



Analysis of Final Disposal of Fecal Waste and Wastewater in Dense Urban Settlements

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ABSTRACT

Access to sanitation in dense settlements is critical. Neighborhoods with communal toilet facilities and groundwater supply sources are important sectors for households that do not have private toilet facilities and do not subscribe to the city's piped sewerage system. This paper aims to examine the system for managing domestic waste of communal toilets in dense settlements of Bandung City, West Java. From December 2022 to May 2024, to meet the research objectives, we used questionnaires and surveys in a quantitative descriptive method; analyzing the waste management of communal toilets that have groundwater supply sources, liquid and fecal waste management, and toilet hygiene were assessed by considering the real conditions of the environment. Domestic waste has not been managed optimally, still causing environmental pollution and affecting groundwater quality. Domestic waste management, considering social and demographic factors, needs a sustainable sanitation system with more effective and efficient waste handling, as 46.7% of households finally dispose of the river, 37.5% to septic tanks, and 15.8% of homes are linked to public piped sewage systems. Limitations of the study are only applicable to the study site of West Java, Indonesia, based on recent historical data.

1. INTRODUCTION

Regulation 14 of 2016 in the Republic of Indonesia pertains to the Management of Housing and Settlement Areas, 4 (1). The implementation of housing and settlement areas is a unified system that is carried out in a coordinated, integrated, and sustainable manner. A dense settlement is a settlement with a high-density population of >200 people/km² (Nursyahbani & Pigawati, 2015). Every individual and community has access to basic sanitation facilities to realize a community free from Open Defecation-Free (ODF) in any place (Kementrian Kesehatan, 2014). ODF refers to a situation where all members of the community no longer practise open defecation and consistently use adequate sanitation facilities, which forms a vital foundation for community-led sanitation programmes. ODF is determined not only by the availability of latrines, but also by the strength of social norms, year-round access to water, household economic conditions, sanitation literacy, support from community health workers and health professionals, and active community participation in behavioural change.

Law number 32 of 2009 explains that the definition of environmental conservation and management is the power,

characteristics, and unity of the environment, all objects and living things, and places that affect life and well-being. Domestic waste from toilets requires multi-sectoral policies and regulations related to health, water, and sanitation. World population growth has resulted in increased production of wastewater, sewage, and leachate, which can damage the environment and impose high costs on society (Bouyakhass et al., 2023). Groundwater is an important resource whose utilization for various reasons causes several environmental and socio-economic problems, such as reduced water supply, land subsidence, and pollution. A healthy toilet must have a waste disposal channel (Shukla et al., 2023), and in Indonesian society, there are generally two terms for toilet waste management: cubluk and septic tank (Kerstens et al., 2016).

Groundwater contamination is linked to the existence of septic tanks, the absence of treatment, the absence of proper sanitation, and the failure to adhere to community hygiene standards (Gamar et al., 2018). Changes in water quality can have major health implications as well as negative impacts on important livelihood processes such as water treatment procedures (Opere et al., 2020). Greywater from source use in toilets potentially contains a variety of contaminants consisting of bacteria and viruses, oils and fats, surfactants,

dissolved and particulate organic matter, as well as inorganic salts (Wallin et al., 2021). The prevalence of waterborne diseases includes hepatitis, intestinal infections, diarrhea, dysentery, cholera, typhoid fever, jaundice, and skin diseases in children, followed by older and younger adults (Khan et al., 2018).

The subsidization and provision of toilet facilities for community sanitation in urban areas that are collectively affordable is also implemented with a policy of financing waste management, so that it is economically beneficial for low-income communities. Although the healthy disposal of household waste has been achieved, an efficient waste source separation system needs to be built thoroughly (Li & Wang, 2021). The preservation of public health and the environment through waste management, as well as its minimization via a circular economy, is essential for achieving sustainable development (Velis et al., 2023).

