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Mapping Sanitation Risk at the Hamlet Level: A Comprehensive Assessment of Sub-District in Central Jakarta

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Abstract. Sanitation in residential areas is significantly essential, requiring more attention, particularly in areas with dense population and developing countries such as Indonesia. High population density increases the challenges of treating solid and liquid waste produced by residents. Therefore, this study aimed to assess sanitation risk in sub-district of Central Jakarta, Indonesia, based on four indicators, namely hazard, exposure, vulnerability, and capacity. The analysis started with hazard indicators, followed by an assessment of potential exposure to hazard, and determination of vulnerability level. In the final stage, the capacity was evaluated to determine the ability of the current system to address sanitation issues. The results showed that most areas of sub-district were at low risk due to the sufficient capacity of the current system to meet the needs of residents. However, there were also areas with poor sanitation, particularly in facing natural disasters such as floods and droughts. Sanitation risk assessment used in this study provided valuable information to identify priority areas for sanitation development. The results would support the government in determining development budget priorities for sanitation infrastructure development.

Keywords: Exposure; Hazard; Priority risk; Sanitation; Vulnerability

1. Introduction

The need for proper sanitation is stated in the policy direction and development strategy of the 2020-2024 Medium Term Development Plan (RPJMN) by BAPPENAS (2020). This policy emphasized that liquid and domestic waste should be properly handled to obtain low-carbon development. Based on the data obtained from DKI Jakarta Statistics Agency/BPS (2020), 83.02% of households already use their sewerage facilities, showing access to proper sanitation. Among these areas, Central Jakarta Region and Thousand Islands have the lowest percentage of access to proper sanitation, accounting for 0.6% and 7.4%, respectively.

Several households still experience poor sanitation, leading to various health problems such as stunting and diarrhea. Previous studies showed the importance of proper sanitation, including access to clean water and maintaining safe distances from water sources (BRPAM DKI Jakarta, 2021). However, the occurrence of the COVID-19 pandemic has added a new dimension to this issue, leading to a high demand for clean water

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(Purnama and Susanna, 2020). According to the Indonesia Water Institute (2021), the need for clean water has tripled compared to pre-pandemic conditions, showing the significant role of hygiene and sanitation activities in mitigating risk associated with the COVID-19 pandemic (Berawi, 2020). This study contributes to the existing body of knowledge by showing the specific challenges faced in Indonesia regarding inadequate sanitation and high vulnerability to COVID-19 transmission through water sources (Zakianis *et al.,* 2021; Cairncross *et al.,* 1996). Moreover, the novelty lies in the examination of the parameters that pose risk to sanitation, the unique challenges posed by the COVID-19 pandemic, assessment of the high demand for clean water, and the provision of specific recommendations. The results offer valuable insights for policymakers, study team, and practitioners in the field of sanitation and public health, emphasizing the urgent need for improved sanitation practices and hygiene awareness regarding the ongoing pandemic (Cameron, Chase, and Suarez, 2021; Campos *et al.,* 2015).

2. Conceptual Framework for Risk Assessment

This study aimed to develop recommendations that support sanitation planning and development. Risk assessment was carried out based on the assumption that the situation of domestic waste disposal occurred in an open environment, thereby allowing exposure to residents. Regarding Environmental Health Risk Assessment (EHRA), the mapping and evaluation of sanitation conditions are carried out to identify and analyze various factors related to social conditions, exposure, water supply, domestic waste treatment, and drainage. By mapping and assessing these aspects, EHRA helps to understand the potential risk and hazard associated with sanitation, as well as their impacts on environmental and public health. The scope of assessment in EHRA includes:

- Social Conditions: Assessment includes examining the social factors and conditions influencing sanitation practices and behaviors. This includes socioeconomic status, cultural norms, education levels, and community engagement (Jimung, 2011).
- Exposure: Assessment focuses on evaluating the potential exposure pathways to contaminants or pathogens resulting from inadequate sanitation conditions (Snoad *et al.,* 2017). This includes assessing the routes of exposure and the associated risk to human health.
- Water Supply: Assessment evaluates the quality, accessibility, and reliability of water sources used for domestic purposes. This includes assessing the presence of contaminants, adequacy of water treatment, and the potential for waterborne diseases (Pond *et al.,* 2020).
- Domestic Waste Treatment: Assessment examines the management and treatment practices for domestic waste, including wastewater and solid waste (Sunik, Kristianto, and Khamelda, 2018). This includes assessing the adequacy and effectiveness of waste treatment systems in minimizing environmental contamination and health risk (Othoo, Olago, and Ayah, 2023).

