ORIGINAL ARTICLE

Spatial autocorrelation analysis of diarrhea incidence in Bandung City, Indonesia in 2024

Yura Witsqa Firmansyah[1], Adi Anggoro Parulian[2], Sapta Suhardono[3], Maura Hardjanti[4], Bhisma Jaya Prasaja[2], Diansyah[5], Ratih Kumala Dewi[6], Muhammad Fadli Ramadhansyah[7], Yohana Allyn Setyawati[2]

[1]Department of Hospital Administration, STIKes Adi Husada, Surabaya City, Indonesia
[2]Department of Health Information and Medical Record, Vocational Faculty of Santo Borromeus University, West Bandung Regency, Indonesia
[3]Environmental Sciences Study Program, Faculty of Mathematics and Natural Sciences, Universitas Sebelas Maret, Surakarta, Indonesia
[4]Department of Nursing, Health Science Faculty of Santo Borromeus University, West Bandung Regency, Indonesia
[5]Harapan Bunda Bandung Hospital, Bandung City, Indonesia
[6]Department of Midwifery, Estu Utomo College of Health Sciences Boyolali, Boyolali City, Indonesia
[7]Faculty of Health Science, Universitas Pembangunan Nasional Veteran Jakarta, Depok, Indonesia
[8]Department of Health Information and Medical Record, Vocational Faculty of Santo Borromeus University, West Bandung Regency, Indonesia

Corresponding Author: Witsqa Firmansyah **Email:** firmansyahyura@gmail.com

Received: 30 December 2024 **Revised:** 8 April 2025 **Accepted:** 9 April 2025 **Available online:** January 2026
DOI: 10.55131/jphd/2026/240107

ABSTRACT

Diarrhea remains a significant public health issue worldwide. The World Health Organization (WHO) estimates that diarrhea accounts for approximately 1.7 billion cases annually, making it a leading cause of child mortality. The morbidity rate for diarrhea in Bandung City across all age groups was 25 per 1,000 population in 2019. This study analyzes the spatial autocorrelation of diarrhea incidence in Bandung City, Indonesia, using Moran's index. A retrospective spatial analysis was conducted on 896 diarrhea cases recorded at Harapan Bunda Hospital, Bandung, from January 1 to June 30, 2024. Spatial autocorrelation was assessed using Moran's I, with spatial units defined at the district level. The analysis incorporated ICD-10 classifications, including A06 (amoebiasis), A09 (diarrhea and gastroenteritis due to infectious causes), and O99.6 (digestive diseases complicating pregnancy). The results of autocorrelation were as follows: mild or some dehydration by age (Moran's I = 0.396, p = 0.001), unspecified amoebiasis (Moran's I = 0.421, p = 0.000), amoebiasis (Moran's I = 0.508, p = 0.000), diarrhea and gastroenteritis of presumed infectious origin (Moran's I = 0.450, p = 0.000), unspecified dehydration status by age (Moran's I = 0.302, p = 0.000), digestive system diseases complicating pregnancy, childbirth, and the puerperium (Moran's I = -0.450 , p = 0.000). These findings indicated a clustered distribution pattern, suggesting that diarrhea incidence in one location correlates with cases in surrounding locations. This study recommends targeted interventions for high-risk clusters, such as community-based health programs and environmental sanitation improvements.

Keywords:
diarrhea, moran's index, spatial epidemiology, Bandung, Indonesia

Citation:
Yura Witsqa Firmansyah, Sapta Suhardono, Maura Hardjanti, Adi Anggoro Parulian, Bhisma Jaya Prasaja, Diansyah, Ratih Kumala Dewi, Muhammad Fadli Ramadhansyah, Yohana Allyn Setyawati. Spatial autocorrelation analysis of diarrhea incidence in Bandung City, Indonesia in 2024. J Public Hlth Dev. 2026;24(1):89-106 (https://doi.org/10.55131/jphd/2026/240107)

