Current status of domestic wastewater management system in Banda Aceh, Indonesia

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Abstract. Almost all cities in Indonesia have not had sewer systems that are qualified for the excellent standard. As a province capital, Banda Aceh has also been facing several domestic wastewater management problems. Based on several previous reports, the water body in Banda Aceh has been contaminated by domestic wastewater pollution. Therefore, serious attention is needed to overcome the problem, such as analysis, investigations, and concepts. This paper aimed to review domestic wastewater management in Banda Aceh and describe the concepts that can be used to solve those problems. The analytical methods used in this study were spatial and descriptive analysis. This study's result was the development of concepts of domestic wastewater management system for preliminary planning in Banda Aceh, which has been considered to be needed as the alternative solution.

1. Introduction
In the recent decade, Indonesia's national development in urban areas is unequally compared to sanitation facilities for the communities. Most urban areas in Indonesia have not a qualifying sewer system, especially the sewerage system. In most cases, domestic wastewater discharge is released directly into a drainage channel, a river flow, and a septic tank. The general types of septic tank used are cesspools in the form of impermeable well rings, and then the run-off water contaminates the soil and water body [1]. Based on recent reports, only one percent of domestic wastewater in Indonesia has been appropriately treated. Then, properly faecal sludge management is less than five percent. Meanwhile, 14 percent of the urban population is still open defecatio [2]. Thus, this fact raises several problems for public and environmental health.

Like the other urban areas of Indonesia, Banda Aceh also faces an increasing population rapidly. In 2018, the Banda Aceh population was 265,111 inhabitants, and the density was approximately 4,321 inhabitants/km2 [3]. These rates of growing population induce high pressures on the environment. The pressure was mainly origin caused by untreated domestic wastewater [4]. The recent report indicates that several rivers in Banda Aceh have been contaminated by mainly domestic wastewater from several parameters such as BOD, COD, Nitrite, and Phosphate, which were above the standard quality value been set in government regulations. These parameters indicate that the source of the
pollutant comes from household wastewater [5]. Meanwhile, some investigations indicate that mostly shallow groundwater quality in Banda Aceh has also been contaminated by domestic wastewater [6,7]. This condition suggested that domestic wastewater management systems (DWMS) in Banda Aceh need to be developed by developing urban scale and settlement-scale off-site systems.

This study provided several approaches for improving the communal-wastewater treatment plants (WWTPs) on settlement scale off-site systems. This research also aimed to compile a concept to solve the problems that arise from the urban scale off-site system development process, namely, (i) determining zones of DWMS service areas, and (ii) selecting the most suitable centralized-WWTP locations for each zonation. This concept was a part of DWMS preliminary design based on environmental characteristics on Banda Aceh. To date, the selection of centralized-WWTP location is part of the problems that emerged in DWMS development process for urban scale off-site systems. The availability of suitable land in an increasingly dense urban environment and a minimal potential problem is a problematic issue. Therefore, the selection of central-WWTP locations is significant to be considered.

2. Methods
This study was conducted from May to June 2020 in Banda Aceh region. Primary data collection was done by making direct observations in the field. Secondary data collection was carried out by tracing data and reporting from related institutions. In addition, secondary data was also collected from various research results related to this study. The analytical methods used in this study were spatial and descriptive analysis. The problems related concept of management in communal-WWTP were analysed descriptively to determine the best solution. Zoning of domestic wastewater services used spatial analysis to determine area service boundaries.

| Criteria                  | Unit   | Suitable          | Conditional suitable | Unsuitable   |
|---------------------------|--------|-------------------|----------------------|--------------|
| Distance to a service area| km     | 0-5               | 6-8                  | > 8          |
| Distance to settlements   | m      | > 300             | 200-300              | < 200        |
| Flood area                | -      | No                | gardens, agricultural land, fishponds, mangrove areas, other productive lands | conservation forest, settlements, businesses and education areas |
| Existing land use         | -      | wetland/swamp, shrub, vacant land | conservation forest, settlements, businesses and education areas |
| Slope                     | %      | <5                | 5-15                 | >15          |
| Distance to road access   | m      | <400              | 400-500              | >500         |
| Land availability         | Ha     | > 2               | 2                    | < 2          |
| Land ownership            | -      | owned by the city government | individual, community, company | dispute land |
| Spatial direction (RTRW)  | -      | other allotment   | river and beach buffer zone, green open space, non green open space, mangrove, fishery, tourism | cultural heritage sites, cemetery, settlements, trading area, office space |

