



DRINKING AND CLEAN WATER QUALITY, SANITATION AND WATER SERVICE LEVELS AT DAYAH INTI DARUL AITAMI, WEST ACEH

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Abstract

This study assesses drinking-water and clean-water quality and sanitation conditions at Dayah Inti Darul Aitami, West Aceh, to support healthier boarding-school environments. A mixed-methods case study was conducted, combining laboratory water-quality testing with field observation/interviews and an exploratory questionnaire of 10 santri. Laboratory results show that Reverse Osmosis (RO)-treated drinking water met key benchmark parameters (turbidity 0.45 NTU, TDS 14 mg/L, pH 6.68) and showed “Not Detected” results in the H₂S pathogen indicator test at both 1×24 h and 3×24 h incubation. In contrast, borehole-derived clean water exceeded the TDS benchmark (412 mg/L) and showed “Detected” results for the H₂S pathogen indicator test at both incubation periods. Questionnaire responses were consistent with these patterns: 8/10 respondents rated drinking-water quality as satisfactory, whereas only 5/10 rated clean-water quality as acceptable, citing odor and discoloration. Sanitation challenges were also reported, particularly inadequate toilet cleanliness (3/10 respondents) and suboptimal solid-waste management (4/10 respondents). Overall, while access to water sources is adequate, improvements are needed in clean-water treatment and source protection, routine monitoring, and sanitation management to reduce health risks and strengthen Eco-Dayah implementation.

Keywords: water quality, sanitation, clean water, eco-pesantren, eco-dayah

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1. Introduction

Water and sanitation are essential human rights and serve as indispensable foundations for health, dignity, and progress. In 2015, the United Nations adopted the Sustainable Development Goals (SDGs), and Goal 6 explicitly intends to achieve universal access to safe drinking water and appropriate sanitation by 2030 (United Nations, 2016).

This pledge reflects decades of international consensus that water and sanitation services are critical determinants of public health outcomes and educational attainment in institutional settings, including schools and boarding institutions. In Indonesia, traditional Islamic educational institutions known as pesantren, or dayah in Aceh, are among the oldest and most significant educational establishments. These institutions primarily serve as sites of Islamic education while also undertaking broader social tasks, such as community capacity-building and nurturing moral values. The volume of these institutions is considerable: there are 26,975 pesantren across the country, of which 1,117 are in Aceh, representing 4.36% of the national total. Collectively, Indonesian pesantren host 1,412,428 residential students, with 124,922 (or 8.84%) of those students residing in Aceh's pesantren/dayah (Kementerian Agama RI, 2023). Because students (so-called "santri") live in dorms and spend the whole day within the school environment, the water and sanitation requirements of pesantren differ substantially from those of typical families. This residential character imposes specific demands on supply, waste management, and hygiene infrastructure that must be addressed in policy and planning.

The fundamental functions of pesantren, as defined by Fahham (2019), including education, Islamic propagation (*dakwah*), and social empowerment. However, the majority of pesantren in Indonesia face significant challenges in maintaining appropriate levels of cleanliness, which often result in serious health repercussions for pupils. Common health issues include outbreaks of scabies, diarrhea, and Acute Respiratory Infections (ARI). Factors contributing to these concerns include the sufficiency of sanitary facilities, the design and mechanism of latrines, students' personal cleanliness, the state of buildings, and student conduct. Another significant factor is the water source, as reflected in the quantity and quality of clean, drinkable water. A study by Wikurendra et al. (2020) analyzing the microbial quality of drinking water at the An-Nuriyah Islamic Boarding School in Wonocolo, Surabaya, found that drinking water from three different sources (refill drinking water, boiled water, and bottled water) did not meet total coliform quality standards. This underscores the need for strict water quality testing and management in the pesantren context, as all sources, regardless of origin, remained contaminated. To ensure that the functions of pesantren/dayah operate effectively and meet all student needs, particularly the need for clean and drinking water, it is essential to research the quality of clean and drinking water, the status of water services, and the identification of water usage patterns and issues related to water and environmental sanitation that students face. Findings from such a study are vital for generating targeted, evidence-based responses by the dayah management and appropriate authorities.

