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PROFILING THE INEQUALITY OF SCHOOL WATER, SANITATION, AND HYGIENE FACILITIES AMONG INDONESIAN REGIONS USING CLUSTER ANALYSIS

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Abstract

Introduction: *Humans rely heavily on Water, Sanitation, and Hygiene (WASH) facilities. Goal 6 of the Sustainable Development Goals (SDGs) emphasizes ensuring communities possess universal access to clean water and sanitation. Because WASH is tremendously crucial in schools, the objective of this study is to provide a comprehensive profile of regional inequalities based on the availability of WASH indicators through cluster analysis.* ***Methods:*** *This study administered cross-sectional data from 514 regencies/cities in Indonesia with three variables, i.e. percentage of access to water, sanitation, and hygiene at public and private elementary schools. The profiling was performed by conducting K-means clustering method.* ***Results and Discussion:*** *Public and private schools were examined separately as the p-value in the difference test was less than 0.05. In accordance with the silhouette plot, the optimal number of clusters was two for each category. For the public-school category, the number of regencies/cities in Cluster 1 was 380 regencies/cities and 134 regencies/cities were in Cluster 2. For the private school category, Cluster 1 incorporated 418 regencies/cities and Cluster 2 merely encompassed 96 regencies/cities.* ***Conclusion:*** *Two clusters for each type of school had been established with Cluster 1 consisting of areas with high availability of WASH facilities while areas in Cluster 2 possessed a relatively low percentage in the three WASH indicators. There were 66 regencies/cities, generally located in eastern Indonesian provinces, grouped in Cluster 2 for both types of schools.*

INTRODUCTION

Universal access to proper Water, Sanitation, and Hygiene (collectively recognized as WASH) facilities possess a crucial role in human health and welfare (1). However, millions of people worldwide still experience difficulties accessing it affecting 1.9 million deaths from WASH-related diseases such as diarrhea, trachoma, acute respiratory infections, and soil-borne helminth infections in 2016 (2). Concerns about this issue were elevated by the global community, which emphasized it explicitly in the Sustainable Development Goals (SDGs) by 2030, specifically targets 6.1 and 6.2 under SDG 6, “Ensure access to water and sanitation for all”. Furthermore, several SDGs ranging from SDG 1, SDG 3, SDG 4, SDG 5, and SDG 11 possess robust connections with WASH-related problems (3).

To address this, the World Health Organization (WHO) and the United Nations International Children’s Emergency Fund (UNICEF) issued reports through the WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply, Sanitation, and Hygiene (WASH) to monitor global progress toward WASH-related SDG targets (4). The report then identified that school was a top priority in monitoring global WASH post-2015 and emphasized the significance of common indicators in monitoring WASH in schools. Three indicators were proposed, with the goal of achieving basic water, sanitation, and hygiene facilities (4). These indicators had been administered as

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study material for profiling and mapping the condition of countries around the world.

At the national level, the Indonesian government issued an annual report through the Ministry of Education, Culture, Research, and Technology that explained the achievements of these three indicators both nationally and regionally. It specifically presented the percentage of schools in each region and at all levels of education that already had access to WASH facilities. According to the 2020 report, the percentages of access to water, sanitation, and hygiene were 86%, 88.45%, and 79.59% for senior high school, 89.75%, 90.03%, and 82.16% for vocational high school, 81.35%, 87.1%, and 74.16% for junior high school, and 79.9%, 86.4%, and 77.06% for elementary school (5). The lowest percentage of the three levels of education was owned by the elementary school level.

In the 2020 elementary school sanitation portrait (5), the areas that had the highest and lowest indicators of water access were DKI Jakarta Province at 94.98% and Papua Province at 37.34%. As for sanitation indicator, the highest percentage possessed by DKI Jakarta Province at 87.22% and Papua Province at 37.99% became the lowest. Meanwhile, the highest and lowest hygiene indicators was for DI Yogyakarta Province at 92.00% and Papua Province at 45.59%.

These disparities were quite concerning, as they highlighted the existence of regional inequality in Indonesia. Presumably, access to WASH facilities in schools must be accomplished without any regional disparities. Ignoring this inequality would result in most schools in several provinces still having inadequate WASH facilities. Hence, it would undoubtedly disrupt numerous things.