Descriptive analysis was used to assess conditions in Banda Aceh and consideration have taken relate to area services zoning. Determination and zoning distribution of services areas in an urban area was based on the number and level of population density, building density, topographic and slope shape, water body of water receiver, and the administrative border [8]. For the selection of centralized-WWTP locations, a combination of spatial analysis and descriptive analysis were used. Spatial analysis was used in the assessment process based on distance centralized-WWTP location plan from service areas, distance to community settlements, existing land use, slope, and road access [9]. The descriptive analysis method was used to add information on centralized-WWTP location selection.
decisions in each zoning of service areas with criteria such as flood hazard, land availability, land ownership, and directions from the RTRW document.

3. Results and Discussion

3.1. Environmental characteristics in Banda Aceh

Geographically, Banda Aceh is located between 05° 16’ 15” – 05° 36’ 16” North Latitude and 95° 16’ 15” – 95° 22’ 35” East Longitude, with an area of 61.36 km². The Banda Aceh population is 265,111 inhabitants. The demographic condition in Banda Aceh can be classified as a pre-urban population density. Banda Aceh has 90 villages. However, only one village has a population density categorized as high-urban (> 250 inhabitants/ha). While, others villages are categorized as low-density villages [3]. The building density levels in Banda Aceh have the same pattern as the population density, where higher density levels increase in the center. Building density concentration in the outskirts of areas is lower than in the center of the area. The characteristics in the east to the south are depending on the rice fields. Meanwhile, in the west to the north associated with community fishpond and tidal areas. The distance the villages to the edge of Banda Aceh wholly are still in a radius of less than 8 km from the city center, with access roads generally in an ideal condition.

For topography and slope, Banda Aceh generally has a flat topography with an average elevation of 0.8 meters above sea level. The variations are ranging from an elevation of 0 to 9 meters above sea level. The slope conditions in Banda Aceh are relatively flat with a range between 0 - 9%. The measurements of 66 dug wells in Banda Aceh indicate that ground water level in Banda Aceh is included in the shallow category with a height variation of 0.3 - 3.5 m from the ground surface [10]. For surface hydrology, Banda Aceh is crossed by nine rivers. Most rivers upstream come from Aceh Besar district, i.e Krueng Aceh, Krueng Cut, Krueng Tanjong, Krueng Lueng Paga, Krueng Daroy and Krueng Neng. While other rivers, namely Krueng Doy, Krueng Titi Panyang and Krueng Geunaseh have an upstream originating from the city. All of the rivers are final disposal facilities of secondary drainage channels.

3.2. The problems of domestic wastewater management in Banda Aceh

Banda Aceh has not had a centralized-WWTP for an off-site system with an urban scale. Meanwhile, the coverage of the existing settlement scale (with communal-WWTP) for the area is narrow. In general, the DWMS in Banda Aceh is still lacking performance, especially for grey-water (sullage). The management of grey-water is carried out by disposal to drainage channels and rivers directly. This problem is due to the lack of available DWMS services for the community. Furthermore, a low level of public awareness of the importance of domestic wastewater management and their attitudes rely entirely on domestic wastewater management only to the government [11].

In early 2020, from 90 villages in Banda Aceh, only 18 villages had an settlement scale off-site system (> 50 to < 20,000 inhabitants). Then, the settlement scale off-site system was not covered all of the areas of each village. The total number of house connections (HC) connected to communal-WWTP services in 18 villages in Banda Aceh only reached 1,209 HC with 5,629 service recipients. Therefore, the percentage of service recipients was only 2.12 percent of total inhabitants. As an "intermediate system", which was a transition system from an individual system (on-site system) to an urban-scale off-site system [12], the settlement scale off-site system development program is still to be developed for other villages now, which do not have domestic wastewater management facilities. The distribution of villages with communal-WWTP and its piping network in Banda Aceh can be seen in Figure 1.