By conducting a comprehensive assessment of sanitation conditions using EHRA, policymakers, study team, and practitioners can gain insights into the existing risk and vulnerabilities. This information provides a guide on the development of targeted interventions, policies, and strategies to improve sanitation practices, mitigate risk, and protect public health as well as the environment (Medema and Ashbolt, 2006).

Sanitation services related to waste management play a significant role in maintaining the environmental carrying capacity of an area (Eisenberg, Scott, and Porco, 2007). These services directly influence environmental carrying capacity through waste management, water quality, disease prevention, and resource conservation. However, improper or

inadequate sanitation services can lead to environmental degradation, ecosystem disruption, and a reduced carrying capacity. The accumulation of untreated waste, release of pollutants, and contamination of water sources also have the capacity to degrade ecosystems, reduce biodiversity, and pose risk to human health. Therefore, integrating sustainable sanitation services is crucial for maintaining and enhancing the environmental carrying capacity. In this study, risk assessment was used based on EHRA and an understanding of WASH (water, sanitation, and hygiene) developed by Global Water Partnership (GWP) for UNICEF (United Nations Children's Fund) (UNICEF and GWP, 2017a; 2017b; 2017c; 2017d; 2017e; 2017f). Although there are limited reports on sanitation risk assessment, a recent study by Roos (2021) has identified the challenge of insufficient data and reliable information regarding sanitation conditions in African cities, which affects effective planning and investment prioritization. To overcome this problem, the study developed and implemented a rapid and participatory risk assessment tool, which facilitated data collection, urban sanitation planning, and community engagement in decision-making processes. To validate the effectiveness of the tool, the results were compared and triangulated with data obtained from traditional household surveys, transect walks, and existing secondary sources. The validation results showed that the tool was user-friendly, cost-effective, and capable of providing a prompt method for data collection, offering reliable insights into neighborhood-level sanitation risk. Therefore, this study aimed to adapt the previous methods used by EHRA to enhance the understanding of sanitation risk assessment.

This study was conducted from October to November 2021 using qualitative methods with the implementation of data collection by interviews and observations. The sample consisted of households selected using Random Sampling Survey Method, where survey form was filled out online and distributed to all hamlets. This method included selecting members of the population randomly without regard to strata (homogeneous) since questionnaires and interviews were distributed online. The sample was part of the population expected to represent the whole population in this study. For the number of samples to be determined, the Slovin formula was used with a 90% confidence level and an 8% margin of error. Sub-district (*kelurahan*) had 9 hamlets (*rukun warga*/RW), and quota sampling was carried out, consisting of a maximum of 100 respondents. The status of respondents included husband or wife, with an age range of 22-67 years. The purpose of this study was to support sanitation services to be more resistant to changing conditions of environmental carrying capacity, either current or future conditions, with risk formula (equation 1) expressed as:

$$Risk = Hazard \times Exposure \times Vulnerability \quad (1)$$

Risk formula includes values for hazard, exposure, and vulnerability. Although capacity is not part of the equation, it is assessed separately to determine risk priorities for vulnerability levels. The capacity parameter is closely related to political issues and the adaptability of an area, leading to difficulty in assessing the capacity score due to complex justification. Moreover, the study framework is shown in Figure 1.