The impropriety, or even unavailability, of those facilities negatively influences various aspects ranging from health, educational performance, to teacher productivity (6). On the health side, appropriate WASH owns a central role in protection against various diseases such as diarrhea (7–11). The prevalence of diarrhea in schools that implemented WASH was significantly lower than in schools that did not, by up to 11.4% (12). Apart from diarrhea, intestinal worms and urinary tract infections are some of the health problems associated with WASH conditions (13). Lack of adequate sanitation, along with other factors, was also unveiled as a risk factor for stunting in children (14). Safe sanitation, such as gender-segregated latrines, would not only benefit students' health but would also provide a sense of security and privacy for students, especially for girls (2).

Therefore, serious attention is required, beginning with revealing in detail "where" and "how severe" the inequality is. However, no research has attempted to employ the three WASH indicators in schools simultaneously to compare conditions across Indonesian regions. Only descriptive statistical figures were displayed, including the percentage and classification of areas in accordance with whether they were above or below the national average.

The objective of this study is to fill the gap and provided a more comprehensive profile of sanitation among regions by grouping regions in accordance with their similarity by implementing cluster analysis. After formulating the group, the distinguishing characteristics of each cluster could be examined. The result would provide several insightful information about which regional groups possess a high level of severity in overall, not partial on particular indicators. Due to its low percentage among the other levels, elementary school would be the only concern. Profiling also encompasses two types of schools: public and private. Because of the government-foundation role in managing them, both were suspected to have differences in terms of service and quality. To ensure the significance of the difference between the two types of school, statistical tests would also be carried out with adjustments to the distribution and data structure used.

METHODS

This study employed cross-sectional data with the research unit being a level II region in Indonesia i.e., 514 regencies/cities across the country. The three variables utilized for grouping those regencies/cities, all in interval measurement scale, were the percentage of elementary schools in 2020 that possess proper access to water, sanitation, and hygiene in each region. These three variables were assessed for both public and private schools. This secondary data was obtained from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, specifically from the Center for Data and Information Technology. To ensure that the medians of the two groups differed significantly, the Wilcoxon signed-rank test, a nonparametric alternative test for the paired sample student's t-test, was administered (15). It was considered as the violation of normality assumption prevented us to work in a usual student's t-test. The Wilcoxon signed-rank test was also administered due to paired objects (both in the form of regencies/cities). If the test discovered that there was a significant difference, both public and private school conditions would be treated separately, and the results were elaborated together. Otherwise, the analysis would begin by aggregating the data from the two types of schools.

Descriptive statistics would be presented for each variable. It would provide an overview of the availability of WASH facilities in elementary schools in Indonesia. Profiling would be then performed by conducting clustering analysis, which is the process of partitioning a set of some objects into two or more non-empty disjoint subsets (called clusters) such that the objects within the same cluster be similar to each other and different from the objects in other clusters (16–18). In this case, the objects that would be clustered were the regencies/cities in Indonesia.

As all of the variables incorporated were numerical variables (measured in interval or ratio scale), the K-Means clustering method was selected. As a method that was extensively administered due to its simplicity, K-Means clustering had been employed in profiling conditions utilizing variables such as the risk of spreading infectious disease (19), community welfare indicators (20), and crime rate (21–23). This study then became the first to administer the WASH availability variables derived from school sanitation indicators encompassing all regencies/cities in Indonesia. It was more extensive than study conducted from (24) which also analyzed school WASH facilities but were conducted within a sub-district in a particular city.

This clustering method required the user to specify how many clusters would be constructed at the outset, even before we conducted the algorithm. This number could be selected based on the preferences of the researcher. The alternative method was to examine a silhouette plot comprising of Average Silhouette Width (ASW) across all possible cluster numbers. It was a more objective procedure than the previous one. The ASW value could reflect the cluster quality, and the number of clusters with the highest value of ASW was preferred (19,25). After the number of clusters was specified, the K-Means clustering could be performed. The algorithm of this method consisted of four steps: (i) random centroid initiation as many as the specified number of clusters, (ii) grouping observations based on the nearest cluster centroid, (iii) updating the centroid value by calculating the mean value of all objects within the corresponding cluster, and (iv) regrouping all objects in the same manner as in the second step and assessing the centroid again. The process would be repeated until none of the cluster members modified (16). The analysis and visualization were carried out using R 4.1.3 and ArcGIS 10.8 version.

