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Wastewater Quality Determines the Quantity of Offsite Sanitation Based on Downstream Standards

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Abstract: Offsite sanitation describes the wastewater management in the chain of generation sources to its disposal into the environment. While the user manages the onsite sanitation system for greywater, blackwater requires offsite treatment. In practice, offsite sanitation management implements scoping service areas for centralised, decentralised, and combined hybrid. This study aims to provide feasibility criteria for the offsite small scale sanitation services and formulate a method compatible with existing methods to accelerate sanitation services. The method used is a downstream approach by assessing the capacity of rivers to receive wastewater discharges. The results consist of river capacity criteria and wastewater quality requirements. The quality load of a river and water dilution ability determine the number of people and the suitability of the sanitation system. The decision-making process in determining the scale of offsite sanitation services directs the problem solution by considering technical, economic, financial, institutional regulations, environmental, and social aspects. Availability of data speeds up problem-solving with effective and efficient use of resources. The core conclusion states that wastewater quality parameters determine the scale of offsite sanitation services. The criteria formation facilitates and accelerates the delivery of technology choices to a definitive number of people and gains their participation in using sanitation facilities.

Keywords: Infrastructure, rural, sustainable management, urban, wastewater treatment, water resources

1. Introduction

Sanitation services are a continuation of the use of clean water by people. The wastewater quality contains various physical, chemical and biological parameters in which substances present at specific concentrations can harm building health. Therefore, good sanitation can reduce the incidence of sick building syndrome (H. Samudro et al., 2022a), an essential concern for architects designing a building (H. Samudro et al., 2022b). In short, in every building with human activity, sanitation is an essential facility that must exist.

Sanitation services are crucial to public health and environmental protection, especially in urban areas. People are responsible for managing wastewater and ensuring it does not negatively impact human health or the environment (Dalahmeh et al., 2009). Sanitation services often begin with the provision of clean and safe drinking water. People use

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this clean water for various purposes, such as drinking, cooking, bathing, and cleaning. After using clean water for various purposes, wastewater is generated.

The wastewater contains a mixture of physical, chemical, and biological pollutants (Obaideen et al., 2022). Physical parameters include factors like temperature, turbidity, and suspended solids. Elevated temperatures can harm aquatic life, and turbid water can reduce light penetration in water bodies, affecting aquatic ecosystems. Chemical parameters encompass many substances, including heavy metals, organic chemicals, and nutrients like nitrogen and phosphorus. High concentrations of heavy metals or toxic organic chemicals in wastewater can harm human and environmental health. Biological parameters can contain harmful microorganisms, such as bacteria, viruses, and parasites (Kusumawati & Mangkoedihardjo, 2021). These pathogens can cause diseases if not properly treated, posing a significant health risk.

When wastewater is not properly managed and treated, it can pose significant health risks to humans and the environment. For instance, contaminated water sources can lead to waterborne diseases with serious health consequences. In addition to health concerns, improperly managed wastewater can harm the environment. It can lead to the pollution of rivers, lakes, and oceans, disrupting aquatic ecosystems and causing harm to aquatic life (Abed, 2022). To address these issues, municipalities and sanitation authorities typically implement wastewater treatment processes to remove or reduce the contaminants present in wastewater (Obaideen et al., 2022). These processes include physical, chemical, and biological treatments designed to improve the quality of the water before it is released back into the environment or used for other purposes. Proper sanitation services are essential for safeguarding public health and protecting the environment from the adverse effects of polluted water.

Sanitation management in urban and rural areas applies onsite and offsite systems. The onsite system treats and disposes of wastewater within the boundaries of the building area (Ghangrekar, 2022). Generally, wastewater streams separate blackwater containing human waste into a septic tank. Furthermore, the septic tank effluent enters the soil absorption (G. Samudro & Mangkoedihardjo, 2011). At the same time, the greywater flows into the soil infiltration, either separately or mixed with the septic tank effluent. In practice, septic tanks and greywater effluent often flow into rainwater drainage channels around buildings in limited land conditions, although this poses a risk to the environment (Arifin et al., 2020). In addition, septic tank sludge requires periodic emptying (Mahon et al., 2022) to undergo processing outside the building. Thus, onsite sanitation practices involve offsite sanitation management for septage treatment. In addition, sanitation services require offsite management in conditions where the onsite system is impossible.

Offsite sanitation systems include a choice of centralised, decentralised or hybrid service scales (Schrecongost et al., 2020) based on the feasibility of the wastewater-producing source, namely the number of people. Social feasibility concerns community participation in using offsite facilities. Financial feasibility concerns the affordability of users to pay for these facilities. In planning, this method is an upstream approach, which determines the number of users and continues with technology selection and final disposal.

An upstream approach is a strategy or methodology that emphasises addressing issues or making decisions at the user stages of a service (Raine, 2010). This approach involves making decisions and taking actions in a particular order, starting with the number of users, technology selection, and ending with final disposal. Determining the number of users is the initial step in the process. Here, one determines how many users or customers the technology or product will serve. This decision is crucial because it influences subsequent steps in the process, including technology selection and disposal. After determining the number of users, the next step is to select the appropriate technology or solution. This decision is made with the specific user base in mind, ensuring that the technology aligns with the needs and expectations of the users (Cossio et al., 2020). The goal is to choose technology that meets the identified user requirements. Once the technology has been implemented and served its purpose, it reaches the end of its lifecycle. At this stage, the final disposal process is planned and executed in an environmentally responsible and sustainable manner.