The concept of Eco-Pesantren, or Eco-Dayah, has emerged as an initiative garnering increasing attention, focusing on integrating the principles of environmental sustainability into the management and practices of pesantren. This notion emphasizes the adoption of environmentally friendly methods, such as renewable energy, effective waste management, and the innovative use of natural resources. By integrating these ideas into daily activities, Eco-Pesantren intends to promote students' and the community's awareness and knowledge of environmental issues (Nurkhin et al., 2023). One essential aspect of Eco-Pesantren is its involvement in environmental conservation.

By cultivating diverse plant species and applying sustainable agricultural practices, Eco-Pesantren makes practical contributions to environmental preservation (Muhardi et al., 2020). By integrating students into real, sustainable environmental actions, this program has the potential to foster environmentally conscious attitudes, which in turn support long-term sustainability (Mila et al., 2021). However, the development of Eco-Pesantren also faces challenges and opportunities, particularly in ecologically sound waste management, clean water distribution, and appropriate sanitation practices (Kristiyanto & Alikodra, 2021). Numerous community organizations and institutions actively support Eco-Pesantren activities. Programs like “Green Pesantren” have gained support from institutions such as the Zakat, Infak, and Sadaqah Agency of Nahdlatul Ulama (LAZISNU) and the Disaster Management and Climate Change Agency (LPBI NU), demonstrating collaboration towards environmental sustainability (Kasanah et al., 2023). Furthermore, the Indonesian Ulema Council (MUI) released a fatwa regulating trash management, demonstrating widespread support for ecologically responsible practices in pesantren (Kasanah et al., 2023). The Eco-Pesantren concept is rooted in Islamic ideas that value the environment, blending sustainable development principles with religious teachings to promote effective environmental management (Koehrsen, 2021). This strategy promotes environmental knowledge and awareness and helps build an ecologically conscious culture in Islamic boarding schools (Safei & Himayaturohmah, 2023). With government support and social intervention measures, Eco-Pesantren has the potential to become environmentally friendly educational institutions that encourage sustainability and environmental preservation (Safei & Himayaturohmah, 2023). Curriculum development for environmental education in pesantren emphasizes the need for tangible, sustainable actions that engage pupils in practical activities to strengthen their environmental awareness (Lutfauziah et al., 2023). Although the literature on WASH conditions in pesantren/dayah is increasing, most of the studies focus only on a single component, e.g., microbiological quality of drinking water (e.g., Wikurendra et al., 2020) or sanitation-associated conditions and health problems in pesantren settings (e.g., Fahham, 2019; Hariyanto et al., 2020). Consequently, timely evidence has been limited for integrated assessments that (i) assess both drinking-water and clean-water quality, (ii) describe sanitation conditions through systematic on-site observation, and (iii) classify overall water service levels within a structured framework such as the WASHCost Water Service Ladder—especially in relation to the Aceh dayah with its specific constraints. This gap limits dayah manager and local authorities to prioritize interventions in general, between water treatments, sanitation management, and environmental education as part of Eco-Dayah initiatives

Thus, this study presents Dayah Inti Darul Aitami (West Aceh) with the following aims: (1) to measure key physical–chemical parameters and H₂S pathogen-indicator results for both RO-treated drinking water and clean water derived from boreholes; (2) to characterize conditions of sanitation and solid-waste management through interviews and direct field observation; and (3) to find the level of water services with the acute-water-service deprivation using Water Service Ladder [3] or WASHCost approach. The exploratory questionnaire (which includes 10 santri) is to be taken very lightly and does not aim at being directly measurable, as it traces only rapid, indicative insights into user outlooks and daily life practices.

2. Methods

This investigation was conducted at Dayah Inti Darul Aitami, located in Ujong Tanjong Village, Meureubo District, West Aceh Regency, Aceh Province, Indonesia (Figure 1). This modern dayah accommodates about 300 students and around 40 teaching professionals and administrative personnel. The project adopted a comprehensive mixed-methods approach, integrating quantitative and qualitative data collection and analytic methodologies to attain an in-depth understanding of drinking water quality, clean water quality, and sanitation conditions at the dayah. This technique was chosen for its capacity to present a more complete picture, in which quantitative water quality data may be complemented by a qualitative understanding of perceptions, behaviors, and the surrounding environmental context (Creswell & Clark, 2017).



