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Sanitation inspection of household fecal containment in Bekasi, Indonesia

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Abstract. On-site sanitation (OSS) is widely known as the preferred system in Indonesia, providing low-cost wastewater treatment. The majority of households use pour-flush latrines coupled with containment in the form of *cubluk*s or septic tanks, but compliance with relevant technical and maintenance standards is low. Poorly designed and unmanaged containment may not treat fecal waste effectively, potentially contaminating the groundwater and the soil and threatening human health. This study aimed to determine the condition and effluent quality of household fecal containment in Bekasi City. A social and technical survey was conducted through questionnaires and observations of 260 households in three poor urban villages of Jatiluhur, Sumur Batu, and Jatirangga, to obtain data on containment design, construction, operation, and maintenance. Effluent samples were collected from eight households, and laboratory tests were conducted to determine the chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), ammonia, and *E. coli* levels. The data was analyzed with descriptive statistics, and the sanitation facilities in the three villages were categorized as safely managed (0.8%); basic (66%); limited (2.3%); unimproved (29%); and open defecation (1.5%) based on JMP sanitation ladder. On average, the effluent samples exceeded relevant quality standards, except regarding BOD (10.9 ± 4.14 mg/L) and pH (7 ± 0.3). The results of this study can be used as a baseline to improve the conditions of sanitation facilities in poor areas.

1. Introduction

The global target of United Nations Sustainable Development Goal (SDG) 6.2 is “by 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation” [1]. The main purposes of sanitation are to improve human health conditions, promote human welfare and quality of life, and protect the environment [2]. To track and monitor the development progress of sanitation services, the Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene (JMP) by World Health Organization (WHO) and United Nations Children’s Fund (UNICEF) established a sanitation ladder tool [1].

Based on a report from the Ministry of Health of Indonesia in 2018, a total of 18.7 million deaths in Indonesia were caused by water, sanitation, and hygiene issues [3]. Human excreta that are not safely managed can pollute groundwater—a source of clean water and drinking water for households—with



fecal pathogens. Poor sanitation not only impacts human health and leads to environmental contamination, but it is also economically harmful. For example, Indonesia suffered a 2.3% loss of Gross Domestic Product (GDP) in 2007 due to poor sanitation and hygiene [4]. However, communities in Indonesia remain unaware of sanitation issues and their adverse effects, with 6.5 million households in Indonesia still practicing open defecation in rivers, rice fields, beaches, and other open areas [5].

In Indonesia, approximately 89% of households have basic sanitation access, and 64% of the total population use a septic tank [6], which is a part of the on-site sanitation (OSS) system. However, the term 'septic tank' is broadly used, even when the tank is not strictly a septic tank. In Bekasi, a highly densely populated city in Indonesia, OSS use is approximately 94% [7]. However, most household tanks have unsealed bottoms or leach pit; these types of tanks are commonly called *cubluk*s, and waste can leach into the ground, potentially polluting the groundwater and the soil. The majority of households in Bekasi City use some form of tank to treat wastewater, but most of the tank facilities do not comply with the technical standards for septic tank design, which were set by the Indonesia National Standard. Many tanks, which are considered the proper OSS system, are often reported to be leaking due to negligible enforcement of the design criteria and the lack of pit emptying [6]. Importantly, prior studies by WSP (2016) in Indonesia indicated that over 60% of respondents in low-income areas had never practiced OSS emptying, similar to previous studies by Mills, et al. (2014) that found 59% of systems had never been emptied after an average 15 years of operation [8][9].

Septic tank performance can be affected by technical factors, such as construction, and non-technical ones, such as operations and maintenance. Additionally, if the number of users exceeds the capacity or size of the septic tank, the wastewater may not be treated in the tank for the required detention time. Furthermore, if the accumulated fecal sludge is not regularly emptied, it may pollute the treated wastewater. In addition, in areas with dense populations, the distance between adjacent houses is short, and road access to the houses is very narrow; this complicates emptying trucks' access to the fecal containment.

Accordingly, the purpose of this study was to observe the household fecal containment conditions in Bekasi City through sanitation inspections that focused on the infrastructure and maintenance contexts. The quality of effluents was also measured and compared to the national standards in Indonesia.