The upstream approach is beneficial because it prioritises the early planning and decision-making stages, ensuring that user needs and considerations are central to the process. This approach can lead to more effective technology selection and a more sustainable approach to technology disposal, as these decisions are made with a clear understanding of the user base and their requirements. The selected technology adjusts the wastewater's quality, producing effluent according to applicable standards and discharging it to the water-receiving body. Hence, offsite sanitation in various service scales requires a final disposal site. For example, the definitive disposal site for wastewater effluent can be land, but in the end, it requires a body of water. The body of water can be deep groundwater (Mester et al., 2022), lakes and rivers (Martínez-Santos et al., 2018), and seas (Freeman et al., 2020). The world's waters are the most considerable portion of the earth's surface environmental media (Boretti & Rosa, 2019), although the distribution is not evenly distributed in all places. However, water has a natural ability in the form of dilution of pollutants and self-purification (Abed, 2022) that supports the final disposal of wastewater.

Meanwhile, this study moves from final disposal to the source of wastewater generation, a downstream approach. In the context of technology selection and final disposal, a downstream approach typically refers to a method or strategy that involves considering the end-of-life aspects of a technology. This approach can be particularly important and suitable in waste management. A downstream approach encourages a holistic view of technology, emphasising minimising environmental impact, efficiently utilising resources, and taking responsibility for the entire product lifecycle. This approach is often seen as more sustainable and responsible, considering the full spectrum of implications associated with receiving water body quality. In relying on dilution and purification, a body of water refers to a river with flowing water. This new approach aims to determine the number of people, which results in an offsite sanitation management scale, whether centralised, decentralised or hybrid. The output of this study provides feasibility criteria for evaluating existing sanitation systems and planning new systems to meet the sanitation service needs of urban and rural populations.

2. Methodology

This methodology describes the procedure for assessing the feasibility of river water in its mixture with wastewater discharges. Assessing the feasibility of mixing river water with wastewater discharges is an important process in water resource management (Skorbiłowicz et al., 2017). This procedure typically involves several steps to ensure the mixture complies with environmental regulations and does not harm the aquatic ecosystem. A general outline of the process includes water quantity, quality, dilution and mixing analysis, depicted in Figure 1, emphasising determining the population served by sanitation services.

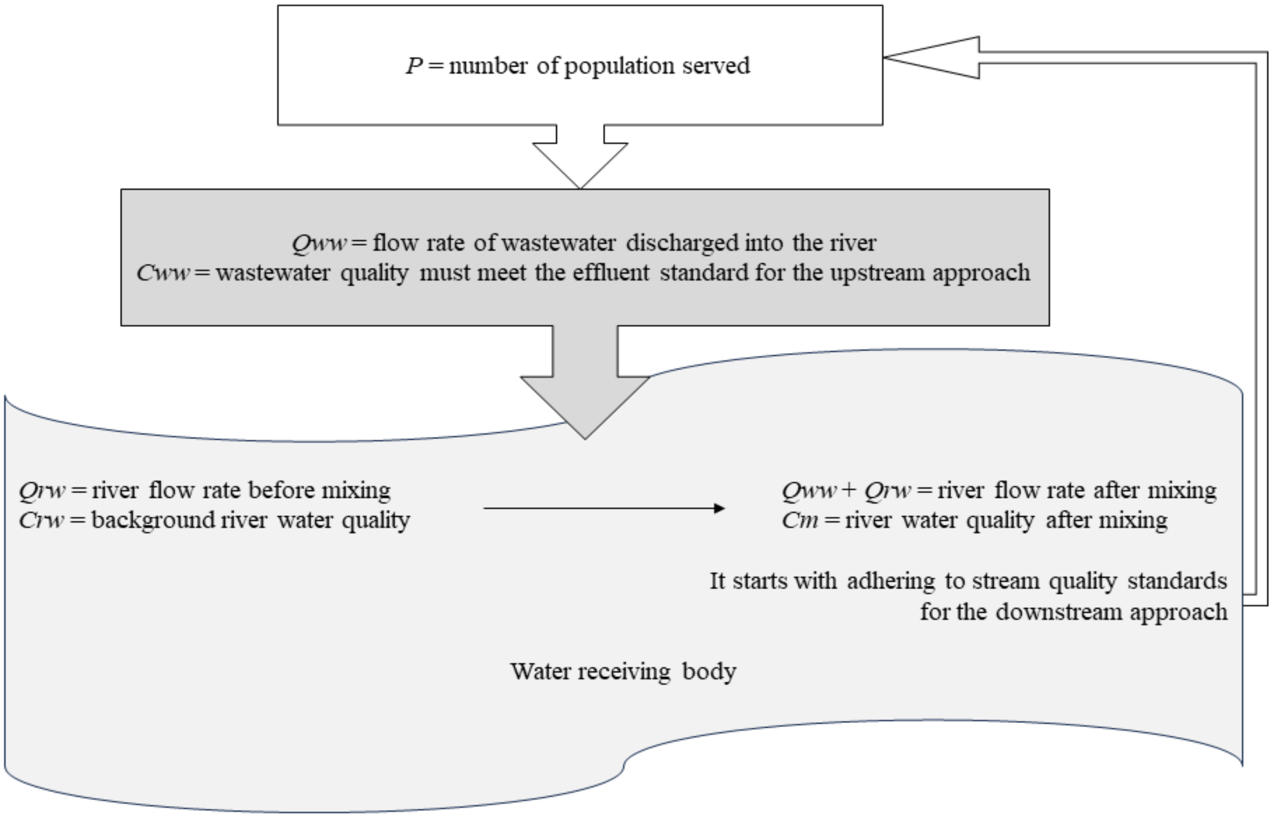

Fig. 1 - Mixture of wastewater into water receiving body

Both rivers and wastewater contain two components, namely the quality of various concentrations of substances and the quantity in the form of flow rate or volume. The product of the two components is a measure of quality load. Mixing the two types of water produces an equilibrium quality load (Schwermer & Uhl, 2021), simply in Equation 1.

$$Cm(Qrw + Qww) = CrwQrw + CwwQww \qquad (1)$$

The concentration of the mixture *Cm* denotes the concentration of mixed substances in rivers and wastewater flowing into the rivers (mg/L). Regarding the quantity of water, *Qrw* is the flow rate of rivers (L/s) before mixing with wastewater. The quantity of *Qww* is the flow rate of wastewater discharged into rivers (L/s). Concerning the quality of rivers, *Crw* is the background concentration of a substance in a river (mg/L) before mixing with wastewater. For wastewater quality, *Cww* is the substance concentration of wastewater discharged into rivers (mg/L).