Municipal solid waste (MSW) disposal is increasing due to population increase and lifestyle changes. Most of the waste that enters streams is domestic waste from household activities (FEREDE, 2018). In urban areas with wide coverage, geology, hydrogeology, and sanitation monitoring practices, there is contamination of pathogenic bacteria (*Escherichia coli*, thermotolerant coliforms, total coliforms, fecal streptococci, and *Clostridium perfringens*), parasites, and viruses (Zume et al., 2021; Sari et al., 2021). Contamination occurs in water and soil, originating from feces, domestic sewage, urban and agricultural waste, and industry. The use of On-Site Domestic Wastewater Treatment Systems (ODWTS) is a practical and favored option for managing municipal domestic wastewater. On-site sewage treatment systems offer better economic efficiency in comparison to sewerage systems, but the affordability of centralized systems also relies on the expenses linked to sewerage infrastructure.

The issue of sanitation, especially open defecation, has become a concentration of government efforts in the integration and management of interventions in sustainable development goals, as well as ecological restoration and water resources management (Anthonj et al., 2018). It was found that 36% of wells contained *E. coli* exceeding quality standards, with contamination from domestic waste (Affum et al., 2015). Diarrhoeal diseases, cholera, and dysentery can be caused by bacteria that contaminate water. The contribution of pollutant sources to water quality requires early detection of toxic elements in groundwater (Suriadikusumah et al., 2021). Waste from the toilet activities of each family is increasingly deposited and becomes a problem for people in densely populated settlements (Gizińska-Górna, 2020). Drainage of community-owned septic tanks that are some distance away, road access, and waste transport cars are obstacles, so that domestic waste by residents is disposed of directly into the river (McGranahan & Mitlin, 2016). Not all households have septic tanks, so the pipes are directly discharged into the nearest river (Daughton, 2018); thus, waste management is certainly related to government policy (Michiani & Asano, 2019).

Waste disposal in cities should be directed to landfills as a target by 2035 (Agyabeng-Mensah et al., 2021). Targets for reducing the impact of waste management, for the disposal, reuse, and recycling of various waste types, are becoming increasingly strict. (Acosta et al., 2020). It is expected that recycling targets will be increased. By 2025, the goal is to

recycle 55% of municipal waste, and by 2030, the target is to recycle 60% (Hupponen et al., 2023). Managing household waste will become very important, and simultaneously create jobs in the waste management sector (Chirinda et al., 2023). Waste classification is essential and valuable for improving urban environmental quality and promoting human well-being (Zheng et al., 2023). Selecting appropriate landfill sites is crucial to maintaining a healthy environment and safeguarding human health. This involves considering various factors such as environmental, economic, and social criteria, which can contribute to the complexity of the landfill site selection process (Rezaeisabzevar et al., 2020).

The need to address waste issues and increase access to non-shared toilet facilities per household (Mutymbizi et al., 2020). Population growth, economic growth, urbanization, and high food consumption can lead to accumulated waste, challenges in management, and addressing environmental issues that are significant to sanitation, the environment, and health (Anuardo et al., 2022). The living conditions make it difficult for underprivileged populations to maintain good hygiene practices, and vulnerable populations, such as the poor and minority groups, struggle with managing hazardous domestic waste (Giné-Garriga et al., 2021). Programs implementing sanitation improvements have been implemented by the Indonesian government with various results and conditions based on goal realization (Marselina et al., 2022). The people of Bandung City with various backgrounds of education and occupation levels still need public efforts in preserving the river and maintaining cleanliness, so that it has an impact on public health (Woldesenbet & Kebede, 2021).

As settlements that are getting older every year, there are changes in the number of residents and also the physical development of community housing. Of course, there will be an imbalance between the availability of land and the need for waterways or household domestic sewerage (Dirix et al., 2021). In the context of system challenges towards sustainable development of a city, it is carried out thoroughly in the installation of domestic sewerage piping, especially from community housing toilets (35, 36). Involvement by the government and infrastructure companies will lead to financial independence and benefits for homeowners who follow the rules. There are rules for septic tank construction in the Indonesian National Standard (Hendriksen & Hoffmann, 2018). Assessing safely managed sanitation faces a major obstacle due to the absence of data on current sanitation infrastructure and the extent of safety in it (Nasim et al., 2022). According to WHO/ UNICEF/ World Bank, access to the services provided, including pit latrines, septic tanks, composting toilets, and Container-Based Sanitation (CBS), is used by approximately 3.4 billion people (Jakariya et al., 2023).