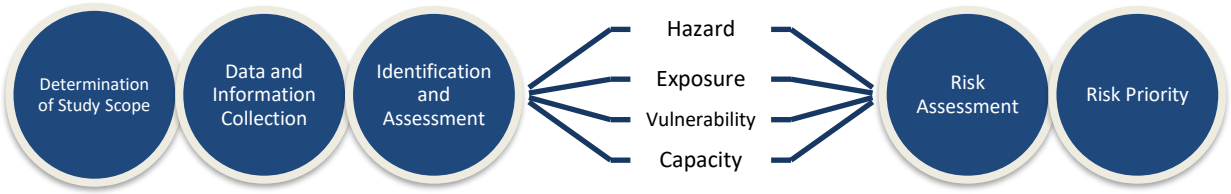

Figure 1 The study method includes data from 'Harapan Mulya, 2021' and Harapan Mulya, 2020' for historical context

This study used literature review related to data collection and stakeholder consultation. Stakeholder workshop was conducted to provide final justification for the results of the assessment. In each parameter, a confidence score was determined as the strength of the study conducted. Moreover, Figure 1 represents the method that was used for risk assessment for sanitation.

2.1. Identification of Parameters

The relevant issues considered for parameter identification are presented in Table 1.

Table 1 Identification of study parameters

Hazard	Exposure	Vulnerability
Environmental and geophysical events	Percentage of critical infrastructure affected	Social
Ongoing conflict, socio-political tensions, and possible triggers	Number of water sources affected	Financial
Current and potential political/social unrest and instability	Percentage of a certain land type affected	Physical
Biological hazard	Percentage of population affected	Environmental
Chemical hazard	Percentage of GDP	Human
Cross-border dynamics (as a destabilizing factor)	Income from livelihoods according to sector, e.g., agriculture, fishing, etc.	Political and institutional

Table 1 provides the identification of study parameters to facilitate the assessment process. After identifying all relevant issues, several aspects were considered in analyzing hazard parameters and vulnerability level.

2.2. Assessment of Parameters

In assessing the parameters, it is necessary to consider past events and potential future occurrences. Table 2 provides a list of questions used in determining the score.

Table 2 List of questions for hazard parameter scoring

Hazard
Is hazard currently being experienced or expected to occur in the future?
How often does hazard occur? Is it annually or more regularly? Does it occur only once every few years or rarely experienced?
Is hazard expected to increase in frequency in the future?

Table 2 provides the idea of question list to identify hazard score, with values of 3, 2, and 1, representing high (H), medium (M), and low (L). Furthermore, it shows the extent of hazard affects the exposed subject. During the assessment, a subject is exposed to more than one type of hazard, showing the need for values of exposure to be separated to ensure a more explicit and measurable method. Table 3 provides suggestions for scoring the component of exposure, using the specified classification (UK Department for Environment Food & Rural Affairs, 2012):

Table 3 Exposure parameter score criteria

Component	High	Medium	Low
Physical	>20% of critical infrastructure affected	5–20% of critical infrastructure affected	0–5% of critical infrastructure affected
Environmental	>20% of water sources affected	5–20% of water sources affected	0–5% of water sources affected
Human	>5% of population affected	0.5-5% of population affected	<0.5% of population affected
Financial	Costs – major damage and disruption	Costs – moderate damage and disruption	Costs – minor damage and disruption

2.3. Confidence Score

This study used two confidence score assessments, which focus on determining the current and future conditions. The two scores were combined to obtain the final value for the parameter.

3. General Overview

3.1. Household Waste Management

Handling cleanliness in sub-district area is carried out by providing cart that accommodates waste from Hamlet 01 to 09. Moreover, waste from the cart is transported using a cross-operational car to a temporary disposal site.

3.2. Domestic Wastewater Disposal

Based on the data, sub-district already has latrines and sewerage (Harapan Mulia, 2021). However, from the results of questionnaires, 10% of respondents were found to use public toilet facilities. Regarding the type of toilet used, 75% of respondents had used a goose-neck latrine, while some applied a cubicle-shaped toilet with a lid. For the type of sewerage, the majority already use individual septic tanks. In hamlet 4 (densely populated and slum area) and hamlet 6, an integrated wastewater treatment plant (*Instalasi Pengolahan Air Limbah*/IPAL) with a capacity of 150 m^3/day has been in operation since January 2022. Although respondents are not charged any fees for the use of the IPAL, the facilities are currently facing challenges due to the continuous disposal of solid waste such as sanitary pads into the drainage system, leading to clogging and wastewater overflow.