Figure 1 Environmental Conditions at Dayah Darul Aitami, West Aceh

The quantitative component of this investigation included systematic water sampling conducted on 3 August 2024. Clean-water samples were collected from the dayah's principal sources (five boreholes; BH1–BH5), whereas drinking-water samples were taken from the reverse osmosis (RO) outlet supplied by these boreholes. In total, four grab samples (2×600 mL for each water type) were collected in pre-cleaned polyethylene bottles—two for clean water from a selected borehole and two for drinking water from the RO outlet. For each water type, one 600 mL sample was partially poured into a dedicated H₂S Pathogen Test Strip bottle until full to assess potential pathogen presence, while the remaining volume from the same bottle was immediately used for on-site measurements of basic physical–chemical parameters, including Total Dissolved Solids (TDS) and Electrical Conductivity (EC). The second 600 mL bottle from each source was retained as a separate sample and transported to a recognized

laboratory within 24 hours for further analysis. All samples were properly labeled and handled following standard water sampling protocols to minimize contamination and ensure data integrity.

The collected water samples were subjected to both on-site and laboratory analyses. Field measurements were conducted immediately after sampling to determine selected physical parameters (TDS and EC), which were not reanalyzed in the laboratory, as they represent in-situ water conditions. The laboratory analyses focused on additional physical, chemical, and preliminary microbiological indicators, including temperature, turbidity, Total Suspended Solids (TSS), and Chemical Oxygen Demand (COD). Furthermore, pathogen-indicator presence was examined through the H₂S Pathogen Test Strips prepared from the separated subsamples.

The analytical results were then checked against the mandatory drinking-water and clean-water quality requirements specified by the Minister of Health Regulation (Permenkes) Number 2 of 2023 (Peraturan Menteri Kesehatan Nomor 2 Tahun 2023 Tentang Peraturan Pelaksanaan Peraturan Pemerintah Nomor 66 Tahun 2014 Tentang Kesehatan Lingkungan, 2023). Some essential characteristics used as benchmarks include *Escherichia coli* (0 CFU/100 ml), Total Coliform (0 CFU/100 ml), Total Dissolved Solids (<300 mg/L), turbidity (<3 NTU), unscented, and pH (6.5–8.5).

The qualitative component of this research was undertaken through three main techniques: questionnaires, interviews, and direct observation. Structured questionnaires were used to collect data on students' impressions of water services at the dayah, patterns of clean and drinking water consumption, their perceptions of water quality, and numerous environmental sanitation-related difficulties they experienced. Given the exploratory character of this study and limited time and resources, the questionnaire was administered to a convenience sample of 10 santri who regularly use the water and sanitation facilities. This small sample was intended to provide rapid, indicative insight into perceptions and everyday practices, rather than to produce statistically representative estimates for the entire student population. The surveys were designed to incorporate both closed- and open-ended questions, allowing the collection of statistical data and deeper insights into students' personal experiences. Questionnaire responses were analyzed descriptively to identify recurring perceptions and issues, without any inferential statistical generalization beyond the small group of respondents. In addition, semi-structured interviews were conducted with the dayah's leadership and staff responsible for water and sanitation management to obtain detailed information on water sources, treatment procedures, management policies, and issues faced. Direct field observations were also conducted to assess the physical state of the dayah environment, including water sources, water storage facilities, toilets, waste disposal sites, and wastewater drainage channels, as well as students' facility utilization patterns. These observations were documented using field notes and images to support the analysis.

Analysis of the quantitative data from water quality testing was conducted using descriptive methods, comparing each test result against the applicable quality standards to determine whether the water samples met the requirements for drinking or clean water. Meanwhile, qualitative data from the questionnaires, interview transcripts, and

observation notes were analyzed using thematic analysis. This approach comprised transcription, familiarization with the data, initial coding, looking for themes, reviewing themes, and recognizing themes that represent significant patterns relating to water and sanitation conditions at the dayah (Braun & Clarke, 2006). By merging these two data sources, this research aims to provide a comprehensive and valid evaluation of water and sanitation conditions in Dayah Inti Darul Aitami, along with evidence-based recommendations for improvement. All research methodologies have examined ethical considerations, including consent from the dayah and participants, as well as maintaining data confidentiality.