To obtain the number of people (*P*) by the sanitation system, Equation 1 requires rearranging into Equation 2.

$$P = \frac{(Crw - Cm)Qrw}{(Cm - Cww)qww} \qquad (2)$$

The *qww* value is the unit of wastewater discharge per person per unit of time in litres per capita per second (L/c/s) to match the units of measurement above.

The subsequent arrangement in Equation 3 is the water dilution level (*Dl*).

$$Dl = \frac{Cm(Qrw - Qww)}{CwwQww} \quad (3)$$

In summary, Table 1 is the criteria for using the three-river water and wastewater equations. Aspects of technical feasibility and environmental and institutional regulations are limitations and indications of the suitability of a river capable of accommodating wastewater disposal.

Table 1 - Assessment of feasibility criteria for rivers

Feasibility aspects	River	Wastewater	Suitability	Problems	Solution
Technical	Minimum *Qrw*	Maximum *Qww*	$Dl > 1$		
Environmental	Minimum *CrwQrw*	Maximum *CwwQww*	$CrwQrw > CwwQww$	$Crw \geq Cm$	Wastewater treatment options
Institutional regulations	Stream standard	Effluent standard	Stream standard		
Economic and Financial					Provide economic and financial feasibility for each technology option.
Data source	Water management authority	Agencies authorised to manage wastewater or clean water companies to estimate *qww*, or field observations by expert consultants.	Desk study by expert consultants	Desk study by expert consultants	Desk study by expert consultants

The output of this downstream assessment provides the fixed population number, wastewater treatment capacity, and technology options, all of which meet comprehensive feasibility to undergo user outreach. User outreach for sanitation services requires a long-term commitment to education, awareness, and engagement.

An exercise on the downstream approach method presents data from the 2020 Surabaya City sanitation master plan in Indonesia to present an example of quantitative calculations. The master plan uses an upstream approach with offsite sanitation planning procedures following the flow of wastewater disposal. Determining the number of target users starts the planning step of service coverage and ends in the waters.

3. Results and Discussion

3.1 Upstream Approach

As an example of the case in Indonesia, Figure 2 presents a partial plan of the Surabaya Sewerage and Sanitation Development Programme 2020 (Mangkoedihardjo, 2010a). Starting with user assessment criteria by prioritising socioeconomic aspects, the planning results determined the downtown area as an offsite sanitation service area with a population of around 300,000. Based on the socioeconomic criteria, the sanitation planning provides a choice of a modular system in each zone. Each has a maximum capacity of 50,000 people, so that each zone can build several modules equipped with wastewater treatment. The treatment process selection considers the quality of domestic wastewater and effluent standards. Then, the treatment module effluent flows into the nearest river. Therefore, the Surabaya sanitation plan forms a hybrid system due to target user coverage.

Technically and environmentally, three rivers cross the service area, which simultaneously divides the service area into three zones. Each zone serves a different number of people, the largest covering around 150,000 people, and has wastewater treatment facilities with adequate capacity. The quality of domestic wastewater and effluent standards determine the wastewater treatment process.