INTRODUCTION

The World Health Organization (WHO) reported that the annual incidence of diarrhea reaches approximately 1.7 billion cases. Diarrhea accounts for 443,832 deaths in children under five years and 50,851 deaths in children aged five to nine years, making it the third leading cause of death in children aged one to 59 months.[1] In Indonesia, 50 out of 1,000 infants die from diarrhea. In 2020, the service coverage for diarrhea patients of all age groups was 44.4%, while for children under five years was only 28.9% of the set target[2]. Inequalities between provinces in service coverage of diarrhea patients of all age groups ranged between 4.9% (North Sulawesi) and 78.3% (West Nusa Tenggara). Meanwhile, inequalities between provinces in service coverage of diarrhea patients of children under five ranged from 4.0% (North Sulawesi) to 61.4% (West Nusa Tenggara).[2]

West Java had a service coverage of 34.2%. In Bandung City, diarrhea in children aged one to five years was among the ten most common diseases in 2020.[3] That same year, 30,954 diarrhea cases were treated across all age groups, representing 38.06% of the diarrhea target in Bandung City. Among these, 10,012 cases involved toddlers, accounting for 23.66% of the target for toddlers. Overall, toddlers represented 32.34% of all diarrhea cases. The morbidity rate for diarrhea across all ages was 25 per 1,000 population in 2019. This rate decreased to 12 per 1,000 population in 2020. The decrease in diarrhea cases in Bandung City may be due to reduced patient visits to health facilities during the COVID-19 pandemic.[3]

Diarrhea typically occurs when disruptions to intestinal ion transport proteins, channels, and physical or chemical barriers disturb the balance of water and electrolytes in the digestive tract.[4] Diarrhea can also indicate various other conditions, such as abnormal bile acid absorption, bacterial or viral infections, carbohydrate malabsorption, disaccharidase deficiency, and chronic inflammatory bowel diseases.[5] Although mortality rates have significantly decreased, diarrhea continues to be a common reason for visits to pediatric emergency departments, particularly in low-income countries across Asia and Africa.[6] The mammalian gut contains a wide variety of microorganisms, including bacteria, fungi, protozoa, and viruses. These microbes are unevenly distributed throughout the digestive system, with each region having its own unique microbial population and functions.[7] Homeostasis and symbiotic interactions promote a peaceful coexistence between the microbiota and the host. This partnership helps inhibit the colonization of most invading pathogens, aids in nutrient absorption, and supports various physiological functions.[8,9] For instance, a healthy gut microbiome can protect the cells lining the intestines from damage and help eliminate disease-causing organisms such as *Salmonella*, which can cause diarrhea.

Similar to other infectious diseases, childhood diarrhea is characterized by an interdependent relationship among the host, the pathogen, and both the human and physical environments, all of which collectively exhibit spatial correlations.[10] Given this spatial nature, Geographic Information Systems (GIS) have become essential tools in epidemiological research.[11] GIS has been extensively utilized in studies covering a broad spectrum of diseases, both communicable and non-communicable, by facilitating the visualization of disease transmission dynamics and the identification of clusters along with their associated risk factors.[12] Moreover, employing spatial analysis techniques, such as spatial autocorrelation, enables the mapping of diarrhea distribution patterns within a region by processing location-based data that reveal significant correlations among observations in adjacent areas.[13]

Bacteria that cause diarrhea can thrive due to environmental influences. Unsanitary environments become a favorable breeding ground for these bacteria.[14] Water at a temperature of 37^0C (human body temperature) is the ideal temperature for bacterial growth.[15] In addition, water containing high levels of organic matter content such as carbon and nitrogen can trigger bacterial proliferation. In contrast, lower oxygen levels in water do not contribute to bacterial growth. Water contaminated with human or animal waste is categorized as fecal contamination.[16,17]

Spatial analysis facilitates the identification and interpretation of disease patterns across different geographical regions. It involves the quantitative examination of phenomena across various locations and can be conducted through visualization, exploratory analysis, or spatial data modeling techniques.[18] This method has been extensively applied in epidemiological research and environmental health, allowing researchers to explore the spatial autocorrelation of disease incidence. Spatial analysis has been used in recent studies. For example, Iryanto et al. (2022) examined the factors influencing diarrhea incidence in Padang City,[19] while Firmansyah et al. (2021) investigated waterborne diseases and water pollution.[20] This research emphasizes the gap in regional location, research by Iryanto et al. 2022 highlighted the distribution pattern of diarrhea incidence in the local area, namely Pauh sub-district, Padang City.[19] This study considers variations between regions at the city level in more depth. Firmansyah et al.'s research in 2021 in Semarang City conducted mapping of the incidence of typhoid, filariasis, and diarrhea,[20] the difference from this study is the research location, namely Bandung City. Therefore, this study aims to analyze the spatial autocorrelation of diarrhea incidence in Bandung City in 2024, identifying potential spatial clustering and high-risk areas for targeted intervention.