In addition to parameter-based assessment of water quality, this study employed the Water Service Ladder framework developed by the WASHCost project to classify the level of water service at Dayah Inti Darul Aitami. The framework evaluates water services using four key indicators: quantity, quality, accessibility, and reliability, each of which is categorized into several service levels, ranging from “no service” to “high”. For this study, water quantity was assessed using information on the number of boreholes, approximate production, and user population; quality was assessed using the laboratory results for drinking and clean water; accessibility was evaluated based on the physical distance and time required for santri to obtain water within the dayah complex; and reliability was determined from interview data with staff and santri regarding the frequency and duration of supply disruptions. Each indicator was then assigned to a service level (high, medium, basic, or substandard) in accordance with WASHCost guidelines and, where relevant, aligned with the “improved” and “unimproved” source categories used by the WHO/UNICEF Joint Monitoring Programme (Moriarty et al., 2011). The resulting classification is presented in the Results section as a Water Service Ladder status table for Dayah Inti Darul Aitami.

3. Results and Discussion

Results

Drinking Water and Clean Water Quality

Laboratory analyses were conducted on RO-treated drinking water and borehole-derived clean water. Table 1 summarizes the measured physical, chemical, and H₂S pathogen-indicator results.

RO-treated drinking water showed temperature 32.0°C, turbidity 0.45 NTU, TDS 14 mg/L, pH 6.68, and COD 22 mg/L, with “Not Detected” H₂S pathogen-indicator results after both 1×24 h and 3×24 h incubation (Table 1). Borehole-derived clean water showed temperature 31.7°C, turbidity 1.25 NTU, TDS 412 mg/L, pH 8.11, and COD 28 mg/L, with “Detected” H₂S pathogen-indicator results at both incubation periods (Table 1). Additional laboratory measurements reported in this study included Electrical Conductivity (EC; RO: 30 µS/cm; borehole: 834 µS/cm) and Total Suspended Solids (TSS; RO: 0 mg/L; borehole: 8 mg/L).

Table 1 Test Results of Drinking and Clean Water Samples from Dayah Inti Darul Aitami, West Aceh

Parameter	Unit	Standard	Drinking Water (RO)	Clean Water (Well)	Status
Physical Parameters					
- Temperature	°C	Air Temp ± 3	32.0	31.7	Compliant
- Turbidity	NTU	< 3	0.45	1.25	Compliant
Chemical Parameters					
- Total Dissolved Solids (TDS)	mg/L	< 300	14	412	Mixed
- pH	-	6.5 – 8.5	6.68	8.11	Compliant
- Chemical Oxygen Demand (COD)	mg/L	-	22	28	-
Biological Parameters					
- Pathogens (1x24h)	-	Not Detected	Not Detected	Detected	Critical
- Pathogens (3x24h)	-	Not Detected	Not Detected	Detected	Critical

Note: "Pathogens" in Table 1 refers to qualitative presence/absence results from the H₂S Pathogen Test Strips at 1x24 h and 3x24 h incubation.

Environmental and Sanitation Conditions

Based on field observations, the dayah was typically described as spacious and green, surrounded by trees and other forested areas, although trash was observed at various locations. Pollution was explored in the questionnaire exploratory (n=10) and most of respondents can tell that the surrounding environment is satisfactory, but there are 4/10 respondents who thinks that dayah management's attention to environmental cleanliness is poor. It is important to note that due to the small sample size these questionnaire results should be considered indicative, and not representative of all students.

As for sanitation facilities, more than half of respondents reported always using available toilets and 60% of respondents rated sufficient toilet availability, while the rate for perceived cleanliness was unsatisfactory in over 30% of cases. In physically observed situations, the foul smell was noted in toilets at dormitories similar with this perception whereas toilets in buildings junior and senior high school respectively were relatively better. Toilet sewage was seen streaming through concrete drains which diverted effluents towards natural earthen channels within the dayah.

Waste management was another practical issue that was flagged. The questionnaire identified a suboptimal waste management system (4/10 of respondents cited that as an area for improvement), particularly due to low collection frequency, and littering

observed in many areas. Dayah management said that volume reduction of waste is often done by incineration.

Patterns of Drinking and Clean Water Use and Environmental Water and Sanitation Problems

The exploratory questionnaire (n=10) and staff interviews provided indicative insights into water use patterns and perceived water quality. The dayah relies on five boreholes as its primary clean-water sources and an RO unit for drinking water production. Eight of the 10 respondents (80%) rated the dayah's RO-treated drinking water as satisfactory, consistent with the laboratory results in Table 1. In contrast, only five respondents (50%) rated the quality of clean water used for daily activities (bathing and washing) as acceptable; respondents reported a fishy odor, yellowish coloration, and insufficient perceived cleanliness. These perceptions align with laboratory findings of elevated TDS and "Detected" H₂S pathogen-indicator results in borehole-derived clean water (Table 1). Because the questionnaire was exploratory, these findings are descriptive only.