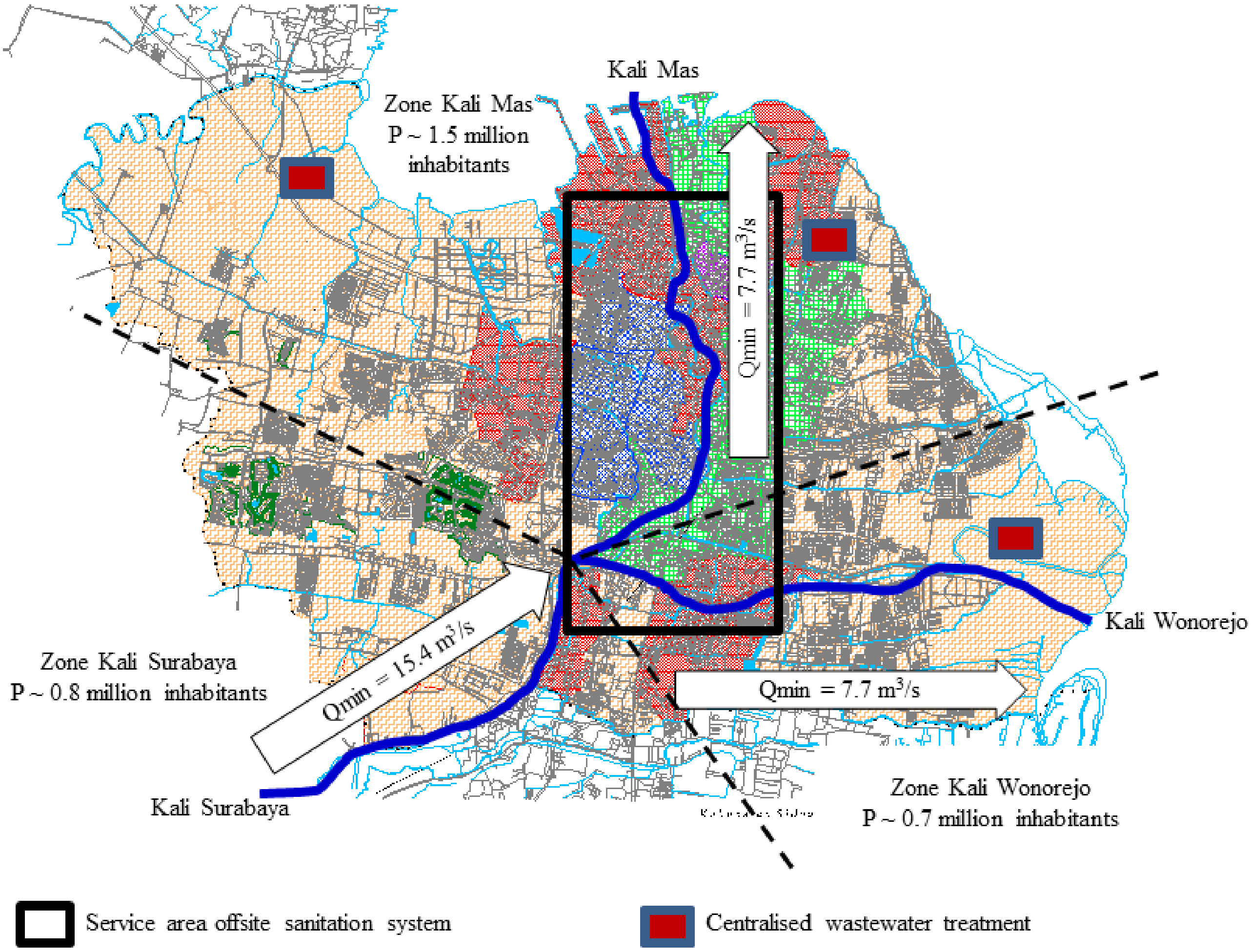

Fig. 2 - Offsite sanitation plan for the city of Surabaya
(adapted from (Mangkoedihardjo, 2010c))

The characteristics of domestic wastewater, such as its composition, volume, and pollutant load, vary depending on several factors like population density, cultural practices, and lifestyle, all of which differ in the city with millions of inhabitants. Domestic wastewater typically contains organic matter such as BOD and COD, suspended solids, nitrogen and phosphorus nutrients, bacteria and viruses' pathogens, and various chemical contaminants (Boutin & Eme, 2016). The specific quality of the wastewater can affect the treatment approach required.

Governments and environmental agencies set effluent standards that specify the maximum allowable concentrations of various pollutants in the treated wastewater before it can be discharged into the environment. These standards are in place to protect the receiving water bodies, ecosystems, and public health provided by presidential decree (President of the Republic of Indonesia, 2021) and ministerial regulation (Minister of Environment of the Republic of Indonesia, 2014).

The choice of a wastewater treatment process depends on the quality of the incoming wastewater and the effluent standards that must be met. The primary goal of wastewater treatment is to remove or reduce the contaminants in wastewater to a level that complies with the established effluent standards. For wastewater with high organic content, processes like activated sludge or biological treatment may be necessary to break down organic matter (Alena et al., 2021). Primary clarification and secondary treatment processes like sedimentation and filtration are used to remove suspended solids. Nutrient removal may be required in areas with strict standards, necessitating additional treatment steps (Rout et al., 2021). Wastewater treatment plants must regularly monitor the quality of the effluent to ensure it meets the set standards. If the effluent falls short of these standards, adjustments and improvements to the treatment process may be necessary. The quality of treated effluent also has implications for the environment. If the effluent does not meet standards, it can harm aquatic life and the ecosystem. Compliance with effluent standards is essential to protect the environment.

In summary, the quality of domestic wastewater and the effluent standards are interlinked and crucial in determining the appropriate wastewater treatment process. The specific characteristics of the wastewater and the local regulations governing effluent quality guide the design and operation of wastewater treatment facilities to ensure that the discharged effluent is environmentally safe and compliant with established standards.

3.2 Downstream Approach

In contrast to the existing Surabaya sanitation planning approach, this study starts from the river. One of the sustainable sanitation programs supports river bases, where rivers are one of the natural resources that receive critical attention to maintain their quality (Schroeder, 2022). Therefore, the assessment aspects in Table 2 present an exercise for any location in Figure 2 within a zone covered by river water with a minimum flow rate of 7,700 L/s.

Rivers and wastewater quality have various physical, chemical, and microbiological quality parameters. In addition, each parameter has concentration limits that can exist in rivers and wastewater. However, the typical quality of domestic wastewater mainly contains organic matter as Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) (Halicki & Halicki, 2022). Therefore, as an exercise, the quality assessment deliberately defines two parameters of organic compounds, BOD and COD and inorganic substances: total nitrogen (Total N) and sulphide (H_2S). The selected parameters are in the standards that apply in Indonesia (President of the Republic of Indonesia, 2021), which define dozens of parameters for certain river water and types of wastewater. Therefore, one can add all the quality parameters to complete the standard requirement.