METHODS

Study Design

This study employed a correlational approach with a retrospective observational design, analyzing existing medical records without prospective follow-up. This study employed Moran's I to assess global spatial autocorrelation (spatial) statistic to identify local clusters of high and low incidence, using a queen-contiguity spatial weight matrix at the sub-district level in Bandung City.

Study Period and Population

Medical records of 896 diarrhea cases at Harapan Bunda Hospital between January 1 and June 30, 2024 were analyzed. Cases were geocoded using patient residential addresses. Exclusion criteria included incomplete addresses and duplicate records. The study period was limited to January to June 2024 to analyze short-term spatial patterns. However, future studies should examine a full-year dataset to account for seasonal variations in diarrhea incidence based on medical records.

Data Collection and Procedures

Data were extracted from hospital medical records, including patient demographics, diagnosis codes, and residential addresses. The geocoded data were mapped for spatial analysis. ICD-10 codes were used to classify diarrhea and related health conditions. Data were anonymized before analysis to maintain patient confidentiality.

GIS Mapping and Spatial Analysis

Geographic Information System (GIS) maps were created using ArcGIS 10.8 software. Patient residential addresses were first geocoded into spatial coordinates (latitude and longitude), and these points were overlaid onto a shapefile of Bandung City, which was obtained from the local municipal authority. The spatial weight matrix, Moran's I analysis, and visualization of spatial clusters were all performed within ArcGIS. The final maps were exported as high-resolution images for inclusion in the analysis and reporting.

To generate a map of diarrhea case distribution patterns using ArcGIS and calculate the Moran Index, the process begins with data preparation, which includes compiling diarrhea case data in CSV or Excel format. This dataset contains essential information such as case ID, address or geographic coordinates, and the number of cases. Additionally, an administrative map of Bandung in shapefile format is required, which can be obtained from the local government or other official sources. If the data is still in address format, a geocoding process is performed to convert it into spatial coordinates. This can be done in ArcGIS using Geocoding Tools, where patient addresses are transformed into coordinate points using references from OpenStreetMap or local databases. The geocoded results are then exported as shapefiles for further analysis.

Once the spatial data is prepared, the next step involves creating a case distribution pattern map. In ArcGIS, the shapefile of the Bandung administrative area is added to the project, followed by a point layer representing the locations of diarrhea cases. The data is then visualized using the graduated symbol method based on the number of cases, allowing variations in distribution patterns to be observed more clearly. To enhance readability, essential map elements such as the legend, scale, and title are incorporated.

Subsequently, spatial analysis is conducted by constructing a Spatial Weight Matrix, which is crucial for calculating the Moran Index. This matrix is generated using the Generate Spatial Weights Matrix tool in ArcGIS, applying the queen contiguity method for polygon-based data or the fixed distance method for point-based data. Once the spatial weights matrix is created, Moran's I is computed using the Spatial Autocorrelation (Moran's I) tool. At this stage, the diarrhea case data were used as input, with the number of cases as the primary variable and the previously created spatial weight matrix as a reference. The results of the Moran's I analysis indicate whether the case distribution pattern is clustered, dispersed, or random. A positive index value suggests a clustered pattern, whereas a negative value signifies a dispersed pattern, and a value close to zero indicates a random distribution. Furthermore, the resulting p-value determines the statistical significance of the observed spatial pattern.

If the Moran's I results confirm clustering, further analysis can be performed using the Hot Spot Analysis (Getis-Ord Gi)* method to identify areas with high (hotspot) or low (coldspot) case concentrations. The outcomes of this analysis are visualized in thematic maps, highlighting zones of high and low risk. Finally, the maps are exported in high-resolution formats such as TIFF or JPEG to ensure clarity and accuracy for further analysis and research reporting. By following this structured procedure, the mapping and spatial analysis of diarrhea case distribution patterns can be conducted transparently and can be reliably replicated by other researchers.