Settlement scale off-site systems with communal-WWTP, in several places still need to be re-examined with the system performances suitability and effectiveness. The study that examined five communal-WWTPs found in three villages in Banda Aceh showed that all of the communal-WWTPs studied had an effluent quality that exceeded the standard quality of domestic wastewater on several parameters required. Some problems exist such as the existence of a congested wastewater flow distribution system and discharged odour pollutants [13]. Problems that occur in the communal-
WWTP were generally related to operation and maintenance of communal-WWTP and its distribution system. It had become common that problems at communal-WWTP were usually related to the self-subsistent and volunteer character of institutional management, so that the management carried out did not maximize and run well. This causes many conditions of communal-WWTP to be unmaintained and decreased performance capability. The situation eventually caused contaminants in effluent receiving water body.

![Figure 1. Distribution of villages with communal-WWTP in Banda Aceh 2020](image_url)

Banda Aceh already has a domestic wastewater management system master plan that was compiled in 2012. In this document, there are two strategies for handling domestic wastewater management, which are the strategy for developing on-site systems that already exist in the community, and the off-site facilities construction. In strategic planning of on-site system development, rehabilitation activities will be carried out on existing septic tanks, and make efforts to increase public understanding of standard septic tanks for domestic wastewater treatment. Beside, community-based sanitation infrastructures have also been constructed, such as public toilet facilities (MCK). The management system in the communal system sanitation infrastructure is carried out by way of self-help by the community, including the management of communal-WWTP. However, due to unclear institutional and management systems in the community, some problems related to operation and maintenance appears in some existing MCK and communal-WWTP buildings.

For off-site systems, the existing master plan has divided domestic wastewater management areas throughout Banda Aceh into four zones of service areas [14]. All zones have separate piping systems and centralized-WWTPs for each of them (Figure. 2). Since 2015, central government has begun to carry construct of urban-scale centralized-WWTP and supporting infrastructure. In the process, there were several problems in the form of rejection by the community, so the pilot project for the development of centralized-WWTP zone 2 in Gampong Pande had to be stopped in October 2017. Eventhough the progress achieved in developing centralized-WWTP and its piping system had
reached more than 70 per cent [15]. The problem arises from the discovery of a burial site is claimed as part of Aceh's history in the centralized-WWTP zone two development location. The site was then excavated and moved to another location that is still in the project area. The local government received several complaints from people who were very worried about destroying of historical sites affected by the excavation process. This condition is then exacerbated by the issue being published several times in local newspapers to becomes a sensitive and massive issue discussed by the public [15]. As a result, up to early 2020, despite having a planning document (master plan) and budget availability for investment cost from the national government, Banda Aceh does not yet have an urban scale off-site system.

![Figure 2. Master plan of DWMS services zoning in Banda Aceh [14](image)](image)

The problems raised above indicate several things, including:

1. Contamination of shallow groundwater and surface water due to domestic wastewater that has not been appropriately managed occurred in several places in Banda Aceh;
2. The settlement scale off-site system that already exists in several villages in Banda Aceh does not function optimally in domestic wastewater treatment. Coverage of a tiny service recipients (2.12% of total inhabitants), requires an increase in domestic wastewater management services by immediately developing urban scale off-site system services;
3. The existing urban wastewater master plan that has been compiled, still needs adjustments to the environmental characteristics and the development of existing conditions in Banda Aceh;
4. The option of urban scale centralized-WWTP location specified in the master plan needs to be re-examined for their suitability;
5. The socialization process of the development project of the urban scale off-site system has not been implemented to the maximum level, so that there was still a reluctance to participate and reject in part of communities.

Problems that arise, especially those related to urban scale off-site systems, must be resolved immediately by reviewing the existing master plan, because it was more than five years old and need
to be adjustments to the latest conditions in Banda Aceh. Determination of four service area zones with centralized-WWTP and its piping system in each zone should be a concern in planning.

3.3. Development concept of communal-WWTP management institution and urban scale off-site system socialization in communities.

Institutional problems in communal-WWTP management can be carried out by developing and increasing management institution’s capacity, a non-government organization from the service recipient community. Developing is carried out routinely and continuously by the local government. They provide coaching and training related to operational and maintenance from communal-WWTP. The local government through it is related institution, must be conducting stimulants. They hold a competition between communal-WWTP management institutions and provide incentives to the winners of the competition. This competition makes managers spur the spirit of community and management institutions to a better-shared responsibility communal-WWTP. The local government is also expected to facilitate association within communal-WWTP management institutions in Banda Aceh. These communal-WWTP management communities can communicate easily and collaborate in doing matters related to communal-WWTP management.