Globally widely used flush toilet drains connected to sewer pipe systems generate fecal sludge (FS), but there is limited knowledge regarding the impact of on-site sanitation system (OSS) type and other emptying and transportation factors on the emptying process of OSS, or how FS is removed from the environment (Conaway et al., 2023). Composting is an effective alternative to recycling fecal sludge into organic fertilizer. The use of earthworms effectively promotes the composting efficiency of fecal sludge and reduces the Global Warming Potential (GWP) (Zhong et al., 2023). The lightly to

moderately polluted classification of fecal sludge pollution index in Indonesia in communal and individual wastewater treatment is in the range of 1.8 to 7.8. Communal wastewater treatment under management averages <50% of design capacity. Treatment type, capacity, detention time, hydraulic loading, organic loading, influent quality, and effluent quality can be used as components and aspects of communal wastewater treatment. The technical implementation of wastewater treatment and septic tanks must be watertight. So human feces that mix with water and cause thousands of bacteria do not cause infiltration, causing pollution of the surrounding environment. The construction of septic tanks must have ventilation or air holes, control holes, and fecal waste inlet and outlet pipes so that periodic desludging to the Fecal Sludge Treatment Plant (IPLT) can be carried out smoothly.

Innovative approaches to fecal sludge management help improve sanitation practices and increase public awareness of sustainable sanitation systems. Fecal sludge from private septic tanks showed lower BOD and ammonia (NH⁺₄-N) values than communal toilets (Rudolph & Muchesa, 2023). Fecal sludge consists of everything that accumulates in on-site sumps, with different characteristics from wastewater sludge and feces (Ward et al., 2023). Household behaviors and practices involving non-compliance with septic tank construction regulations include not adhering to design standards, irregular cleaning, improper disposal of items in toilets, inadequate or improper design of pouring stations, tools, and equipment, and insufficient awareness and knowledge among all stakeholders (Gautam et al., 2021). Fecal sludge and septage management (FSSM) include: 1) Fecal sludge is gathered from its original location, then emptied and conveyed to the intended destination; 2) The private sector operates mechanized pit emptying services; 3) Collaboration among private sector firms has enhanced the efficiency and comprehensiveness of this management; 4) Regions with insufficient value in terms of capital appreciation and productivity, containment and reuse, or disposal have been limited.

Indonesia is one of the lagging countries in achieving its focus on establishing wastewater and solid waste collection, treatment, and recovery systems. In Indonesia, the majority of households utilize septic tanks for their wastewater needs, but 95% of these septic tanks leak, leading to groundwater pollution. Less than 1% of the population in 2012, serviced only 12 operating WWTP plants in Indonesia (Kerstens et al., 2015). Toilets' pre- and post-construction needs, like water supply availability and safe, sustainable disposal, treatment, and recycling of sanitary waste, are often overlooked.

Sanitation refers to the management of human feces and consists of three major components: collection at the toilet, transport (via sewer or emptying service), and treatment (Bernal et al., 2021). SNI: 03-2398-2017 on septic tank planning procedures states that a septic tank is a watertight room consisting of one or several rooms useful for accommodating and treating household domestic waste, especially toilets (Tim Penyusun, 2022). In the process of digging an infiltration septic tank concerning the SNI, the minimum height is 1.5 m, so that the excavation of the soil is made at least 2 m, then a divider is made and a sewer pipe is set from the toilet hole to the septic tank. The pipe must be watertight, anti-corrosive, and without joints. The pipe is

connected with a T-connection at the outlet of the tank, with the pipe sloping from the toilet to the drain (Krueger et al., 2020). Finishing the septic tank is done by making a layer of wall under the septic tank. After finishing, ventilation holes are made in the septic tank cover so that the circulation is smooth and the septic tank does not explode.