Data Analysis

The spatial distribution analysis in this study is limited by the reliance on data from a single hospital, encompassing both outpatient and inpatient cases. Consequently, the findings may reflect the hospital's catchment area rather than the true disease patterns across Bandung City.

Future research should aim to integrate data from multiple healthcare facilities or public health databases to improve the representativeness and validity of spatial epidemiological analyses. To explore the spatial correlation between diarrhea incidence and related health conditions, six hypotheses were tested. These hypotheses examined whether the spatial distribution of diarrhea cases was associated with the distribution of the following conditions, as recorded in hospital medical records and coded using ICD-10, mild or some dehydration by age, unspecified amoebiasis, amoebiasis, diarrhea and gastroenteritis of presumed infectious origin, unspecified dehydration status by age, digestive system diseases complicating pregnancy, childbirth, and the puerperium. For each condition, the null hypothesis posited no spatial correlation between diarrhea incidence and the condition in neighboring sub-districts, while the alternative hypothesis suggested a significant spatial correlation.

Ethical Consideration

This study was approved by the Ethical Review Board of Universitas Santo Borromeus with an approval number 072/USTB/Etik/Has./VI/2024. All medical record data were anonymized before analysis to protect patients' privacy.

RESULTS

The frequency distribution of patients was analyzed based on gender, age, and type of insurance used. Table 1 below describes the frequency distribution of patients based on age, while Table 2 describes the type of insurance used by patients. In addition, Table 3 describes gender characteristics of the patients.

Table 1. Demographic Characteristics (Age) of Patients Diagnosed with Diarrhea at Harapan Bunda Hospital from January 1 to June 30, 2024 (N=896)

Age of Patients				
		Frequency	**Percentage**	**Valid Percentage**
Valid	Toddlers (0–5 years)	640	71.4	71.4
	Children (6–11 years)	146	16.3	16.3
	Early adolescence (12–16 years)	20	2.2	2.2
	Late adolescence (17–25 years)	11	1.2	1.2
	Early adulthood (26 – 35 years)	28	3.1	3.1
	Late adulthood (36 – 45 years)	24	2.7	2.7
	Early elderly (46 – 55 years)	12	1.3	1.3
	Late elderly (56 – 65 years)	8	0.9	0.9
	Seniors (65 years and above)	7	.8	.8
	Total	896	100.0	100.0

Table 1 shows that the highest proportion of patients belonged to the toddler age group (71.4%). This was followed by the children age group (16.3%) and the early adulthood group (3.1%). **Table 2** presents the gender

distribution of patients. There were 404 female patients (54.9%) and 492 male patients (45.1%), with a total of 896 patients.

Table 2. Demographic Characteristics (Gender) of Patients Diagnosed with Diarrhea at Harapan Bunda Hospital from January 1 to June 30, 2024 (N=896)

Gender of Patients				
		Frequency	**Percentage**	**Valid Percentage**
Valid	Male	492	54.9	54.9
	Female	404	45.1	45.1
	Total	896	100.0	100.0

Table 3. The Insurance Type of Patients Diagnosed with Diarrhea at Harapan Bunda Hospital from January 1 to June 30, 2024 (N=896)

Insurance Type of Patients				
		Frequency	**Percentage**	**Valid Percentage**
Valid	National Health Insurance (JKN)	584	65.2	65.2
	Public	173	19.3	19.3
	Partnership	129	14.4	14.4
	Total	896	100.0	100.0

Table 3 provides the types of payment methods used by patients undergoing diarrhea treatment at Harapan Bunda Hospital, Bandung. The majority of patients, 584 (65.2%), used the National Health Insurance (JKN), followed by 173 (19.3%) patients who opted for self-payment, and 129 (14.4%) relied on partner insurance. Insurance type is an important variable in this study because it can significantly influence access to healthcare services and reflect underlying economic disparities. Individuals with comprehensive insurance coverage often have better access to healthcare, enabling earlier diagnosis and treatment, which can affect the distribution and patterns of diseases. Conversely, those with limited or no insurance may delay seeking care, leading to underreporting or clustering of cases in certain areas. Additionally, differences in insurance type can highlight socioeconomic inequalities, which are crucial for understanding broader public health trends and planning equitable healthcare interventions.