RESULTS

Some statistics for the three variables from 514 regencies/cities were demonstrated in Table 1. The results of the Wilcoxon test were displayed in the eighth column of Table 1. The p-value that was less than 0.05 from this test implied that the median of the three variables for the two types of schools was significantly different. Another result was that the maximum value of sanitation percentage in public elementary schools merely obtained 95.83% (Blitar City, East Java). It indicated that there were no single regencies/cities in Indonesia in which all indicators acquired a perfect score of 100%. Some cities which possessed good achievements incorporated Blitar City, Yogyakarta City, North Jakarta City, Salatiga City, and Madiun City. They owned the highest average of the three variables for public schools. As for private school category, 17 regencies/cities from 14 provinces obtained percentage of 100% for the three indicators.

Table 1. Descriptive Statistics of the Three WASH Variables

Variable	Count	Mean	Variance	Max	Min	P-Value
Water						
Public	514	71.28	424.00	100.00	2.63	2.6×10^{-12}
Private	514	75.41	582.22	100.00	0.00	
Sanitation						
Public	514	65.24	283.19	95.83	0.00	8.0×10^{-3}
Private	514	65.84	582.90	100.00	0.00	
Hygiene						
Public	514	74.47	203.40	100.00	4.76	1.3×10^{-12}
Private	514	77.16	476.57	100.00	0.00	

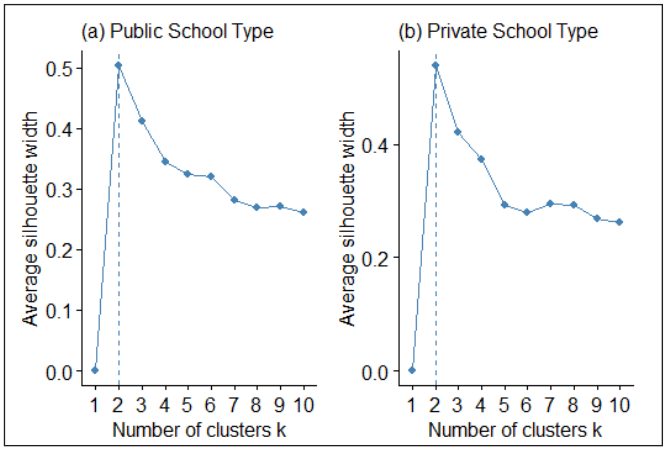

Figure 1. Silhouette Plot for (a) Public and (b) Private School Type

Utilizing the silhouette plot in Figure 1, the optimal number of clusters was determined to be two for each school category. Two was selected as it corresponded to the highest ASW value. The K-Means algorithm was then employed to create two clusters, labeled Cluster 1 and Cluster 2. The number of regencies/cities in Cluster 1 for public schools was 380, excluding the other 134 regions in Cluster 2. Figure 2a depicted the cluster visualization for public schools. Each cluster was labeled in a different color. The boxplot in Figure 2b was administered to examine the characteristics of both clusters. Figure 2b reveals that Cluster 1 owned a higher value distribution than Cluster 2. These results

were consistently discovered in the three variables in which Cluster 1 members possessed an average of 80.68%, 72.21%, and 79.92%, respectively for water, sanitation, and hygiene indicators. These numbers were significantly higher than the Cluster 2 with 44.64%, 45.48%, and 59.01%.