Small-scale pollutant sources such as septic tanks are significant contributors to river pathogens (Richards et al., 2016). The assessment criteria for public restroom technologies consider economic, social, and environmental advantages, while correlation studies emphasize the economic, technical, and environmental aspects of restroom performance (Souza, 2023). Sewage treatment of portable toilets and small-scale septic tanks is needed to minimize public health and environmental risks as a sustainable approach (Rodriguez et al., 2023). Human waste treatment is regulated by law in many countries, given the high content of organic components and pathogens. Integration of environmental or land use data with Microbial Source Tracking (MST) is essential for a better understanding of nutrient content and fecal contamination (Vadde et al., 2022). Needed to reveal the management of domestic waste in urban settlements that causes environmental pollution and hinders the success of sustainable development goals. This study aims to evaluate and think critically about sanitation for the sustainability of public toilets accessed by the community.

2. METHOD

To analyze the domestic waste management system of communal toilets in dense settlements, this study used the Quota Sampling method in determining the sample of biotic components. This sampling method is done by determining the sampling to be used in advance, or the number of respondents has been determined in advance for the questionnaire (Harmon et al., 2016). Quantitative descriptive research was conducted using surveys and questionnaires (Creswell, 2003). The objective of this study was to analyze the domestic waste management of communal toilets in dense urban settlements in Kelurahan Sukajadi, Bojongloa Kaler, Astana Anyar, and Andir. The locations were chosen to represent Bandung's dense urban settlements and to identify community sanitation access measures and strategies in communal toilet waste management. Quota sampling research using the Yamane formula with data on the total population of 2020 in Bandung City, West Java Province, Indonesia, people from BPS Bandung City data, the number of residents in the four research locations was then calculated:

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

Notes:

n = number of samples required

N = total population

e = sample error rate of 5%

Based on the population of the four research locations, the number of samples is obtained, namely, 400 respondents, as displayed in **Table 1**:

Table 1. Location, Population, and Research Sample

No.	Location	Population in 2020 (people)	Sample (people)
1	Bojongloa Kaler	124.323	124
2	Astana Anyar	73.232	73
3	Andir	99.119	99
4	Sukajadi	103.060	103
Total		399.734	400

Source: Researcher's data

We conducted a survey and questionnaire in four sub-districts in the research location, which were designated as sampling locations. **Figure 1:**

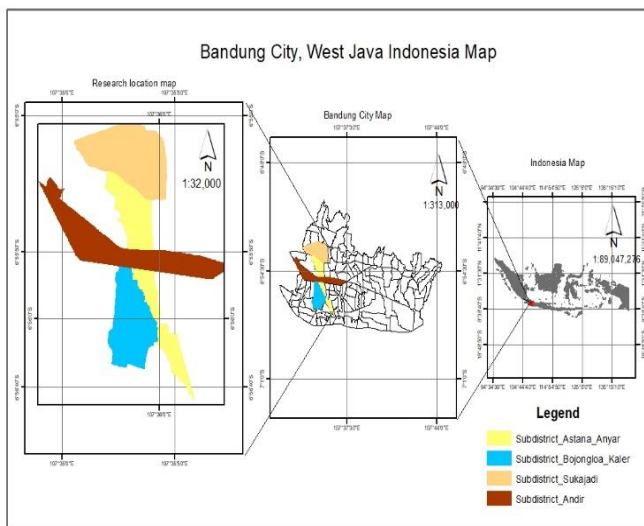


Figure 1. Location Map of Bandung City in Indonesia

3. RESULTS AND DISCUSSION

The study was conducted in a densely populated settlement, and households had limited access to toilets. This is because most residents are tenants with low incomes. The sanitation system used is predominantly a pit latrine or toilet connected to a septic tank and then piped into the river, which causes the septic tank to fill up quickly, so frequent disposal is necessary for fecal sludge. Pit latrines (both old and improved types) are still in use in the densely populated urban areas that were examined, especially those located on the banks of rivers. The system of collecting, emptying, transferring, and treating domestic effluents is still not well managed and is a public sector issue, as it can result in health risks. Domestic waste from latrines during periods of high rainfall can overflow, polluting the environment. In Bandung City, about 68.7% of households have PDAM as their main water source. For access to SPAL connection, 12.78%, and 87.22% of sewage is disposed of using non-drainage methods in a majority of households, as shown in Error! Reference source not found. :