The unit of analysis for the distribution of diarrhea cases in Harapan Bunda Hospital, Bandung, comprised 896 cases. However, the clustering classification requires clearer explanation. The green level (0 cases per 10,000), yellow (1–100 cases per 10,000), orange (101–200 cases per 10,000), and red (>200 cases per 10,000) categories should be explicitly contextualized in terms of public health concerns. The complete distribution of cases is presented in Figures 1, 2, 3, and 4 below.

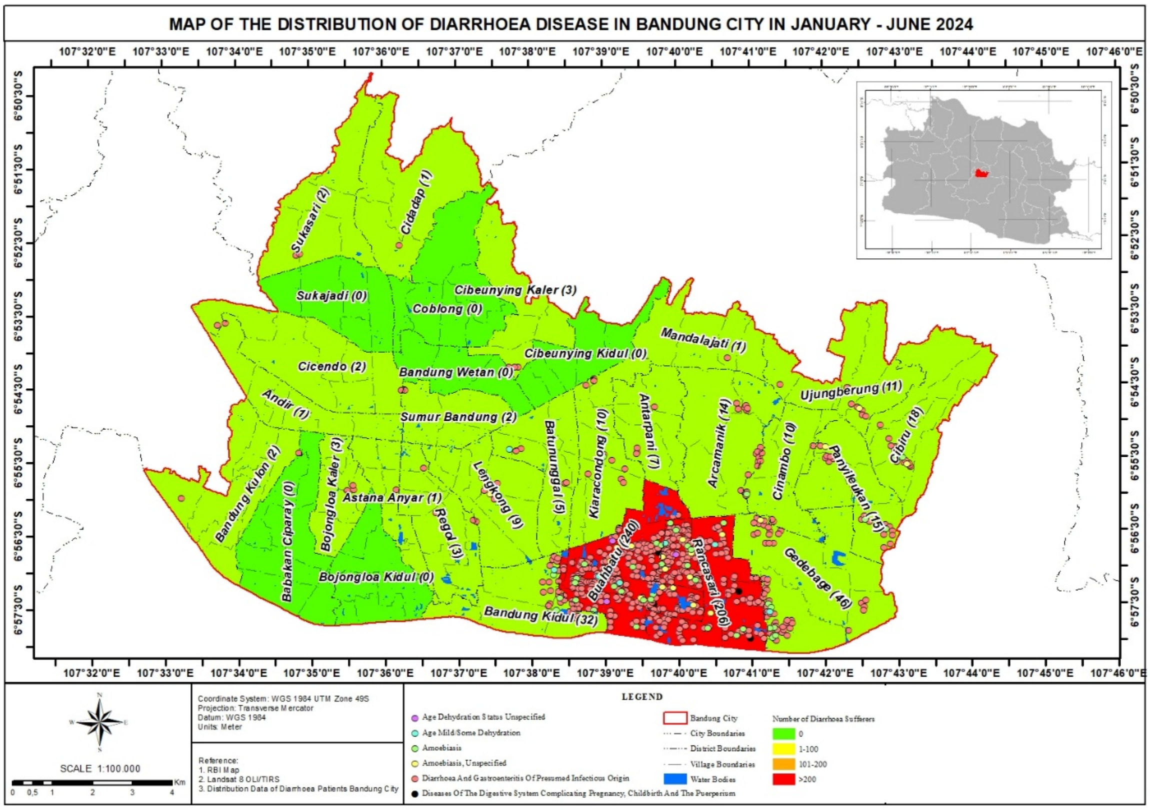

Figure 1. Cluster Distribution of Diarrhea Incidence in Bandung City

Figure 1 illustrates the spatial distribution of diarrhea incidence in Bandung City from January to June 2024, color-coded to indicate varying case densities. The most diarrhea cases scattered in Buahbatu (240 cases per 10,000) and Rancasari (206 cases per 10,000) areas in Bandung City are categorized as level 4 (red color) with a range of > 200 cases per 10,000. Second place was Rancasari (206 cases per 10,000), followed by Gedebage (46 cases per 10,000), Kidul Bandung (32 cases per 10,000), and Cibiru (18 cases per 10,000). The results of spatial distribution were as follows, mild or some dehydration by age (10 cases per 10,000), unspecified amoebiasis (22 cases per 10,000), amoebiasis (68 cases per 10,000), diarrhea and gastroenteritis of presumed infectious origin (781 cases per 10,000), unspecified dehydration status by age (four cases per 10,000), digestive system diseases complicating pregnancy, childbirth, and the puerperium (six cases per 10,000). This map suggests that public health interventions should prioritize high-incidence regions for targeted resource allocation and sanitation improvements.