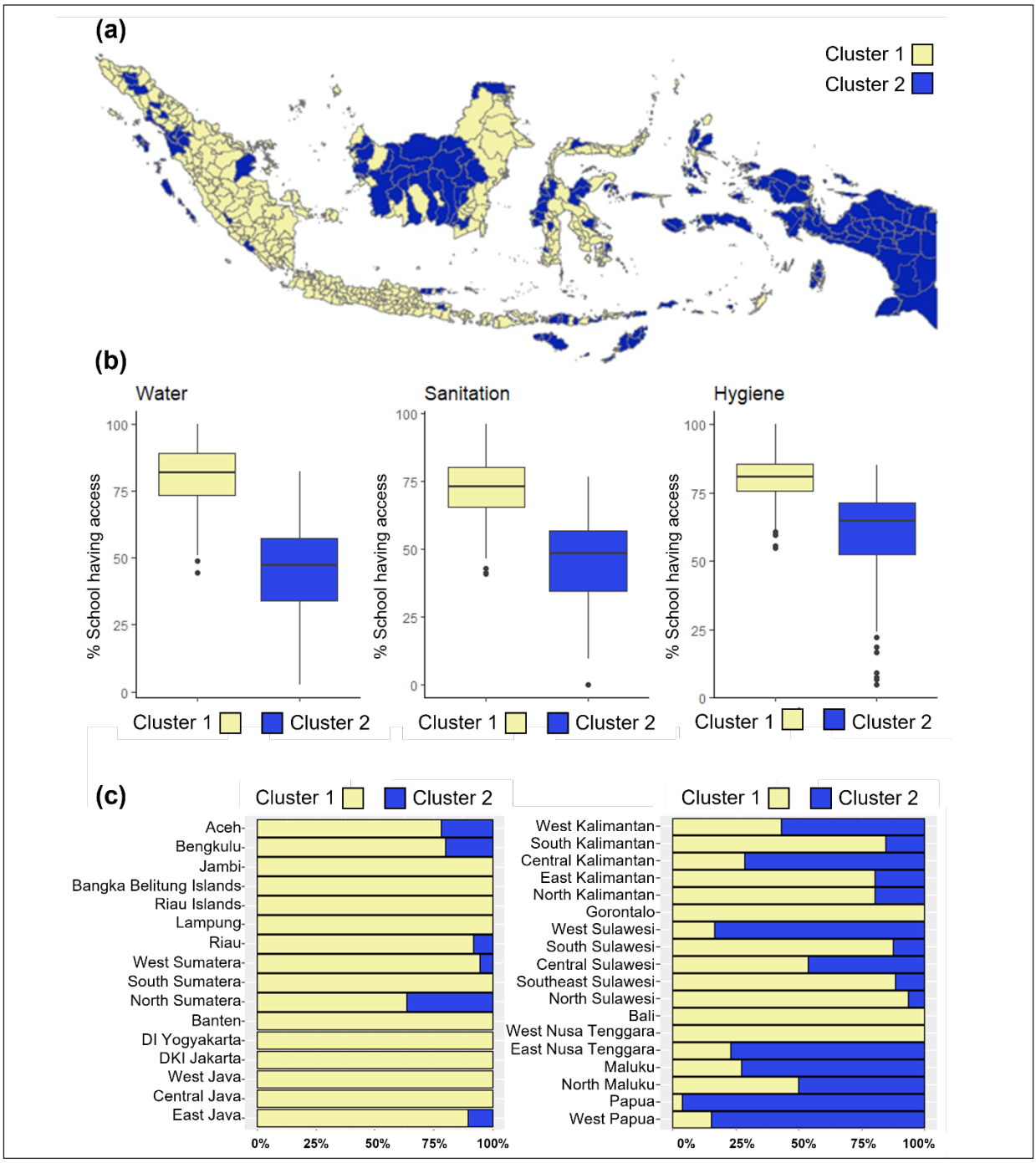

Figure 2. The Results of Clustering for Public Schools Included (a) Visualization of Cluster Members, (b) Cluster Characteristics for Each Variable, and (c) Percentage of Regencies/ Cities Involved in Each Cluster for All Provinces

There were 13 provinces, encompassing Jambi, Bangka Belitung Islands, Riau Islands, Lampung, South Sumatera, Banten, Yogyakarta, Jakarta, West Java, Central Java, Banten, Bali, and West Nusa Tenggara that did not possess regencies/cities in Cluster 2 at all. It implies that 100% of regencies/cities from those 13 provinces classified in Cluster 1. Meanwhile, most of the regencies/cities in the provinces of West Kalimantan (57% of its regions), Central Kalimantan (71% regions), West Sulawesi (83% regions), East Nusa Tenggara (77% regions), Maluku (73% regions), Papua (97% regions), and West Papua (85% regions) belong to in Cluster 2.