Table 2 - Assessment of river water and wastewater quality parameters to obtain the number of people and the level of water dilution

Parameters	References	BOD	COD	Total N	Sulphide (H_2S)
Crw (mg/L)	Set deliberately	3	30	20	0.002
Cm (mg/L)	Stream standard class 3 (President of the Republic of Indonesia, 2021)	6	40	25	0.002
Qrw (L/s)	(Mangkoedihardjo, 2010c)	7,700	7,700	7,700	7,700
Cww (mg/L)	Effluent standard class 2 (Minister of Environment of the Republic of Indonesia, 2014)	150	300	60	1
qww (L/c/s)	(Mangkoedihardjo, 2010b)	0.002	0.002	0.002	0.002
Number of people (*P*)	Equation 2	80,000	148,000	550,000	0
Level of water dilution (*Dl*) in the fold	Equation 3	1.9	3.3	2.5	Undefined

The quality of river water prior to wastewater discharge (*Crw*) requires factual observational data. In this exercise, the authors subjectively determine the background concentration, which must be less than and equal to the concentration of stream standard (*Cm*) for class 3 in Indonesia (President of the Republic of Indonesia, 2021). Class 3 water use is for freshwater aquaculture, animal husbandry, irrigating plants, and other similar uses. Meanwhile, the minimum river water flow rate (*Qrw*) takes monitoring data from the water authority agency in one of the rivers in Surabaya (Mangkoedihardjo, 2010c).

Furthermore, the quality of wastewater discharged into rivers (*Cww*) must meet effluent standards based on the Regulation of the Minister of Environment of the Republic of Indonesia Number 5 of 2014 (Minister of Environment of the Republic of Indonesia, 2014). Appendix XLVII provides quality standards for wastewater effluent originating from domestic activities class 2 as the worst quality. The unit of wastewater discharge per person per unit of time (*Qww*) uses monitoring data from the Surabaya sanitation plan.

Table 2 shows that the concentration of sulphide in water (*Crw*) is the same as that of sulphide mixed water (*Cm*) as the stream standard concentration. An equal concentration of sulphides indicates that the water cannot accept additional sulphides from wastewater due to standard requirements unless it requires prior treatment. Consequently, the degree of dilution of water (*Dl*) is undefined. Therefore, sulphides must be a concern in wastewater treatment before discharge into rivers. Furthermore, the three parameters BOD, COD and Total N require a decision-making process in determining the number of people that affects the capacity of required wastewater treatment.

3.3 Number of People

Without intending to evaluate the upstream approach, which sets a target number of people, this downstream approach results in a range of people being served based on the number of parameters evaluated. Nonetheless, one can immediately make the right choice quickly.

Table 2 clearly shows that the smallest number of 80,000 people among the calculation results of the specified parameters is the safest choice for the number of people. The lowest river water dilution level of 1.9 is the lowest among other quality parameters supporting this choice. The results of calculating the number of people based on COD and Total N produce more than the BOD basis. Furthermore, the results for the number of people based on these two parameters must decrease to the same as those based on the BOD of 80,000 people. The results of Equation 3 show an increase in the level of water dilution for COD and Total N.

Determining the number of people shows the need for the scale of offsite management and wastewater treatment capacity. Once again, as a case example, assuming an area with a maximum population of 80,000 people in a single sanitation service area, the offsite management scale is centralised. However, if the area is part of an urban area, then the area changes to a decentralised scale. A hybrid scale becomes realised when all urban areas use various scales of offsite sanitation systems.

A hybrid scale of sanitation systems, where urban areas utilise onsite and offsite sanitation systems, can offer a practical and sustainable approach to managing sanitation and wastewater in diverse urban environments (H. Samudro et al., 2023). Onsite sanitation systems refer to systems where wastewater and sewage are treated or managed at the location where they are generated. The onsite system can include septic tanks, pit latrines, and decentralised treatment systems (Chirisa et al., 2017). On the other hand, offsite sanitation systems involve the collection and centralised treatment of wastewater and sewage at a distant location. The discharge is often achieved through sewage collection networks that transport waste to treatment facilities.

The idea of a hybrid scale of sanitation systems in urban areas would incorporate onsite and offsite systems to cater to their diverse sanitation needs. Some reasons this hybrid approach (Pietruszkiewicz et al., 2011) for the optimum number of people served may be beneficial are described in Table 3.

Table 3 - Beneficial assessment of the hybrid approach for the optimum number of people served

Reasons	Beneficial output
Flexibility	Different areas within an urban environment might have varying population densities, infrastructure availability, and geophysical conditions. A hybrid approach allows flexibility in choosing each area's most appropriate sanitation system (Massoud et al., 2009).
Cost-effective	Onsite systems are often more cost-effective for low-density or remote areas (Khurelbaatar et al., 2021), while offsite systems make sense for densely populated regions. By using a mix, municipalities can optimise their investments.
Resilience	Hybrid systems can enhance the resilience of sanitation infrastructure (Capodaglio et al., 2021). In natural disasters or infrastructure failures, onsite systems can continue functioning, providing a backup.
Environmental considerations	In areas where groundwater contamination is a concern, onsite systems can be employed to treat and contain waste locally (Masindi & Foteinis, 2021). Centralised offsite systems can be designed in more densely populated areas with more advanced treatment options.
Sustainability	A hybrid approach can align with sustainability goals (Capodaglio et al., 2021). Onsite systems may promote nutrient recycling and reduce the energy required for transport, while offsite systems can be designed to maximise energy recovery and resource reuse.
Adaptability	The hybrid approach can be adapted to meet evolving needs as urban areas grow and change (Lawrence et al., 2019). It allows for a more dynamic response to demographic shifts and urban expansion.

It is important for urban planners, engineers, and policymakers to carefully assess the specific needs of each area within the urban environment and consider factors like population density, infrastructure availability, water resources, and environmental conditions when deciding on the mix of sanitation systems to implement. Also, these systems' proper management, maintenance, and monitoring are crucial to ensure public health, environmental protection, and long-term sustainability.