2. Materials and methods

2.1. Study area

The study was conducted in three urban villages in Bekasi City: Jatiluhur, Sumur Batu, and Jatirangga. The locations were selected based on the focus of the study on areas with a high population density, a high poverty level, the absence of a piped water service (leading to a high groundwater usage), and a high number of slum areas. The selection of the households for the effluent quality assessment was based on the following four criteria:

- Households that have previously undergone a sanitation inspection
- Households that use groundwater as the main source of drinking water
- Households that have individual fecal containment via a septic tank or a *cubluk*
- Containment units that are accessible for emptying via a suction hole or a manhole

2.2. Sanitation inspection and experimental set-up

The sanitation inspections were conducted through direct interviews using Survey Solutions and direct observations by enumerators in order to identify the number of household occupants, the types of household sanitation facilities, whether the households were using a septic tank or a *cubluk* for fecal containment, the age of the fecal containment tank, the frequency of fecal containment content emptying, problems in the operation of the fecal containment, disposal of fecal sludge, and availability of access road near the fecal containment. We also observed the construction detail of the fecal containment tank. The relevant construction details consisted of the containment tank construction material, material used for the bottom of the containment tank, and number of compartments. A total of 272 households in the three villages were inspected. The sample size for inspection was proportional to

the population of the villages. However, there were some errors when inputting the data, and some households did not know the type and details of their sanitation facilities; after removing these households, the final sample size was 260. These samples were used for OSS facilities categorization. The finding of 163 within 260 households with septic tank and *cubluk* were used for further discussion on fecal containment design, construction, operation and maintenance.

Based on the sample criteria and adjustments of time due to Covid-19 outbreaks in Indonesia and limited access hole for emptying, the septic tank and *cubluk* effluent sampling was conducted for eight households in Sumur Batu and Jatirangga. The number of households for effluent sampling was not based on statistical considerations and probably too small to allow firm conclusions to be drawn about the effluent quality throughout the study area. The study was intended to give preliminary characteristics of effluent which might be impacted by typical user behaviors and fecal containment conditions. The effluent was sampled through the suction access hole using a two-meter septic checker (Figure 1). The parameters tested in this study included physical parameters (total suspended solids (TSS), total dissolved solids (TDS), and electrical conductivity (EC)), chemical parameters (pH, chemical oxygen demand (COD), biological oxygen demand (BOD), and ammonia), and microbiological parameters (total coliform and *E. coli*). The pH, TDS, and EC tests were carried out on-site using the Hanna probe tool. Meanwhile, TSS (gravimetric method), COD (closed reflux method), BOD (BOD0-BOD5 measurement method), and ammonia (phenate method) were measured in the Environmental Laboratory, Faculty of Engineering, Universitas Indonesia. Microbiological parameter testing was performed using IDEXX-Colilert 18 quantitray with the most probable number (MPN) method.

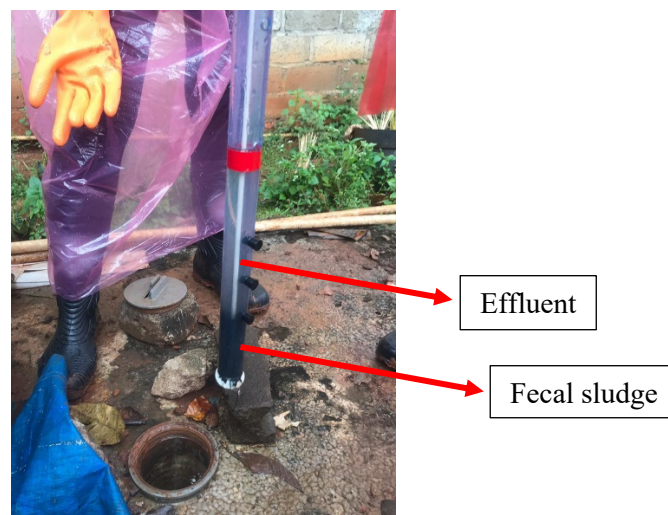


Figure 1. The effluent sampling with the septic checker.