Conversely, attitudes about the quality of clean water utilized for daily activities, such as bathing and washing, present a contrasting perspective. Five of the 10 respondents (50%) assessed the quality of clean water as reasonably acceptable; yet there are grievances about a fishy odor, a yellowish hue, and insufficient cleanliness. The complaints align with laboratory test results indicating that the total dissolved solids (TDS) in clean water surpass the standard (412 mg/L) and that pathogens are present (Table 1). Elevated TDS levels can render water salty or impart an unusual taste, in addition to causing stains on garments and utensils. The presence of pathogens in potable water poses a significant health risk, as using contaminated water for daily activities can lead to numerous dermatological conditions and infections, as evidenced by prior studies conducted in the pesantren setting. (Fahham, 2019; Hariyanto et al., 2020). This suggests that while access to water sources is adequate, with five boreholes meeting the dayah's water requirements, the quality of the distributed water remains a significant issue. Enhancements to source water management, encompassing well-pollution protection and the implementation of appropriate treatment technologies for potable water, are critically required.

Regarding the use of sanitation facilities, over 50% of respondents report consistently using the restrooms available at the dayah. Nonetheless, certain students remain inconsistent in their application. The causes of this inconsistency require further examination, including whether they are related to toilet conditions, water access, or other factors. While 60% of respondents consider the number of bathrooms at the dayah adequate, concerns arise about their physical condition and hygiene. Three of the 10 respondents (30%) perceived bathroom cleanliness as insufficient, expressing dissatisfaction with the unclean and poorly maintained facilities. Unsanitary toilets can serve as incubators for pathogens and facilitate the transmission of illnesses, such as diarrhea and urinary tract infections. Furthermore, the foul stench primarily originating from dormitory bathrooms can adversely affect comfort and health. Initiatives to enhance toilet cleanliness must include increasing cleaning frequency, providing sufficient sanitation amenities (such as soap and running water), and educating students on the need to maintain personal and toilet hygiene. School health and hygiene

initiatives have demonstrated efficacy in enhancing students' sanitary practices (Freeman et al., 2014).

Waste management, as previously said, constitutes a significant issue. Up to 40% of respondents assess waste management in the dayah as inadequate, primarily due to infrequent waste collection. This issue is intensified by litter scattered across various locations in the dayah, indicating a lack of knowledge and engagement among confident student in upholding environmental cleanliness. The waste incineration conducted by management, while aimed at minimizing waste volume, is suboptimal and poses a risk of air pollution. Proposed solutions to this issue include increasing garbage collection frequency in partnership with the local Sanitation Department, providing sufficient, categorized trash containers, and implementing the 3R (Reduce, Reuse, Recycle) initiative or composting for organic waste. The incorporation of environmental education within the dayah curriculum, as suggested by the Eco-Dayah concept (Hamdan et al., 2022) it is crucial in enhancing awareness and modifying student behavior regarding waste management. Engagement of students in cleanliness and waste management initiatives will enhance the dayah environment's cleanliness and health while fostering a feeling of duty and stewardship for their surroundings (Herdiansyah et al., 2019).

Despite several features functioning effectively, such as the quality of reverse osmosis-produced drinking water and the adequate number of toilets deemed sufficient by the majority of students, several issues remain unresolved. The difficulties encompass inadequate water quality failing to meet standards, particularly regarding TDS and pathogen contamination; insufficient bathroom cleanliness; and inefficient waste management. Resolving these issues requires coordinated efforts by dayah management and students, as well as support from relevant stakeholders, including the local government and community organizations. The implementation of Eco-Dayah principles, which prioritize environmental sustainability, community engagement, and the integration of religious values, can serve as a practical framework for achieving sustainable progress at Dayah Inti Darul Aitami.