The results of the Moran's Index (MI) analysis of diarrhea cases using GIS tools are presented in the following figures. Three classifications can be generated from MI, including dispersion, random distribution, and clustering. Additionally, this study tested several hypotheses, which are discussed in this section.

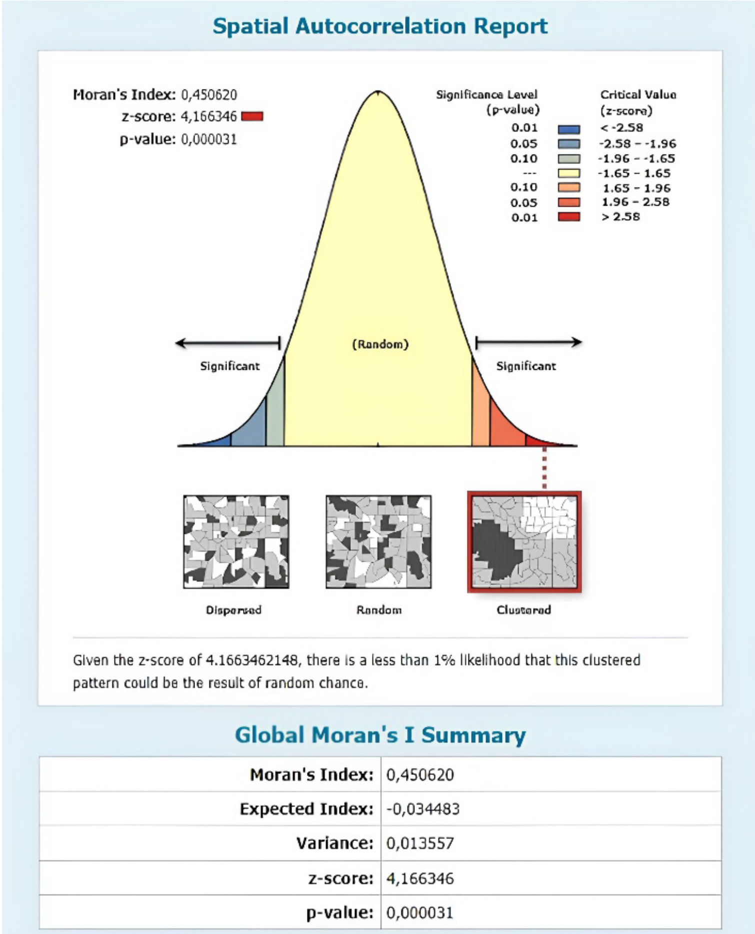

Figure 2. Moran's Index Analysis Result of Digestive System Diseases Complicating Pregnancy, Childbirth, and The Puerperium in Bandung City from January to June 2024

Based on **Figure 2**, the expected value is -0.034, while the MI value is 0.45, indicating that the autocorrelation exceeded the expected value. The z-score of 4.16 falls within the cluster curve (z-score > 2.58) and is positive. With a p-value of 0.000 at a 5% significance level, the null hypothesis is rejected and the alternative hypothesis is accepted. This finding suggests that the incidence of digestive system diseases complicating pregnancy, childbirth, and the puerperium in a given location is spatially correlated with diarrhea incidence in neighboring locations.