3. Results and discussion

3.1. Household OSS facilities

The status and conditions of the household OSS facilities in Bekasi were categorized based on the JMP sanitation ladders. Basic and limited sanitation services involve the use of improved sanitation facilities designed to hygienically separate excreta from human contact and include a toilet connected to a septic tank, a single pit latrine, and a pour-flush latrine. Meanwhile, unimproved sanitation includes sanitation using ponds, hanging latrines, and other open areas. The results showed that 66% of the households already had basic sanitation, while 29% and 2.3% had unimproved and limited sanitation, respectively (Figure 2). The total percentage of households with access to safely managed sanitation was 0.8%, while 1.5% of the households practiced open defecation. Open defecation is strongly associated with poverty in developing countries, especially in the selected study location. Limited sanitation services reflect both cultural practices and socio-economic constraints in densely populated areas [6]. Based on previous

research, open defecation may occur for several reasons, such as not having a toilet at home or having alternative uses for toilet structures [10]. Despite having private toilets or access to public toilets, people may still perform open defecation due to norms that limit the use of toilets and general cleaning problems. Ending open defecation is very important because it is one of the pillars of community-based total sanitation (STBM), which aims to break the chain of disease transmission based on the Ministry of Health of Indonesia Regulation No. 3/2014.

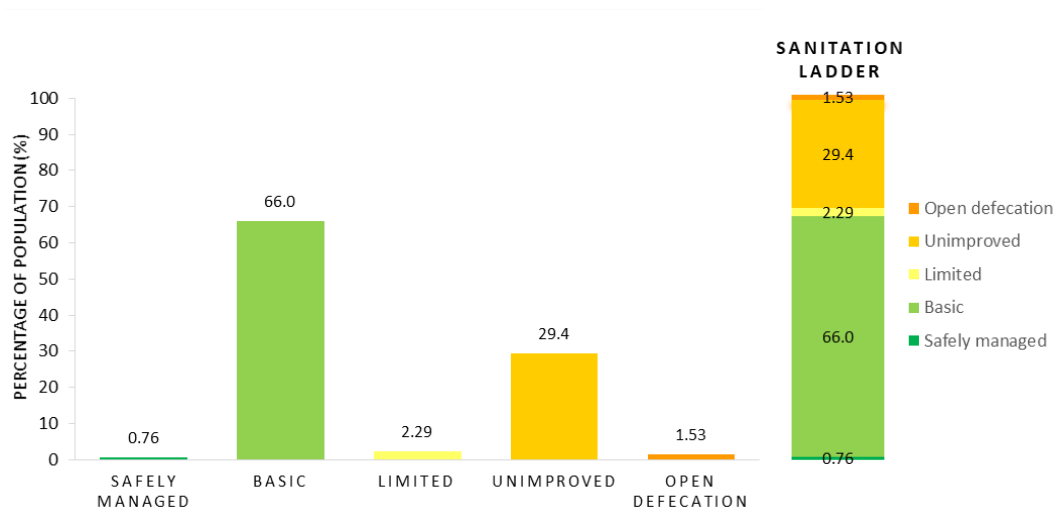


Figure 2. Sanitation facility type based on JMP sanitation ladders (n = 260).

3.1.1. Septic tank and cubluk: Operations and maintenance.

On this section, the discussion will be focused on septic tank and *cubluk* with the total sample size of 163. Containment emptying is a basic practice and one of the most important maintenance activities for preventing contamination. To perform containment emptying, the septic tank and *cubluk* needs to have an accessible suction hole or a manhole with a diameter that can accommodate a vacuum or the other emptying tools. However, approximately 45% of the households did not have any access for emptying, and 23% had access through a ventilation pipe that was not suitable or practical for emptying (table 1). Around 45% of the households had septic tank or *cubluk* that were built more than 10 years prior to the study period. Ideally, a septic tank or *cubluk* has to be emptied every three years [11]; however, the inspections showed that 70.6% of the households had never performed containment emptying.