3.4 Wastewater Treatment

The concern for the wastewater treatment mentioned above, as an example case in Table 2, is the reduction of sulphide to a level below the river water quality standard. At the same time, the processing results of organic matter and total nitrogen must produce effluent quality standards. In addition, in Table 2, the standard effluent quality for BOD and COD organic matter is at a biodegradable level with a BOD/COD ratio of 0.5 (Mangkoedihardjo, 2023). This information becomes an input for wastewater treatment experts to provide technology options for the same capacity as the number of people. Furthermore, wastewater treatment technologies require some options to each be subject to an assessment of economic viability and financial affordability (Perard, 2018). Therefore, the involvement of financial economists becomes necessary for determining one or two feasible technology options.

Assessing wastewater treatment technologies' economic viability and financial affordability (Molinos-Senante et al., 2010) is crucial for ensuring that a chosen solution is both sustainable and cost-effective. Some key considerations and options to subject to assessments are summarised in Table 4.

Table 4 - Key factors of wastewater treatment feasibility

Key factors	Description
Capital cost	Evaluate the upfront capital costs required to implement a specific wastewater treatment technology (Ćetković et al., 2022). The technology includes equipment, infrastructure, land acquisition, and construction costs.
Operating and maintenance costs	Consider the ongoing operational and maintenance expenses associated with the technology (Ćetković et al., 2022). The cost includes labour, energy, chemical usage, and repairs.
Life cycle costs	Calculate the total cost over the entire lifespan of the technology (Rathore et al., 2022). The cost involves the initial capital and operating costs and replacement or refurbishment costs over time.
Energy efficiency	Assess the energy requirements of the treatment technology (Maziotis et al., 2023). More energy-efficient solutions can lead to cost savings over time.
Scalability	Determine if the technology is scalable to accommodate changes in the volume of wastewater to be treated (Abdelmoez et al., 2013). Scalable solutions can adapt to future needs and may offer better long-term economic viability.
Environmental compliance	Analyse whether the technology helps meet regulatory requirements for effluent quality (Elbakidze & Beeson, 2021). Non-compliance can lead to fines and legal costs.
Resilience and reliability	Evaluate the technology's ability to withstand environmental factors and its overall reliability. Frequent breakdowns and repairs can increase costs (Ćetković et al., 2022).
Return on investment (ROI)	Calculate the expected ROI by estimating the cost savings or revenue generation potential from using the technology (Rathore et al., 2022). Consider the payback period.
Grant and incentive programmes	Explore whether government grants, subsidies, or tax incentives (Bian & Zhao, 2020) are available for implementing specific wastewater treatment technologies. These can significantly impact financial affordability.

Table 4 continues
Table 4 continued

Key factors	Description
Lifecycle analysis	Perform a comprehensive lifecycle analysis to account for all costs, including externalities such as social and environmental impacts (Rathore et al., 2022).
Financing options	Consider financing options, such as loans, bonds, or public-private partnerships, to help with initial capital costs (Turley & Semple, 2013).
Revenue generation	Explore potential revenue sources (Rathore et al., 2022), such as the sale of treated water or by-products like biosolids, to offset operating and maintenance costs.
Risk analysis	Assess the risks associated with the technology (Elbakidze & Beeson, 2021), including regulatory changes, market fluctuations, and unforeseen issues, and incorporate risk mitigation strategies into the financial assessment.
Comparative analysis	Compare the economic viability of different wastewater treatment technologies to select the most cost-effective option (Goffi et al., 2019).
Affordability for the local community	Consider the ability of the local community or organisation to afford the technology (Mormina, 2019). Ensure that wastewater treatment costs do not place an undue burden on residents or stakeholders.
Public-private partnerships	Explore partnerships with private companies to share the financial burden and expertise in implementing wastewater treatment solutions (Turley & Semple, 2013).
Monitoring and evaluation	Implement a system for ongoing monitoring and evaluation of the technology's economic performance to make adjustments as needed.

It is essential to involve various stakeholders, including financial experts, engineers, environmental scientists, and regulatory authorities, in the assessment process to make well-informed decisions regarding wastewater treatment technologies. The choice should balance economic viability with environmental sustainability and social affordability.

3.5 Decision-making Process

Based on the author's best experience, community acceptance of offsite sanitation facilities is a job that is not as easy as working on technical, economic, financial, institutional and environmental aspects. The problem of social participation is the same in other countries (Fakere & Ayoola, 2018; Jiménez et al., 2019; Nelson et al., 2021). Therefore, the stage that determines the realisation of this offsite infrastructure is socialisation to the number of people defined above. Communities as users must participate in using sanitation facilities so that the socialisation stage allows people to choose which technology is technically, economically and financially appropriate. Once the user decides on the chosen technology, it expresses social acceptance of running an offsite sanitation system.

Figure 3 presents the decision-making process for accepting a river-based offsite sanitation system based on the flow diagram of Figure 1. Rivers become the point of reference and move upstream in the form of wastewater treatment needs and end in acceptance by the community as users of sanitation facilities.

Next to the upstream, namely, the service area for the maximum number of the population served. By considering the technical and environmental aspects, sanitation planning experts can develop service clusters forming a centralised, decentralised, or hybrid service management system. Once a management system is defined, social experts can deliver technological options and gain societal acceptance.

At the same time, sewer design experts can connect wastewater flow between user sources. Furthermore, the sewer piping network conveys the wastewater to the treatment plant. Ultimately, the effluent from wastewater treatment is safe to flow into rivers.

The feasibility process for offsite sanitation systems based on river assessments provides an alternative methodology for evaluating and planning sanitation systems. Moreover, it aims to achieve a sanitation service system that is technically appropriate, economically viable, financially affordable, socially acceptable, environmentally safe and sustainable.