Status of the Water Service Ladder Based on WASHCost Indicators

As described in the Methods section, this research employs the Water Service Ladder framework established by the WASHCost project (Moriarty et al., 2011) to offer a more organized assessment of the water service level at Dayah Inti Darul Aitami, West Aceh. This methodology evaluates water service quality using four primary indicators: quantity, quality, accessibility, and reliability. Each indicator possesses levels ranging from "no service" to "high," which collectively ascertain the overall state of water service. This condition can then be associated with the "improved" and "unimproved" water source classifications employed by the WHO/UNICEF Joint Monitoring Programme (JMP) (WHO & UNICEF, 2012).

Based on the research results, the status of the Water Service Ladder at Dayah Inti Darul Aitami is as shown in Table 2.

Table 2 Water Service Ladder Status Based on WASHCost Indicators at Dayah Inti Darul Aitami, West Aceh

Indicator	High	Medium	Basic (Normative)	Substandard	Status at Dayah
Quantity (liters/person/day)	60	> 40	> 20	5	Medium (assumed >40 lpcd, supported by 5 boreholes and RO)
Quality	Good (meets all parameters)	Acceptable (some not met)	Substandard (important parameters not met)	Unacceptable (many not met)	Substandard for Clean Water; Good for Drinking Water
Accessibility (minutes/person/day)	< 10	< 30	> 5	> 60	Basic (assumed >5 mpcd, within Dayah complex)
Reliability	Very reliable (almost no disruption)	Reliable (rare disruption)	Problematic (frequent disruption)	Unreliable (often unavailable)	Problematic (occasional disruptions)
Status (JMP)	Improved (piped on premises)	Improved	Improved	Unimproved	Improved (boreholes and RO are improved sources)

Discussion

The laboratory results demonstrate a clear contrast between RO-treated drinking water and borehole-derived clean water (Table 1). RO-treated drinking water showed very low turbidity and TDS and “Not Detected” H₂S pathogen-indicator results at both incubation periods, indicating that the RO unit substantially improves drinking-water quality. In contrast, borehole-derived clean water exceeded the TDS benchmark and showed “Detected” H₂S pathogen-indicator results, suggesting potential microbiological risk for water used in daily hygiene. Similar water-quality concerns have been reported in other pesantren settings (Wikurendra et al., 2020; Hariyanto et al., 2020) and are consistent with broader sanitation-related health challenges documented in pesantren/dayah environments (Fahham, 2019).

Sanitation observations and questionnaire responses indicate that improvements are needed in toilet cleanliness and solid-waste management. The observed discharge of wastewater through drains into earthen channels highlights the importance of managing potential contamination pathways between sanitation infrastructure and groundwater sources used for clean water. Maintaining adequate separation between wells and potential contamination sources and strengthening wastewater handling are therefore relevant considerations for dayah infrastructure planning (Auvaria et al., 2019).

The Water Service Ladder assessment (Table 2) provides a structured interpretation of the service context. While the dayah's sources can be categorized as "improved" by JMP criteria (WHO & UNICEF, 2012), the service-level assessment shows a mixed picture: drinking-water quality can be classified as good, whereas clean-water quality remains substandard due to elevated TDS and H₂S indicator detection. Quantity, accessibility, and reliability classifications remain provisional because direct measurement of per-capita water use and systematic logging of supply interruptions were outside the scope of this study; these aspects should be addressed in future work to strengthen the service-level assessment (Moriarty et al., 2011).

From an Eco-Dayah management perspective, the findings suggest priority actions in three areas: (i) improve borehole protection and consider additional treatment/disinfection steps for clean water before distribution; (ii) implement routine monitoring for both drinking and clean water; and (iii) strengthen sanitation management (toilet cleaning routines and waste handling) alongside environmental education and student engagement to support sustainable behavior change (Herdiansyah et al., 2019; Lutfauziah et al., 2023; Nurkhin et al., 2023). Longer-term infrastructure options, including communal domestic wastewater treatment (WWTP), may be considered in collaboration with relevant stakeholders to support sustainable sanitation improvements consistent with Eco-Dayah principles (Side & Littaqwa, 2021).

This study has several limitations that should be acknowledged. First, the questionnaire component involved only 10 santri, selected using a convenience purposive sampling approach. The small number of respondents and non-probability sampling mean that the findings from the questionnaire are exploratory and cannot be generalized statistically to all students at Dayah Inti Darul Aitami or to other dayah. In this research design, the questionnaire was intended only as a rapid diagnostic tool to complement the more robust components, namely laboratory water quality testing and direct field observations of sanitation facilities. Future studies should employ larger, probabilistic samples and include multiple dayah in order to obtain more representative data on students' knowledge, attitudes, and practices related to water, sanitation, and hygiene.