The observed septic tank and *cubluk* may have decreased the efficiency in fecal sludge treatment. Most septic tank and *cubluk* bottoms were compacted due to the accumulation of fecal sludge. For the *cubluk*s, this indicated that the ability of the sludge to infiltrate the soil had been blocked by years of operation. This result is consistent with a previous study which found that the rate of sludge accumulation in a system that had never been emptied was decreased to 14 liters per person per year (l/p.y) compared to a system that was emptied regularly, which had a rate of 41 l/p.y [9]. However, the finding of 71% of the household septic tanks or *cubluk*s have never been emptied. This might be due to approximately 76% of the households not having experienced any overflows, clogs, or other problems with their toilets or septic tank and *cubluk*. Additionally, households may have never practiced containment emptying due to unavailable access for emptying and the limited access for emptying trucks. Although an emptying motorcycle can be used as an alternative to an emptying truck, it is less effective due to the small capacity of the tank and the lack of availability of stool transfer stations [9].

In terms of external pollution, approximately 82% of the septic tanks or *cubluk*s had never been influenced by floods or water from the above ground level, which indicates that the containment infrastructure can offer protection from external pollutants. However, since most of the septic tanks and

*cubluk*s did not have access points that could be opened, it is not surprising that water from the above ground level could not enter the containment.

Table 1. Septic tank and *cubluk* operations and maintenance (n = 163).

Variable	Category	Percentage (%)
Overflow of septic tank or <i>cubluk</i>	No	75.5
	Yes	11.7
	Do not know/not answered	12.9
Floods or surface water entering septic tank or <i>cubluk</i>	No	82.2
	Yes	4.9
	Do not know/not answered	12.9
Age of septic tank or <i>cubluk</i>	< 5 years	23.3
	5–10 years	18.4
	> 10 years	45.4
	Do not know/not answered	12.9
Type of access hole	No access	45.4
	Manhole	16.6
	Semi-permanent seal	0.6
	Ventilation pipe	23.3
	Other	11.0
	Do not know/not answered	3.1
Emptying frequency since septic tank or <i>cubluk</i> was built	Never	70.6
	1–2 times	10.4
	> 2 times	3.1
Disposal of fecal sludge	Do not know/not answered	16.0
	Catchment field/infiltration pit/the ground	63.8
	Centralized sewage	1.8
	Sewage treatment plant	4.9
	Open drainage	0.6
	Open field	1.2
	River/pond	1.2
	Other	5.5
	Do not know/not answered	20.9
	Number of users	< 5
5–10		46.6
> 10		3.1
Do not know/not answered		0.6
Availability of access road near septic tank or <i>cubluk</i>	No	21.5
	Yes	78.5
	Do not know/not answered	-

3.1.2. Septic tank and *cubluk* construction.

The majority of the construction materials used for the septic tanks or *cubluk*s were stones/bricks (78%), followed by reinforced concrete (13.5%) (Table 2). Based on septic tank design standards, stones/bricks are suitable for areas with low water tables to ensure that the tank is impermeable to water, while reinforced concrete material is relatively suitable for all soil conditions. Most of the septic tanks or *cubluk*s had one or two compartments (52% and 28%, respectively). Septic tank design standards contain guidelines for single and double compartments, but the suitability of the design dimensions and the completeness of the system require further study. Meanwhile, a *cubluk* with a single chamber infiltration hole has a different sedimentation and digestion sludge system than a septic tank that is designed according to the standards. Based on previous research, there are some differences in surface area and volume between septic tank and *cubluk*, and no use of baffles in a *cubluk* [9]. The use of baffles can

reduce the flow of contact water with the biomass in sedimentary sludge, because they can prevent the backflow of waste to the inlet-outlet pipe, which is possible in systems with overflow pipes [9]. According to the present findings, the most used type of fecal containment was the *cubluk*; as such, approximately 75.5% of the tanks were not sealed with concrete bottom. This could lead to contamination of a groundwater well within 10 meters of the *cubluk* [12]. Additionally, a prior study on ammonia, nitrate, and nitrite found that contaminants levels is likely higher when the distances between the borehole well and the pit latrine is less than 11 meters [13]. The standard minimal distance between a septic tank and a water source is 10 meters, but implementation of this measure is difficult in highly densely populated areas.