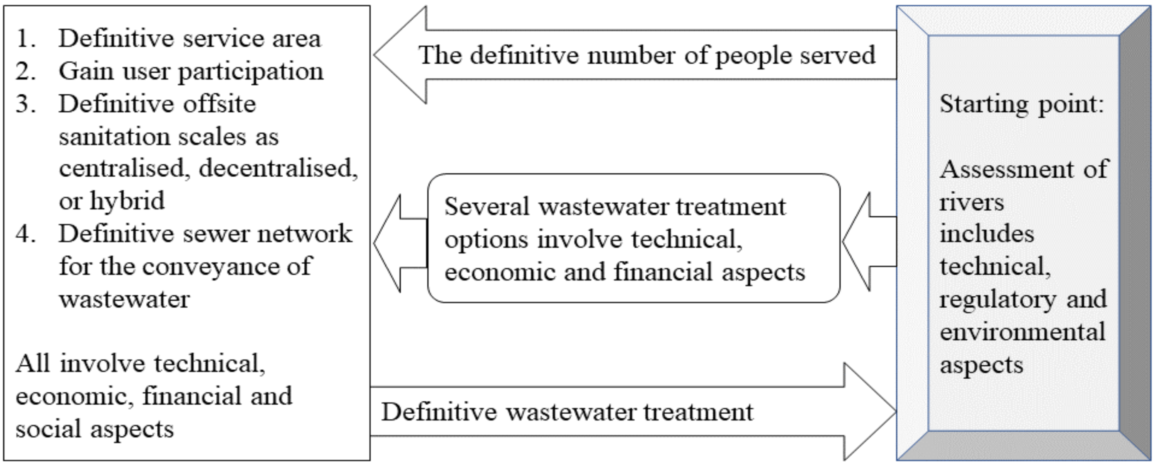

Fig. 3 - Feasibility process of offsite sanitation by disposal in rivers

Technically appropriate means the sanitation system should employ appropriate technology and methods to address sanitation needs effectively. It should be designed using techniques and equipment suitable for the specific context. The sanitation system should be economically viable, considering the available resources and budget constraints. It should be cost-effective, ensuring that implementation and maintenance costs do not outweigh the benefits. Financially affordable means the sanitation services should be affordable for the communities or individuals using them. This assessment involves considering the economic capacity of the users and finding ways to make the services accessible to all income groups. Socially acceptable may be crucial in implementation. The sanitation system should be culturally and socially acceptable to the target population. It should consider local customs, habits, and preferences to ensure that the community adopts and uses it. Environmentally safe assures the system should be designed and operated to minimise adverse environmental impacts. This factor includes proper waste treatment and disposal methods that do not harm the environment. Sustainable services provide the sanitation system should be built to last and continue to provide services over the long term (Willetts et al., 2020).

3.6 Downstream or Upstream

For the downstream approach, selecting a site for discharging wastewater into rivers is a critical process that requires careful consideration to protect the environment and human health. The goal is to minimise the environmental impact and ensure that the river's water quality is not compromised. Key factors and considerations for site selection (Hamdhani et al., 2020) are provided in Table 5.

Table 5 - Assessment of site selection for discharging wastewater into receiving water body

Key factors	Description
Regulatory compliance (Elbakidze & Beeson, 2021)	• Check local and state regulations to ensure compliance with discharge limits, permits, and reporting requirements. • Understand the specific requirements and standards for protecting water quality and aquatic ecosystems.
Site characterisation (HaRa et al., 2019)	• Conduct a comprehensive site assessment to understand the river's physical, chemical, and biological characteristics. • Consider the river's flow rates, water quality, depth, and seasonal variations.
Dilution and mixing refers to Figure 1	Choose a location downstream of the discharge point where the river's flow can effectively dilute and disperse the wastewater, minimising its impact.
Distance from sensitive areas (HaRa et al., 2019)	Avoid discharging near sensitive areas such as drinking water intakes, recreational areas, and habitats of endangered species.

Table 5 continues

Table 5 continued

Key factors	Description
Water quality modelling (Schwermer & Uhl, 2021)	Use water quality models to predict the impact of the discharge on the river's ecosystem. Evaluate the potential effects on aquatic life, such as fish and other organisms.
Elevation and flow rates (Tazioli, 2011)	Consider the elevation of the discharge point relative to the river to ensure proper flow and mixing. Avoid areas with low flow rates that could result in stagnant water. Choose a yearly minimum flow rate to ensure water availability.
Infrastructure (Hummel et al., 2018)	Assess the availability of infrastructure for safe and controlled discharge, such as outfalls, pipelines, and treatment facilities.
Monitoring and reporting (Boutin & Eme, 2016)	Implement a robust monitoring and reporting program to track the impact of the discharge on water quality. Ensure that real-time data is available to promptly respond to any unexpected events or violations.
Wastewater treatment (Naidoo & Olaniran, 2014)	Evaluate the need for wastewater treatment before discharge to meet regulatory standards and reduce the impact on the river.
Stakeholder engagement (Kvam, 2019)	Engage with local communities, environmental organisations, and regulatory agencies to gather input and address concerns.
Best management practices (Lam et al., 2011)	Implement best management practices to minimise the environmental impact, such as using advanced treatment technologies and pollution prevention measures.
Contingency plans (Hummel et al., 2018)	Develop contingency plans to respond to emergencies like spills, equipment failures, or extreme weather events.
Long-term sustainability (Capodaglio et al., 2021)	Consider the long-term sustainability of the discharge site and the potential for future changes in regulations or environmental conditions.
Public outreach (Kvam, 2019)	Communicate the plans and potential impacts to the public, ensuring transparency and trust.

Site selection for discharging wastewater into rivers is a complex process that requires interdisciplinary expertise and a commitment to protecting water resources and ecosystems. Collaboration with relevant agencies and stakeholders is essential for responsible and sustainable wastewater management.