4. Conclusion

Laboratory testing at Dayah Inti Darul Aitami showed a clear contrast between drinking water and clean water quality. RO-treated drinking water met key benchmark parameters and showed "Not Detected" results in the H₂S pathogen-indicator test (Table 1). In contrast, borehole-derived clean water exceeded the TDS benchmark (412 mg/L) and showed "Detected" H₂S pathogen-indicator results, indicating that clean water used for daily activities requires improved quality control.

Field observations and an exploratory questionnaire (n=10) indicated sanitation challenges, particularly suboptimal toilet cleanliness (3/10 respondents) and inadequate solid-waste management (4/10 respondents), despite generally adequate access to water sources within the dayah complex. The Water Service Ladder assessment further suggests that, while the sources are "improved" by JMP criteria, service quality remains constrained by clean-water quality and reliability limitations (Table 2).

Based on these findings, priority actions include strengthening borehole protection, introducing appropriate treatment/disinfection for clean water before distribution, and implementing routine water-quality monitoring for both drinking and clean water. Complementary improvements in toilet cleaning routines, waste handling, and environmental education aligned with Eco-Dayah principles are also required to reduce health risks and sustain a healthy learning environment.

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REFERENCES

- Auvaria, S. W., Nilandita, W., & Nengse, S. (2019). Perencanaan Sistem Manajemen Lingkungan Pada Aspek Air Bersih, Limbah, Energi, Dan Penghijauan Di Pondok Pesantren (Studi Kasus: Pondok Pesantren An-Najiyah Surabaya). *Al-Ard: Jurnal Teknik Lingkungan*, 4(2), 36–45. <https://doi.org/10.29080/alard.v4i2.505>
- Braun, V., & Clarke, V. (2006). Qualitative Research in Psychology Using thematic analysis in psychology Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <http://www.tandfonline.com/action/journalInformation?journalCode=uqrp20%5Cnhttp://www.tandfonline.com/action/journalInformation?journalCode=uqrp20>
- Creswell, J. W., & Clark, V. L. P. (2017). Designing and Conducting Mixed Methods Research. In *Organizational Research Methods* (Vol. 12, Number 3rd Edition). SAGE Publications. https://books.google.com/books/about/Designing_and_Conducting_Mixed_Methods_R.html?hl=id&id=eTwmDwAAQBAJ
- Fahham, A. M. (2019). Sanitasi dan Dampaknya bagi Kesehatan: Studi dari Pesantren. *Aspirasi: Jurnal Masalah-Masalah Sosial*, 10(1), 33–47. <https://doi.org/10.22212/aspirasi.v10i1.1230>
- Freeman, M. C., Stocks, M. E., Cumming, O., Jeandron, A., Higgins, J. P. T., Wolf, J., Prüss-Ustün, A., Bonjour, S., Hunter, P. R., Fewtrell, L., & Curtis, V. (2014). Systematic review: Hygiene and health: Systematic review of handwashing practices worldwide and update of health effects. *Tropical Medicine and International Health*, 19(8), 906–916. <https://doi.org/10.1111/TMI.12339;WGROU:STRING:PUBLICATION>
- Hamdan, A. M., Widyanto, A., Bakri, M. B., Fakriah, N., Rohendi, A., Meutia, & Rahmi, M. (2022). *Kajian Penataan Arsitektur Dayah di Aceh Berdasarkan Konsep Eco-Dayah sebagai Upaya Peningkatan Kualitas Lingkungan, Ekonomi dan Sosial*.
- Hariyanto, H., Turista, D. D. R., Ulya, N., & Rizmanda, E. (2020). Identification of Salmonella sp in Islamic Boarding School in Bath Water Sumbergempol Sudistrict.