The analysis was then divided into groups of islands. First, the Sumatera archipelago was made up of ten provinces, with six provinces having 100% membership in Cluster 1. North Sumatera had the lowest percentage of Cluster 1 regencies/cities, with 64% of its regencies/cities in Cluster 1. Only Bangkalan, Bondowoso, Sampang, and Sumenep regencies on the island of Java were assigned to Cluster 2, while the

remaining 115 regencies/cities were assigned to Cluster 1. Overall, 64 regencies/cities on the island of Sulawesi were classified as Cluster 1 (79%), while 17 others (21%) were categorized as Cluster 2. This general picture was rather contradictory when contrasted to one of its provinces (West Sulawesi), which had 17% of its regions in Cluster 1 and 83% in Cluster 2. Then, on the island of Kalimantan, despite the fact that 33 regencies/ cities (59%) were in Cluster 1 and the remaining 23 (41%) were in Cluster 2, there was still one province that had strongly been dominated by Cluster 2. The province was Central Kalimantan with a proportion of 29% (Cluster 1) versus 71% (Cluster 2). Bali and West Nusa Tenggara were completely incorporated in Cluster 1 of the three provinces in the islands of Bali-Nusa Tenggara. Meanwhile, the majority of regencies/cities in East Nusa Tenggara remained in Cluster 2 (with 77% of its regions were in Cluster 2). Furthermore, conditions in Maluku-Papua were generally occupied by Cluster 2. As many as 83% of their regencies/cities belong to Cluster 2. Specifically for Papua province, there was only 1 region (Jayapura City) in Cluster 1 and 28 other regencies/cities in Cluster 2, which makes it the most dominated province by Cluster 2 with a coverage of 97%. In more detail, the proportion of cluster members in each province could also be examined through Figure 2c.