3.3. Existing Drainage and Flooding Conditions

The results showed that from January, February, to March 2019, there were puddles of water on several roads and residential areas with low land (Harapan Mulia, 2020). This was due to numerous clogged drains blocking the flow of water, affecting areas such as hamlets 05, 07, and 08. Based on field monitoring results, water level reached 20 cm for hamlets 05 and 08, while hamlet 07 was at 40 cm. The flood-prone map of sub-district showed that three hamlets were susceptible to flood risk. Based on the interview results, the flooding that occurred in sub-district could still be overcome in 6 hours.

3.4. Clean Water Supply and Drinking Water

Residents in sub-district mostly used deep and shallow groundwater, including piped water. Based on the results from the questionnaire, the availability of clean water was still sufficient for daily needs. Approximately 75% of respondents were using piped water as a source of clean water, with groundwater serving as an alternative. When the continuity of clean water sources is hampered, residents tend to use bottled drinking water or purchase at the nearest water kiosk good quality. However, there are only a few complaints in hamlets 03, 06, and 07, regarding the quality of water, particularly groundwater sources, which had bad odor and cloudy.

3.5. Hygienic Behaviour

Hygienic behavior is monitored through the Environmental Health Section of the Public Health Center of District by checking the quality of refilled drinking water, and food samples, as well as inspections of sanitation in public and food processing places. Based on the results, there were still samples that did not meet the quality standards, specifically for biological parameters, such as coliforms and *E. coli*. To overcome this problem, the Public Health Center has carried out further guidance and monitoring. Sanitation inspection is also performed with assistance in disinfection procedures and the application of health protocols to prevent the spread of COVID-19. Additionally, monitoring and inspection of

WWTP water samples and clean water are carried out twice a year to ensure compliance with health standards.

3.6. Hygiene-related Diseases

Inadequate sanitation facilities can cause death from diarrhea and significantly impact tropical diseases, such as intestinal worms, schistosomiasis, and trachoma (Iryanto, Joko and Raharjo, 2021). Hygiene-related diseases in sub-district are mainly dengue hemorrhagic fever during 2020, accounting for the lowest number of cases at 79%.

4. Risk Assessment of Sanitation System

4.1. Assessing Level of Risk

4.1.1. Hazard

In this study, hazard parameters related to WASH sector were selected, including environmental events and degradation, biological, chemical, and economic downturns (Moe, 2014). Changes in land use were not included but were categorized as external factors impacting other hazard groups such as deforestation. For each indicator, the impact was observed based on the frequency, intensity, and geographic area affected.

4.1.2. Exposure

In determining the value of exposure, a specific analysis is needed on the object being exposed. This can be carried out by observing the condition of the object in the past when was exposed to danger. Exposure identification was carried out based on predetermined hazard factors. Since one type of hazard can have a significant impact, there is a need to record each hazard and the corresponding exposure.

4.1.3. Vulnerability

The aspects considered are physical, social, financial, environmental, human, and political institutions. Among the six components, questions related to sanitation were asked on a questionnaire or by interviewing the local government.

4.1.4. Capacity

The resilience of humans, infrastructure, the environment, and others exposed to hazard is highly dependent on capacity level. Moreover, capacity can be influenced by the level of awareness, knowledge, data, monitoring, as well as the suitability of plans and policies implemented (Rizani *et al.,* 2019). Based on the assessment of the capacity component, this study found that capacity level in sub-district was still in the appropriate range for sanitation needs in the environment, as shown by the score obtained 1.38 (low risk). Table 4 provides capacity assessment for different components.