Table 2. Percentage of Households by Final Disposal Site for Fecal Waste

No.	Faecal Landfill	Percentage (%)
1	Septic tank	41,8
2	SPAL	12,78

No.	Faecal Landfill	Percentage (%)
3	River	44,82
4	Ground Holes	0,24
5	Fields/gardens	0,36
Total		100

Source: Researcher's data

From **Table 2**, the research results show that households without sewer connections use private and communal septic tanks. Many of the septic tanks are inadequately built, cannot undergo emptying, or release untreated human waste into sewers that flow wastewater into adjacent water bodies. In the settlements of Bandung City, houses near the river do not have sewerage connections, so they discharge directly into the river.

3.1 Households With Healthy Toilets Based on Toilet Type in Bandung City

Domestic waste contains liquids and solids, water waste, and fecal waste. Wastewater from public sanitation activities in settlements is a source of groundwater pollution in urban areas. The capacity, quality, and carrying capacity of water bodies are declining because the increase in population is not matched by the ability of water bodies to cope. Domestic waste is a source of pollutants in well water, which can be organic or inorganic. Domestic wastewater pollutant parameters include COD, BOD, TSS, Ammonia, oil, fat, detergent, pH, and temperature. Domestic wastewater contains microorganisms such as bacteria, protozoa, fungi, viruses, and so on, and has physical, chemical, and biological characteristics. Physical characteristics include turbidity, temperature, and TSS. Chemical characteristics include BOD, COD, pH, and detergent, while biological characteristics include total coliform. The study results include the attributes and criteria for the standard quality of sanitary water of Permenkes RI No. 32 of 2017 and No. 2 of 2023, which were used in analyzing the quality of well water at 24 location points. As a result of domestic waste disposal without prior treatment, it disturbs environmental aesthetics and degrades water quality. The real picture in the field, based on the results of this research survey, is that household domestic waste, especially communal toilets, is discharged directly into water bodies, drainage channels, sewers, and rivers.

3.2 Domestic Waste from Toilets, Liquid and Feces

The number of toilets based on the Bandung City government's health criteria in the four sub-districts of the study location, based on data from the Bandung City Health Office (2023), is shown in **Error! Reference source not found..** Andir sub-district has a recorded number of communal toilets 98, semi-permanent healthy toilets 225, and permanent healthy toilets 4400. In the Astana Anyar sub-district, there are 259 communal latrines, 2239 semi-permanent healthy latrines, and 1345 permanent healthy latrines. In Kecamatan Bojongloa Kaler, there are 336 communal latrines, 0 semi-permanent healthy latrines, and 2795 permanent healthy latrines. In the Sukajadi sub-district, there were 321 communal latrines, 4679 semi-permanent healthy latrines, and 1504 permanent healthy latrines. The criteria for latrines used are based on Permenkes

RI No. 3 of 2014 concerning STBM, among others: permanent healthy latrines (JSP), which are latrines equipped with a gooseneck model latrine and a watertight septic tank and or wastewater treatment system (SPAL).

The total population and number of communal latrines are shown. Kecamatan Andir has 99,000 people with 98 latrines, Kecamatan Astana Anyar has 73,232 people with 259 latrines, Kecamatan Bojongloa Kaler has 124,323 people with 336 latrines, and Kecamatan Sukajadi has 103,060 people with 321 latrines.