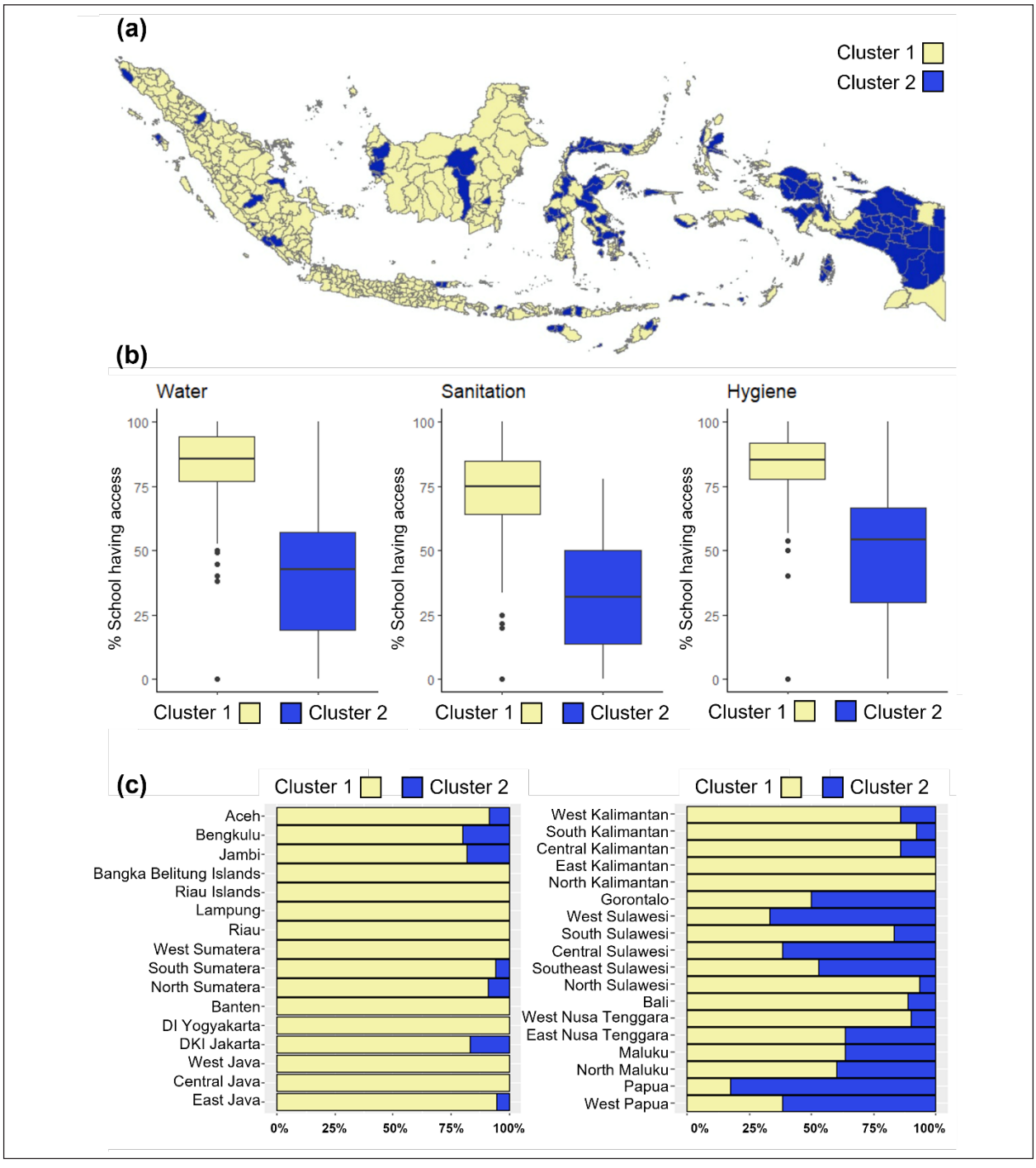

Figure 3 The Results of Clustering for Private Schools Included (a) Visualization of Cluster Members, (b) Cluster Characteristics for Each Variable, and (c) Percentage of Regencies/ Cities Involved in Each Cluster for All Provinces.

Moving on to the type of private school, two clusters were also performed. Cluster 1 incorporated 418 regencies/cities and Cluster 2 only encompassed 96 regencies/cities. This partitioning was visualized in Figure 3a with the same color code as in Figure 2a. Based on Figure 3b, there were similarities in characteristics in comparison with the boxplot for the public school. Generally, regions in Cluster 1 owned higher percentage of the availability of WASH facilities in comparison with members in Cluster 2. It was also revealed in each variable, in which the average availability of water, sanitation, and hygiene facilities in Cluster 1 was 83.79%, 73.84%, and 84.03% respectively. Meanwhile, Cluster 2 possessed 38.94%, 31.01%, and 47.25%.

When the analysis was performed per island group, there were differences in membership patterns in comparison with the public school category. There were 5 provinces on the island of Sumatera with 100% of their regions in Cluster 1 for the private school category. The five provinces were West Sumatera, Riau, Lampung, Riau Islands, and Bangka Belitung Islands. This composition was different from the public school category in which the provinces with 100% Cluster 1 were South Sumatra, Lampung, Riau Islands, Bangka Belitung Islands, and Jambi. The province with the lowest Cluster 1 membership was Bengkulu with 80% of its regencies/cities which belong to Cluster 1. On the island of Java, there were only the Seribu Islands (DKI Jakarta), Bangkalan (East Java), and Sampang (East Java) regencies which were categorized in Cluster 2. It remained 116 other districts/cities (2.5%) in Cluster 1.

On the island of Sulawesi, 53 regencies/cities (65%) included in Cluster 1 and 28 others (35%) were categorized as Cluster 2. West Sulawesi and Central Sulawesi still became the provinces with the highest percentage of Cluster 2 in Sulawesi, each reaching 67% and 62% of their region. North Kalimantan and East Kalimantan possessed 100% membership in Cluster 1 for the island of Kalimantan. The three other provinces had also been controlled by Cluster 1 with percentages of 86% (Central Kalimantan), 86% (West Kalimantan), and 92% (South Kalimantan).

For the Bali-Nusa Tenggara group, there were 31 regencies/cities (81%) placed in Cluster 1. Meanwhile, 10 other regencies/cities (19%) were in Cluster 2 and conquered by East Nusa Tenggara with 8 regencies/cities. In the islands of Maluku-Papua, the provinces of Maluku and North Maluku had been dominated by Cluster 1, to be precise with percentages of 64% and 60% of its region were in Cluster 1. Meanwhile, the other two provinces, which were Papua and West Papua, were still dominated by Cluster 2, especially in the province of Papua.