Table 4 Capacity assessment of sub-district

No.	Component	Elements	Score
1	Social	Preparedness plans, community participation, environmental community	1.125
2	Financial	Budget for emergency sanitation needs disaster mitigation support	2
3	Physical	Technology and infrastructure of water resources	1.33
4	Environmental	Supervisory partner, alternative protected water resource	1.33
5	Human Resource	Livelihood, support job switching	1.5
6	Political (and institutional)	emergency coordination mechanism, political response to climate change (Oates *et al.,* 2014)	1.4
		Average Score	1.38

4.2. Risk Prioritization

Hazardous event consists of environmental conditions indicators such as flood, drought, and air pollution, analyzed across all hamlets with equal score priority. However,

exposure analysis based on critical infrastructure, water sources, and population affected, as well as cost, showed different score for each hamlet (Whitley *et al.,* 2019). For the vulnerability aspect, the analysis was also conducted in each hamlet with elements or questions based on interviews and questionnaires. Risk scores were derived from the multiplication of hazard, exposure, and vulnerability, resulting in different average score for each hamlet, as shown in Table 5. Sanitation facilities for each hamlet attached to the Appendix are also considered in determining risk score.

The final risk score can be used in determining priorities of policymakers. In this calculation, capacity is not included but assessed separately to assist in prioritizing risk for easy identification of resilience level. Hamlet 01 has the highest priority for handling sanitation, followed by hamlets 02, 03, and 07, while hamlets 04, 05,06, 08, and 09 are considered low sanitation risk areas. Specifically, hamlet 01 must consider land subsidence and water pollution, affecting the degradation of quality of water sources. Sub-district area still has a high level of vulnerability related to sanitation infrastructure, which requires improvement and adequate housing conditions for a healthy sanitation environment (Whulanza and Kusrini, 2023). Hamlets 04 and 07 also experience the issue of sea level rise, leading to a decrease in the quality of water sources.

Capacity that requires further development includes the availability of staff and training related to the operation and maintenance of the current sanitation infrastructure. Residents should also be engaged in operations and maintenance to foster a sense of responsibility in maintaining the quality of the environment. Understanding related sanitation issues requires improvement considering that there are still residents who are directly engaged in handling sanitation issues. Regarding natural disasters such as floods and water pollution, the local government should prepare a quick response plan that is more practical based on budget allocation (Hartono *et al.,* 2010). Therefore, disaster management can be carried out immediately without being hampered by bureaucracy.

In Jakarta, various initiatives and programs are being implemented to address sanitation challenges and promote public health. These efforts can be further improved by integrating sanitation risk assessment as a crucial component. One of the initiatives is the Jakarta Sanitation and Clean Water Program, which focuses on enhancing access to clean water and proper sanitation facilities. By incorporating sanitation risk assessment into this program, policymakers can effectively identify areas with high risk, prioritize interventions, and allocate resources efficiently. The assessment also facilitates identifying potential sources of contamination, assessing health risk, and areas requiring targeted sanitation interventions.

Table 5 Risk priority analysis describes risk scores by hamlet and categorizes priority risk levels by color coding

Indicators	Hamlet								
	01	02	03	04	05	06	07	08	09
Hazardous Event	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
Exposure	1.48	1.32	1.30	1.34	1.30	1.30	1.39	1.25	1.32
Vulnerability	2.23	1.69	2.00	2.15	2.00	2.00	2.00	2.08	2.00
Risk Score	5.34	4.96	4.96	4.72	4.60	4.60	4.91	4.53	4.66

Note: Risk priority for handling sanitation issues (Red: high risk; yellow: medium risk; green: low risk)

5. Conclusions

In conclusion, this study successfully assessed sanitation risk for WASH compiled by UNICEF, which focused on hazard, exposure, vulnerability level, and capacity. The analysis

started with hazard indicators, followed by assessment of potential exposure to hazard, and determination of vulnerability level. In the final stage, the capacity aspect was evaluated to determine the ability of the current infrastructure to address sanitation issues. The indicator assessment was also followed by a confidence score analysis, which was carried out through discussion or deliberation with stakeholders and residents. Risk prioritization was conducted by multiplying hazard indicators, exposure, and vulnerability level to obtain a score that could be classified into high, medium, and low risk. The results showed that most areas in sub-district were still at a low-risk stage, considering the sufficient capacity system to facilitate the needs of residents. In the future, more detailed studies should be carried out related to local government policies in overcoming environmental issues. This would enable local government to be more responsive and allocate a separate budget specifically for the implementation of sanitation infrastructure development.

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