For the downstream approach, determining the priority sanitation service area involves identifying and ranking areas or neighbourhoods based on specific criteria to ensure efficient and equitable allocation of sanitation resources and services. The steps to determine the priority sanitation service area are presented in Table 6. Determining priority sanitation service areas is crucial in addressing public health and environmental issues (Cronk & Bartram, 2018). It helps ensure that resources are directed where they are most needed and that sanitation services are provided equitably.

Table 6 - Assessment criteria of priority sanitation service area

Key factors	Description
Define objectives	Clearly define the objectives and goals of the sanitation service area prioritisation. The objective may include goals such as improving public health, minimising environmental impact, or ensuring equitable service distribution.
Data collection	Gather relevant data that will help in the prioritisation process. This data can include information about population density, current sanitation infrastructure, disease prevalence, environmental factors, and socioeconomic indicators.

Table 6 continues

Table 6 continued

Key factors	Description
Criteria for prioritisation (Graham et al., 2019)	1. Establish a set of criteria to evaluate different areas. Common criteria include: a. Public health impact. Assess the potential health risks associated with inadequate sanitation. b. Environmental impact. Consider the environmental consequences of poor sanitation. c. Socioeconomic factors. Evaluate the economic and social conditions in the area. d. Existing infrastructure. Assess the condition of the current sanitation infrastructure. e. Population density. Consider the number of people living in the area. 2. Weighting criteria. Assign weights to each of the criteria based on their relative importance. For example, public health impact might be given a higher weight if the main goal is to reduce the spread of diseases. 3. Data analysis. Analyse the data and apply the weighted criteria to calculate a score for each area. This score will help prioritise the areas. Various software and statistical tools can be used for this purpose. 4. Ranking and Classification. Rank the areas based on their scores, from the highest to the lowest. This method can classify areas into different priority levels, e.g., high, medium, and low priority.
Consult stakeholders (Kvam, 2019)	Involve relevant stakeholders, such as local government, community representatives, and sanitation experts, to review and provide input on the prioritisation.
Resource allocation (Graham et al., 2019)	Allocate sanitation resources and services to the high-priority areas first. These areas are likely to have the greatest need for improvements.
Monitoring and evaluation (Boutin & Eme, 2016)	Continuously monitor and evaluate the impact of the sanitation services in the prioritised areas. Adjust priorities as needed based on changing conditions.
Public awareness and education (Kvam, 2019)	Educate the community in the prioritised areas about the importance of proper sanitation practices and the services provided.
Long-term planning (Capodaglio et al., 2021)	Develop a long-term plan for improving sanitation services in all areas, ensuring that the entire region benefits over time and that lower-priority areas are not neglected.
Adaptability (Lawrence et al., 2019)	Be prepared to adapt the prioritisation as new data becomes available or the situation changes. Priorities may shift over time.

From the offsite management scale perspective, the primary difference between the downstream and upstream approaches is as follows. The downstream approach at the beginning of the planning stage produces a level of water dilution to indicate the feasibility of the waters as final disposal. Table 1 states the level of water dilution as a technical feasibility requirement. Furthermore, this approach can determine the definitive number of people, the coverage area, the sanitation system, and treatment options.

While the upstream approach can determine whether or not the water can dilute the wastewater effluent later, in this position, complex problems can arise when there is no technically and environmentally feasible water body to dispose of the effluent. Otherwise, a sophisticated treatment process is required to replace the water dilution function.

Therefore, it may be good to use a hybrid approach by running both to strengthen the respective planning methods depending on the availability of water bodies. However, policymakers and professionals can make decisions considering the efficiency of resources.

4. Conclusions

The feasibility assessment for rivers includes technical conditions, environment and institutional regulations. The suitability of a river for wastewater disposal requires that the river quality load be greater than the wastewater quality load. In addition, the degree of dilution of the river must be greater than one. Wastewater treatment options should include the substance exceeding stream standards. Meanwhile, the feasibility criteria for discharging wastewater into rivers resulted in definitively served populations following the effluent quality parameters. This formation facilitates and accelerates the delivery of technology choices to a definitive number of people and gains their participation in using sanitation facilities.

Assessment of the capacity and quality of a river to receive wastewater requires calculating many quality parameters. For this reason, this study recommends that programming experts formulate fast methods for assessing tens or even hundreds of quality parameters. Rapid river assessments can provide sufficient time for the hard work of community acceptance and adequate and affordable wastewater treatment options.

It is necessary to conduct pilot studies in controlled conditions to test the feasibility of the proposed mixture. The pilot can provide valuable data on the actual performance of the mixture in terms of water quality and ecological impact. Once the pilot study is determined, a monitoring and sampling plan can be designed to ensure ongoing compliance with regulatory standards. Define sampling locations, frequencies, and the parameters to be measured. In addition, perform a risk assessment to identify potential adverse effects and their probabilities. The risk should consider worst-case scenario mitigation measures and involve local communities, relevant stakeholders, and regulatory agencies in decision-making. Their input and concerns should be considered in the feasibility assessment.

It is essential to recognise that the specific steps and requirements may vary depending on the characteristics of the river and wastewater and the goals of the mixing process. Always consult with environmental experts and regulatory authorities to ensure the feasibility assessment meets all legal and environmental standards.

Author Contributions

GS: Methodology, Formal Analysis, Writing—Original Draft Preparation on sanitation; HS: Visualization, Writing—Original Draft Preparation, focusing on building onsite sanitation; SM: Conceptualization, Investigation, Formal Analysis, Writing—Review and Editing, Validation, Supervision, and he served as Team Leader of the Surabaya City Sewerage and Sanitation Development Programme, 1996-2000.

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