In total, there were 11 provinces which regencies/cities were all identified as members of Cluster 1, which were the provinces of Bangka Belitung Islands, Riau, Riau Islands, Lampung, West Sumatera, DI Yogyakarta, West Java, Central Java, Banten, East Kalimantan, and North Kalimantan. However, there were four provinces controlled by Cluster 2 unlike the previous eleven provinces. It encompasses West Sulawesi (67% of its regions), Central Sulawesi (62% regions), Papua (83% regions), and West Papua (62% regions). The proportion of cluster membership in each province was demonstrated in detail in Figure 3c.

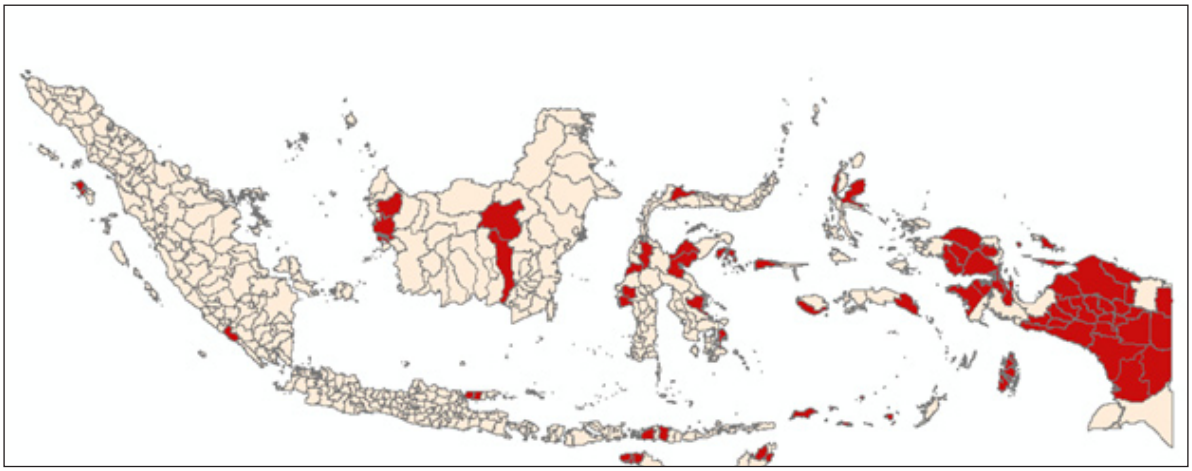

Figure 4. Regencies/Cities Categorized as Cluster 2 for Both Public and Private Schools were Labeled in Dark Red

Some provinces possessed different condition when it was compared with the results of public school and private school. For example, Bali and DKI Jakarta were two of six provinces which possessed 100% of their regencies clustered in Cluster 1 for public school but did not acquire 100% percentage for private school category. Meanwhile, there were four provinces which possessed 100% membership in Cluster 1 for private school types. However, for public school types, it was below 100% for Cluster 1. It comprises of the provinces of West Sumatera, Riau, North Kalimantan, and East Kalimantan.

Table 2. Regions where Both Public and Private School Fell into Cluster 2

Province	Regencies/Cities
Bengkulu	Kaur
North Sumatera	West Nias, North Nias
East Java	Bangkalan, Sampang
West Kalimantan	Kuburaya, Landak
Central Kalimantan	Kapuas, Murung Raya
West Sulawesi	Mamasa, Central Mamuju, Polewali Mandar
Central Sulawesi	Banggai Islands, Banggai Laut, Buol, North Morowali, Sigi, Tojo Una-Una
Southeast Sulawesi	North Boton, North Konawe
East Nusa Tenggara	Malaka, West Manggarai, East Manggarai, Sabu Raijua, West Sumba, Southwest Sumba, Central Sumba, North Central Timor
Maluku	South Buru, Aru Islands, Southwest Maluku, East Seram
North Maluku	West Halmahera, East Halmahera, Taliabu Island
Papua	Asmat, Biak Numfor, Boven Digoel, Deiyai, Dogiyai, Intan Jaya, Jaya Wijaya, Keerom, Yapen Islands, Lanny Jaya, Mappi, Memberamo Raya, Central Membramo, Mimika, Nduga, Paniai, Bintang Mountains, Puncak, Puncak Jaya, Sarmi, Tolikara, Waropen, Yahukimo, Yalimo
West Papua	Fak-Fak, Maybrat, Arfak Mountains, South Sorong, Tambrauw, Bintuni Bay, Wondama Bay