- International Journal of Clinical Inventions and Medical Sciences (IJCIMS)*, 2(2), 33–37. <https://doi.org/10.36079/LAMINTANG.IJCIMS-0202.103>
- Herdiansyah, H., Sukmana, H., & Lestarini, R. (2019). Eco-Pesantren as A Basic Forming of Environmental Moral and Theology. *Kalam*, 12(2), 303–326. <https://doi.org/10.24042/klm.v12i2.2834>
- Kasanah, N., As Sajjad, M. H., & Rohmatullah, D. M. (2023). Responsive Islamic Boarding School Management to Environmental Sustainability Through Green Pesantren Program. *Muslim Heritage*, 8(2), 267–278. <https://doi.org/10.21154/muslimheritage.v8i2.5017>
- Kementerian Agama RI. (2023). Satu Data - Kementerian Agama RI. In *Satu Data Kemenag* (p. 1). <https://satudata.kemenag.go.id/publikasi/read/pondok-pesantren-dalam-angka-tahun-2023>
- Koehrsen, J. (2021). Muslims and climate change: How Islam, Muslim organizations, and religious leaders influence climate change perceptions and mitigation activities. *Wiley Interdisciplinary Reviews: Climate Change*, 12(3), 1–19. <https://doi.org/10.1002/wcc.702>
- Kristiyanto, K., & Alikodra, H. S. (2021). Eco Pesantren development: Challenges and opportunities to conservation development. *Biogenesis: Jurnal Ilmiah Biologi*, 9(1), 87–92. <https://doi.org/10.24252/bio.v9i1.21084>
- Lutfauziah, A., Al Muhdhar, M. H. I., Suhadi, S., & Rohman, F. (2023). Curriculum Development for Environmental Education at an Islamic Boarding School. *Journal of Turkish Science Education*, 20(3), 490–503. <https://doi.org/10.36681/tused.2023.028>
- Mila, F., Yanuwadi, B., & Laksono, A. S. (2021). Environmental Management at Pondok Pesantren an-Nur 2 Al Murtadlo Malang Regency With the Implementation of the Eco-Pesantren Program. *International Journal of Research and Studies Publishing*, 11(8), 193–199. <https://doi.org/10.29322/ijsrp.11.08.2021.p11626>
- Moriarty, P., Batchelor, C., Fonseca, C., Klutse, A., Naafs, A., Nyarko, K., Pezon, C., Potter, A., Reddy, V. R., & Snehalatha, M. (2011). Ladders for assessing and costing water service delivery. *IRC - International Water and Sanitation Center*, (April), 24. <http://www.washcost.info/page/753>
- Muhardi, M., Nurdin, N. H., & Irfani, A. (2020). The role of knowledge-based ecological pesantren in environmental conservation. *Journal of Physics: Conference Series*, 1469(1). <https://doi.org/10.1088/1742-6596/1469/1/012126>
- Nurkhin, A., Martono, S., Ngabiyanto, N., Mukhibad, H., Rohman, A., & Kholid, A. M. (2023). Green-pesantren and environmental knowledge and awareness: Case study at Pondok Pesantren As Salafy Al Asror Semarang. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1248, Number 1). <https://doi.org/10.1088/1755-1315/1248/1/012003>
- Peraturan Menteri Kesehatan Nomor 2 Tahun 2023 Tentang Peraturan Pelaksanaan Peraturan Pemerintah Nomor 66 Tahun 2014 Tentang Kesehatan Lingkungan (2023).

- Safei, A. A., & Himayaturrohman, E. (2023). Development of Environmentally Friendly Culture in the Islamic Boarding School Through Social Intervention Strategy. *Al-Hayat Journal of Islamic Education*, 7(1), 226. <https://doi.org/10.35723/ajie.v7i1.323>
- Side, G. N. De, & Littaqwa, L. A. A. (2021). Perencanaan IPAL Komunal Untuk Mendukung Konsep Eco-Pesantren Di Pondok Pesantren NU Al Mansyuriah Bonder Kabupaten Lombok Tengah. *Jurnal Teknik Lingkungan*, 27(2), 36–52. <https://doi.org/10.5614/j.tl.2021.27.2.4>
- United Nations. (2016). *Goal 6: Water and Sanitation - United Nations Sustainable Development*. <https://www.un.org/sustainabledevelopment/water-and-sanitation/>
- WHO, & UNICEF. (2012). Progress on Drinking Water and Sanitation - 2012 Update. In *World Health Organization*. http://whqlibdoc.who.int/publications/2012/9789280646320_eng_full_text.pdf
- Wikurendra, E. A., Wijaya, S., & Nagy, I. (2020). Microbiological Quality Analysis of Drinking Water in An- Nuriyah Islamic Boarding School Wonocolo Surabaya. *Journal of Global Research in Public Health*, 5(2), 217–220.