Socialization regarding implementation of the urban scale off-site systems development project needs to be carried out more optimally and in a planned manner. This implementation involved community leaders and religious leaders in every village in Banda Aceh. The information dissemination must be provides a high awareness for the community about benefits of urban scale off-site systems, and their importance in the system. After the level of community participation has reached the expected level, the next stage of socialization is to increase community knowledge about maintaining the system function well for a long time. The problem often occurs in an off-site system is a distribution system of domestic wastewater that is blocked due to foreign matter in the form of solid waste disposed of by the community through HC into piping system. High awareness of maintaining the piping systems makes domestic wastewater distribution system performance optimal for a long time, for example by not removing solid waste, installing trap /water seal in sewerage channels, and flushing properly.

3.4. Service area zoning from DWMS.

Zoning of existing DWMS service area in the existing urban wastewater master plan consisted of four zonings, dividing the Banda Aceh area vertically from the south to the north. In determining service area zoning, consideration of criteria for similarity in number and population density, cannot be used fully because in neighboring villages and administratively located in a sub-district, do not show a significant level of uniformity so that it is difficult to be used as a basis in determining to the zone. Consideration of population criteria is only used to adjust the population proportion of each zoning area determined. For criteria of building density which tend to be concentrated in the central part of the city, it spreading around in the peripheral area. This becomes the direction to determine the area to be one zonation, separately from other zonation with low building density. The terrain characteristics with a small slope percentage value make a relatively flat topographic shape, and a decreased elevation tendency in the northern part of the city, making the domestic wastewater distribution system utilize the power of gravity from south to north of the city.

Based on the considerations mentioned above, the service areas zoning concept was divided into three service area zones by expanding zone 1 and zone 2, and combining zone 3 with zone 4. Consideration for eliminating zone 4 contained in the previous master plan, because zone 4 it only consists of three villages (Kopelma Darussalam, Rukoh, and eastern Alue Naga Village) which are mostly centers of higher education (Kopelma Darussalam and Rukoh Village), so the amount of domestic wastewater generated will increase at certain times. Another consideration is efficiency and budget savings, where by combining zone 3 and zone 4 into one service area zone, only one centralized-WWTP service is needed to build and serve this area. Alternative options for centralized-WWTP locations in each zone of service area can be seen in Figure 3.
3.5. Centralized-WWTP locations in each service area zoning.

Regarding centralized-WWTP which has problems in zone 2, as well as centralized-WWTP placement locations in other zones, it is necessary to make adjustments by finding alternative locations for new centralized-WWTP areas. Several alternative locations for zone 1 are Deah Glumpang (the old location according to master plan), Gampong Pie, Ulhee Leue, and Lambung Village. As addition of another alternative location for zone 1 in this study namely Blang Oi Village. Zone 2 has three alternative consisted of Gampong Pande (the old location according to master plan), Lampulo, and Panteriek Village. Alternatives in zone 3, Alue Naga west side of river (the old location according to master plan), Ceurih, Alue Naga Village in eastern river (the old location for zone 4 in the master plan), and Rukoh Village. As the addition of another alternative location for zone 3 in this study namely Tibang Village. Alternative options for centralized-WWTP locations in each zone of service area can be seen in Figure 4.

Based on spatial analysis and descriptively information exploration on all alternative centralized-WWTP locations, three villages were most suitable for centralized-WWTP locations, namely Blang Oi Village for zone 1, Lampulo Village for zone 2, and Tibang Village for zone 3. The results of the centralized-WWTP location suitability level in more detail can be seen in Table 2.

Consideration for the selection of centralized-WWTP locations in zone 3, namely Tibang Village with consideration as follow: a) its position’s quite far from the settlement (± 200 m), so that tends to safe from the possibility of direct contact between domestic wastewater and community; b) The land at this location is a fishpond area owned by community with an approximate area of ± 2.5 Ha, and can be expanded further to Alue Deah Teungoh Village as needed; c) Allotment of land with RTRW was as a mangrove forest area, so it is necessary to make adjustments in local regulation (Qanun) of RTRW to become land with direction for other designations. The selection of centralized-WWTP locations in zone 2, namely Lampulo Village, with consideration as follow: a) located around area of the Lampulo fish landing port (TPI), where available land belongs to Government of Aceh Province with an area of ± 51.8 Ha. This land can be made a centralized-WWTP by holding talks with
Provincial Government in order to obtain a permit to use part of land.; b) Land location is far from settlement (± 500 m), it is safe from possibility of direct contact with community, so that risk of social problems that can arise is relatively small; c) Besides in Lampulo Village, centralized-WWTP zone 2 which has been built 70 per cent in Gampong Pande, in future, will also be able to utilized for a limited operation service, in accordance the already installed capacity (± 5,000 HC) for villages around that centralized-WWTP.