DISCUSSION

The clustering results presented earlier were intended to determine “where” and “how severe” the inequality was. After constructing two clusters for each type of school, it was discovered that Cluster 1 encompassed areas with a high availability of WASH facilities. Cluster 2, on the other hand, did not perform as well as Cluster 1. The boxplots in Figures 2b and 3b confirmed the results that Cluster 2 was in worse condition than Cluster 1. The previous visualization also revealed that the area in Cluster 2 was still dominated by regencies/cities in the eastern part of Indonesia. Based on these findings, the eastern part of Indonesia required more serious attention in terms of the availability of WASH facilities in elementary schools.

However, one thing which has to be considered was that there was a difference in the distribution pattern of Cluster 2 between the types of public and private schools. Several areas such as Central Halmahera Regency in North Maluku and South Manokwari Regency in West Papua were categorized into Cluster 1 for public schools but belong to Cluster 2 for private schools. There were 30 regencies/cities with similar conditions in total. With the opposite condition, there were 68 regencies/cities situated in Cluster 1 for private schools but were members of Cluster 2 for the public category. This difference could be affected by several things beginning from the different roles of controlling and managing public-private schools.

The condition which has to be provided crucial attention was the condition in which both types of schools were classified into Cluster 2. It indicated that the WASH availability for elementary schools was universally low in that region, regardless of the public and private school categories. Unfortunately, this situation was revealed in 66 regencies/cities from 13 provinces. The complete list was illustrated in Table 2 and demonstrated in Figure 4. Table 2 also presented that 38 out of 66 regencies/cities, equal to 58% percentage, were merely originating from four provinces, encompassing Maluku, North Maluku, Papua, and West Papua. Most of these areas also belong to Cluster 2 for all types of elementary school. Therefore, it could be indicated that the eyes should be directed to the eastern part of Indonesia. It is corroborated by the fact that most areas in these provinces are not good enough for the availability of WASH facilities as the inclusion of these areas belongs to Cluster 2 for all types of elementary school.

Immediate steps must then be required to ensure that the disparity in WASH facilities in schools is eliminated in order to achieve future national goals. WASH facility investment may also possess a multi-sectoral catalytic effect (26). Even some simple facilities such as hand washing facilities, equipped with soap and water, could influence the risk of transmitting viruses and bacteria that caused various diseases among children (27–29). The incidence of diarrhea, a disease with the most common cause being poor sanitation conditions, could significantly decreased too (29–31). Moreover, WHO had also declared hand hygiene a primary pillar for preventing the transmission of Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), the virus responsible for the ongoing Coronavirus Disease of 2019 (COVID-19) pandemic (32–34). Thus, provision of WASH facilities, along with continuous message reinforcement and other interventions, is urgently required in an effective health

campaign so students' health levels in school can be enhanced (35–37). Furthermore, it will have a positive chain effect in various aspects of society.

Generally speaking, this study could serve as a starting point for understanding the inequity that exists. Identifying these factors could assist policymakers at the national and regional levels in evaluating previous development policies and programs. It could also be beneficial to create improvement plans which are more appropriate and effective based on current conditions. However, its development and continuation were still substantially up in the air. Further research might involve covariate analysis of geographical and socioeconomic conditions among clusters and their relationship with the availability of WASH facilities in elementary schools. Analysis of other levels of education could also be conducted, either concurrently or partially.

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CONCLUSION

Two clusters for each type of school had been formed with Cluster 1 consisting of areas with high availability of WASH facilities in elementary schools while areas in Cluster 2 had a relatively low percentage of availability in the three WASH indicators. There were 66 regencies /cities, mostly located in provinces in eastern Indonesia, grouped in Cluster 2 for both types of schools. Due to the characteristics of Cluster 2, these areas need serious attention to prevent negative impacts caused by the inadequacy of WASH facilities in elementary schools.

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