually carried out naturally [33]. Types of wastewater treatment using pond technology (pond or lagoon) are divided into several types, including: a). aerobic pond, which is a shallow pond system where dissolved oxygen is present at every water depth so that it is in an aerobic condition; b). anaerobic pond is a treatment pond which in a process does not include oxygen and encourages the anaerobic bacteria growth to degrade wastewater. The sludge will be stored and produced at a pond bottom and then form a hard part (crust) on a pond surface [40]; c). Facultative pond, is where wastewater at a same time is in an aerobic and anaerobic conditions simultaneously. The aerobic zone is on a top layer or surface pond, while anaerobic zone is at a bottom layer or pond bottom; d). Lagoon, the type of lagoon can be distinguished based on degree of mechanical mixing performed. If enough effort is given to obtain an aeration degree of all wastewater including suspended solids, it is categorized as an aerated lagoon. However, if an effort given is only capable to provide mixing some part of an existing wastewater, while suspended solids will settle at a
lagoon bottom resulted anaerobic digestion process, then this reactor is included in a facultative lagoon category [33].

e. Stabilization pond

The stabilization pond is an artificial soil pond consisting of a series of anaerobic, facultative and maturation ponds [19].

4. Rotating Biological Contactor (RBC)

is a medium arranged in a series of circular discs rounded, that are rotated slowly on an axis using a motor or air drive. This disc series are rotated in a room within flow of wastewater so that it sink in a half. The disc can be made from palm fiber material strung together into a disc, or from polystyrene plastic, Poly vinyl chloride (PVC) or polypropylene material. RBC usually is a secondary processing unit which is commonly preceded by a primary processing unit, which are; septic tank, anaerobic filter, clarifier, and some other pre-treatment [19,41].

5. Upflow Anaerobic Sludge Blanket (UASB)

reactor is a single wastewater treatment process tank, where wastewater enters a reactor and move up-flow. The layer of suspended sludge blanks in contact with wastewater process it while flowing through. The UASB reactor is an anaerobic reactor which is often used in both high and low temperature environments. One important thing is that sludge/sediment will be stuck in a reactor. Therefore, at the top of reactor is installed three-phase separator, which will separate sludge, water and gas are produced. The upflow velocity of mud/water mixture should not exceed the settling rate, so that a sludge layer remains afloat (0.6 to 0.9 meter / hour) [19,42].

6. Moving Bed Biofilm Reactor (MBBR)

is a domestic wastewater treatment technology that combines two microbial growth patterns. First is bacterial growth pattern with embedded culture such as a biofilter, and second is bacterial growth pattern with a suspended culture such as in a conventional activated sludge system. With additional media into an aeration bath, so that biological growth process of microbes with suspended cultures and embedded cultures will occur simultaneously. In this way, it is hoped that in addition to increase a number of microorganisms that will break down pollutants, the oxygen supply will also be more evenly distributed so that ability to absorb oxygen becomes greater and optimal in eliminating pollutant levels, especially ammonia [43].

7. Extended Aeration pond actually is not an aeration pool like other aeration pond in general, this process is a development of Conventional activated sludge (CAS) process wherein does not require an initial settling basin. This process is usually used for wastewater treatment with a package system which requires a provision which need a longer aeration time (about 30 hours) due to waste water entering a reactor is not treated first through a primary deposition process. This system will operate at F/M Ratio (Food to Microorganism Ratio/Food to Mass Ratio) is lower compared to CAS systems and requires less aeration compared to conventional processing [33].

8. Oxidation Ditch, in principle, the Oxidation Ditch system is an extended aeration process which was originally developed based on a circular channel with a depth of 1 to 1.5 meters with construction material from masonry. Its main function is to reduce BOD, COD, and nutrient concentration in wastewater. Oxidation Ditch is an activated sludge process that uses an oval-shaped aeration tank, therefore it is conditioned for wastewater and activated sludge to flow around the trajectory of an oval tank. This rotating movement is assisted by a surface aerator or mixer/other type of aerator. Just like the Extended Aeration operation, the Oxidation Ditch also operates with a low BOD loading, resulted less excess sludge produced compared to conventional activated sludge process [44].

6. Conclusion

The achievement of basic access sanitation, especially domestic wastewater in urban areas, has reached more than 73 percent but can still prevent pollution from untreated discharge. Until now, the urban scale off-site system that operates has not been evenly distributed. After more than seven decades, the existing urban scale off-site sanitation infrastructure facilities are only available in 12 cities throughout Indonesia, with service performance mostly below 70 percent of its total capacity. The policy direction for handling domestic wastewater by developing a settlement scale off-site system (DEWATS) is an inadequate alternative solution. This is due to the weak ability of communal-WWTP in producing effluent quality according to the standards. The sustainability of DEWATS must
be considered because of self-financing that has not been able to finance operations and maintenance independently. The above facts indicate that the solution to sanitation problems is through the development of an urban scale off-site system better be a priority in Indonesia in order to get the maximum results as expected.

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