Table 2. Design and construction materials of septic tank and *cubluk* structures (n = 163).

Variable	Category	Percentage (%)
Septic tank or <i>cubluk</i> construction material	Stone/brick	77.9
	Reinforced concrete	13.5
	Other	0.6
	Do not know	8.0
Type of septic tank or <i>cubluk</i> bottom	Unsealed	75.5
	Sealed (concrete)	19.0
	Do not know	5.5
Number of compartments	1	52.1
	2	28.2
	> 2	1.8
	Do not know	17.8

3.2. Effluent characteristics

Based on the laboratory analysis of the eight effluent samples from the selected households (Table 3), each parameter exceeded the quality standard established by the Ministry of Environment and Forestry of Indonesia Regulation No. 68/2016 except BOD and pH. The ratio of BOD/COD showed the degree of difficulty involved in the decomposition of organic material by microorganisms or bacteria. In this study, the average BOD/COD ratio was $3.11 \times 10^{-2} \pm 2.3 \times 10^{-2}$, indicating low biodegradability, since the ideal ratio is 0.2–0.5 [14][15]. Low BOD/COD may be due to the presence of surfactants and sodium hydroxide contained in soap products that might be associated with the behaviour of Indonesian people to uses soap for anal and toilet cleansing. HCl, which is generally an active ingredient in bleach for toilet cleaning. The active ingredients contained in this toilet cleaning soap in general can be toxic and kill organisms or bacteria in water; A previous study on pit latrines obtained similar BOD/COD results of less than 0.3 with sample variation, including the smallest ratio of 0.038; the study mentioned that a small ratio can be caused by inorganic pollutants that enter the pit, such as motor oil [16]. Low biodegradability may also occur if the contents of the fecal containment are stored for a long time [17]. This condition presumably occurred in the present study sample, since the majority of the septic tanks and *cubluk*s were never emptied.

Table 3. Characteristics of septic tank and *cubluk* effluent (n = 8).

Parameter	Unit	Mean \pm Std. Dev	Median	Maximum*
Physical Parameter				
TSS	mg/L	94.5 \pm 100	57	30
TDS	ppm	652 \pm 467	489	-
Electrical conductivity	ms/cm	0.895 \pm 0.615	0.68	-
Chemical Parameter				
pH		7 \pm 0.3	6.9	6–9
COD	mg/L	569 \pm 524	500	100
BOD	mg/L	10.9 \pm 4.14	8	30
BOD/COD		$3.11 \times 10^{-2} \pm 2.3 \times 10^{-2}$	2.12×10^{-2}	-
Ammonia	mg/L	63.5 \pm 57.9	49	10

Parameter	Unit	Mean \pm Std. Dev	Median	Maximum*
Microbiological Parameter				
Total coliform	MPN	$1.55 \times 10^6 \pm 2.04 \times 10^6$	8.46×10^5	3,000
<i>E. coli</i>	MPN	$1 \times 10^6 \pm 1.35 \times 10^5$	3.39×10^5	-

*Based on *Peraturan Menteri Lingkungan Hidup dan Kehutanan Republik Indonesia No. 68/2016* (Ministry of Environment and Forestry of Indonesia Regulation No. 68/2016)

4. Conclusions

Despite the success of reducing open defecation to 1.5%, Bekasi still has the challenge of improving sanitation facilities, as most households (66%) used basic sanitation, and 50% of the total households in the study area used *cubluk*s. In high density areas that use groundwater as the main source of clean water, a *cubluk* is not a suitable fecal containment given the potential for adverse contamination effects. Additionally, most of the households studied had never emptied their fecal containments because they had never experienced any problems and did not have an access point for emptying. Accumulated sludge may decrease the effectiveness of the fecal sludge treatment, as the sludge is most likely compacted at the bottom of the fecal containment.

Low performance was also indicated by the low BOD/COD ratio. The effluent quality of the assessed fecal containments (i.e., septic tanks and *cubluk*s) indicated low biodegradability. This may have occurred due to the excessive use of soap and bleach for cleaning, which can be associated with specific behavior of anal and toilet cleansings. However, this hypothesis should be further explored in future research.

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