![Figure 4. Alternative centralized-WWTP location options in Banda Aceh](image)

**Table 2. Results of centralized-WWTP location selection assessment in Banda Aceh**

| Alternative locations | Village | Distance to service area (Km) | Distance to Settlements (m) | Flood Area | Existing land use | Slope (%) | Distance to road access (m) | Land Availability (Ha) | Land ownership | Spatial direction (RTRW) | Problem | Conformity level category |
|-----------------------|---------|-------------------------------|-----------------------------|------------|-------------------|-----------|---------------------------|----------------------|----------------|--------------------------|---------|--------------------------|
| 1 (A) | Deah Glumpang | 0 - 5 | < 200 | Yes | Green open space | 0 - 2 | < 400 | 1,2 | City government | Green open space | Too close to settlements | Unsuitable |
| 1 (B) | Gp. Pie | 0 - 5 | < 200 | No | Green open space | 0 - 2 | < 400 | 2,2 | Individual | Green open space | Too close to settlements | Unsuitable |
| 1 (C) | Ulee Lheue | 6 - 8 | 200 - 300 | No | Green open space | 0 - 2 | < 400 | 2,5 | City government | Tourism | Unsuitable |
| 1 (D) | Lambung | 0 - 5 | < 200 | No | Green open space | 0 - 2 | 400 - 500 | 2 | City government | Green open space | Too close to settlements | Unsuitable |
| 1 (E) | Blang Oi | 0 - 5 | 200 - 300 | No | Fishpond area | 0 - 2 | 400 - 500 | 2,5 | Individual | Mangroves | Land acquisition and reclamation of fishpond areas | Suitable |
| 2 (A) | Gp. Pande (IPAL existing) | 6 - 8 | > 300 | No | Other allotment | 0 - 2 | < 400 | 20 | City government | Other Allotment | Discovery of Cultural Heritage Sites | Unsuitable |
| 2 (B) | Lampulo | 6 - 8 | > 300 | No | Fishery and fishing industry | 0 - 2 | < 400 | 51,8 | Provincial government | Fishery | Coordination with the local government regarding land is needed | Suitable |
The selection of centralized-WWTP locations in zone 3, namely Tibang Village with consideration as follow: a) land is owned by city government, more than 200 m from settlement, has been surrounded by a fence, and is not a flood area; b) For zone 4 contained in master plan, which is eastern part of Kr. Cut river which has been removed and merged with zone 3; c) in eastern part of Krueng Cut will only be built collecting pit equipped with lifting pump station, so that domestic wastewater from this area can be pumped cross the river through piping and then it is processed on centralized-WWTP in Tibang Village. Centralized-WWTP locations in three service areas zoning can be seen in Figure 5.

Figure 5. Selected centralized-WWTP location

5. Conclusion
Several approaches for improvement of settlement-scale off-site systems consist of institutional problems that occur in communal-WWTP management and can be carried out by developing and increasing management institutions' capacity routinely and continuously. The local governments hold
a competition between communal-WWTP management institutions and provide incentives to the competition winners. The local government facilitates the formation of associations within Communal-WWTP management institutions in Banda Aceh. Problem-solving related to land limitations for centralized-WWTP is solved by the concept of determining services area zoning and site selection for centralized-WWTP. Based on the analysis conducted, the zoning of the service area will be divided into three zonation’s by centralized-WWTP location placement, respectively zone 1 is located in Blang Oi Village, zone 2 is located in Lampulo Village, and zone 3 is located in Tibang Village. The existing centralized-WWTP in zone 2 (Gampong Pande) will also be able to operate in a limited manner following installed capacity so that it will be able to help serve wastewater treatment in zone 2.

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