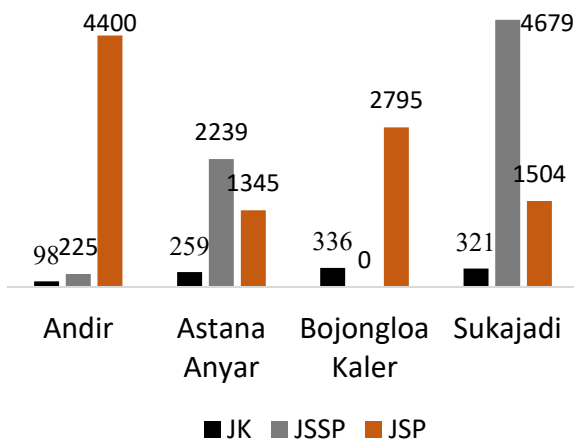


Figure 2. Number of Healthy Latrines by Latrine Type in Bandung City

Description:

JK = Communal latrine

JSSP = Semi-permanent healthy latrine

JSP = Permanent healthy latrine

Access to communal latrines by the community has economic benefits for the community as it can reduce the cost of sanitation and water. The population and number of communal latrines are shown in Error! Reference source not found.3:

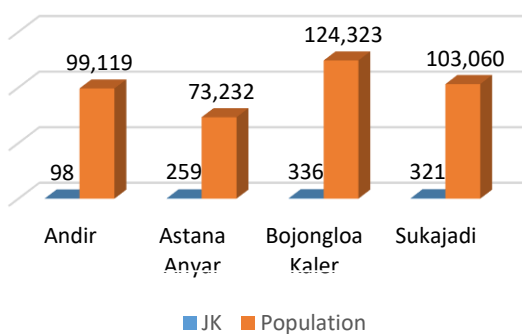


Figure 3. Population and Number of Communal Latrines

Domestic waste is handled in different ways by households, such as utilizing sewers or private and communal septic tanks. Although septic tanks and pit latrines can store waste for extended periods, they need to be emptied with caution. Household access to sewerage varies widely. Sewer-

connected toilets require a regular water supply for flushing. If the water supply is intermittent, the sewer system will experience issues with its functionality, leading to a higher chance of contaminating the piped water supply.

The results of the study related to the final disposal of domestic toilet waste from 400 respondents representing each household are: 46.7% of households' final disposal into the river, 37.5% of waste into septic tanks, and 15.8% of households connected to the sewer, safely managed by PDAM pipeline. Communities that rely on private wells often use private septic tanks as their primary alternative for sewage disposal.

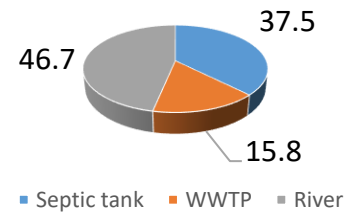


Figure 4. Percentage of Toilet Waste Landfill

The survey findings and field interviews also emphasized the inadequate construction of latrines and the substandard practices for emptying them, schedules, and the inability to prevent contamination, posing a risk to groundwater sources near rivers, as well as high residential density. Domestic waste from sanitation activities is directly disposed of using pipes that drain into nearby waterways or stormwater drainage channels. Open drains mean that many households have access to drains. In the study settlements, some toilets do not have access to sewer infrastructure. Limited land and economic factors mean that local governments need to conduct environmental evaluation and mitigation, and the management and treatment of domestic waste should be regulated, especially toilet waste, to ensure that it is safe for the community in densely urbanized settlements.

4. CONCLUSION

Domestic waste management, considering social and demographic factors, indicates the need for a sustainable sanitation system with more effective and efficient waste management, as 46.7% of household final discharge to the river, 37.5% of household final discharge to septic tanks, and 15.8% of households are connected to safely managed PDAM piped sewers. The percentage of communal toilets that do not manage waste is high, hindering the achievement of the SDGs by 2030 and risking a poor environment. It is crucial to adjust the quantity of clean communal toilets based on the number of users. The results highlight the pressing need to guarantee fundamental sanitation facilities in Bandung City, West Java. Decision-makers must allocate funds for sufficient communal toilets and proper household waste disposal. This study has limitations as it was conducted solely in a densely populated residential area of Bandung City, West Java; consequently, the results cannot necessarily be generalised to other regions with different social, economic, and sanitation infrastructure characteristics. Furthermore, the data used is of a quantitative

descriptive nature, based on surveys and questionnaires conducted over a specific period of time, and therefore does not fully capture the dynamics of changes in community behaviour and environmental conditions over time.

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