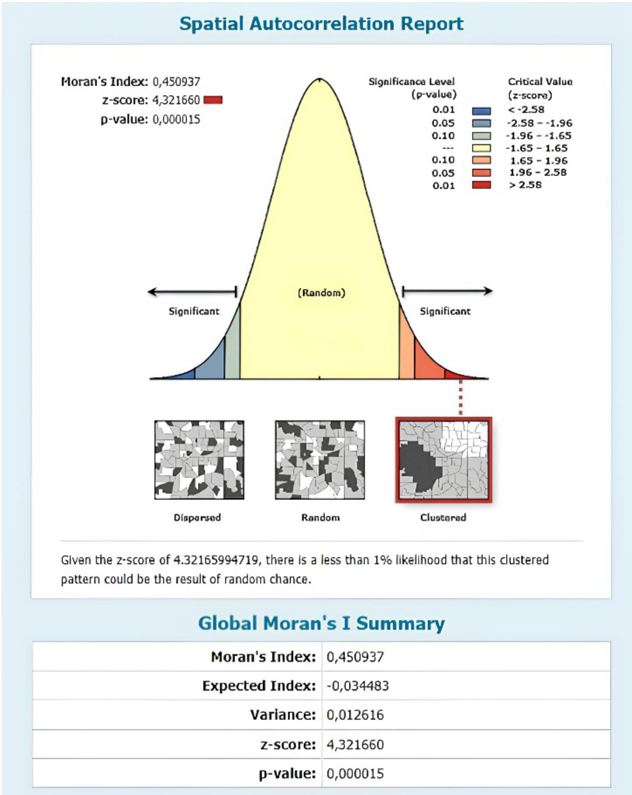

Figure 3. Moran's Index Analysis Result of Diarrhea and Gastroenteritis of Presumed Infectious Origin in Bandung City from January to June 2024

Based on **Figure 3**, the expected value is -0.03, while the MI value is 0.45, indicating that the autocorrelation exceeded the expected value. The z-score of 4.32 falls within the cluster curve (z-score > 2.58) and is positive. With a p-value of 0.000 at a 5% significance level, the null hypothesis is rejected and the alternative hypothesis is accepted. This finding suggests that the incidence of diarrhea and gastroenteritis of Presumed infectious origin in a given location is spatially correlated with diarrhea incidence in neighboring locations.

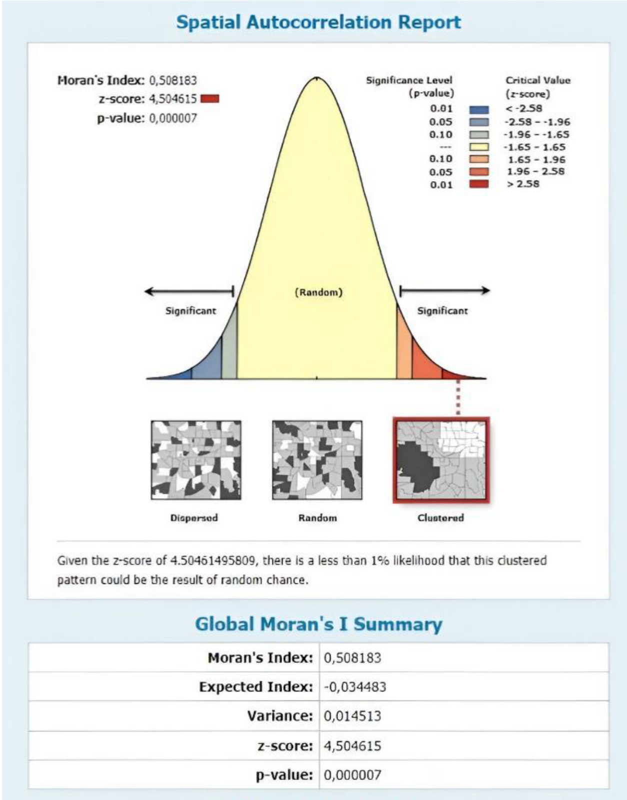

Figure 4. Moran's Index Analysis Result of Amoebiasis in Bandung City from January to June 2024

Based on **Figure 4**, the expected value is -0.03, while the MI value is 0.50, indicating that the autocorrelation exceeded the expected value. The z-score of 4.50 falls within the cluster curve (z-score > 2.58) and is positive. With a p-value of 0.000 at a 5% significance level, the null hypothesis is rejected and the alternative hypothesis is accepted. This finding suggests that amoebiasis incidence in a given location is spatially correlated with diarrhea incidence in neighboring locations.

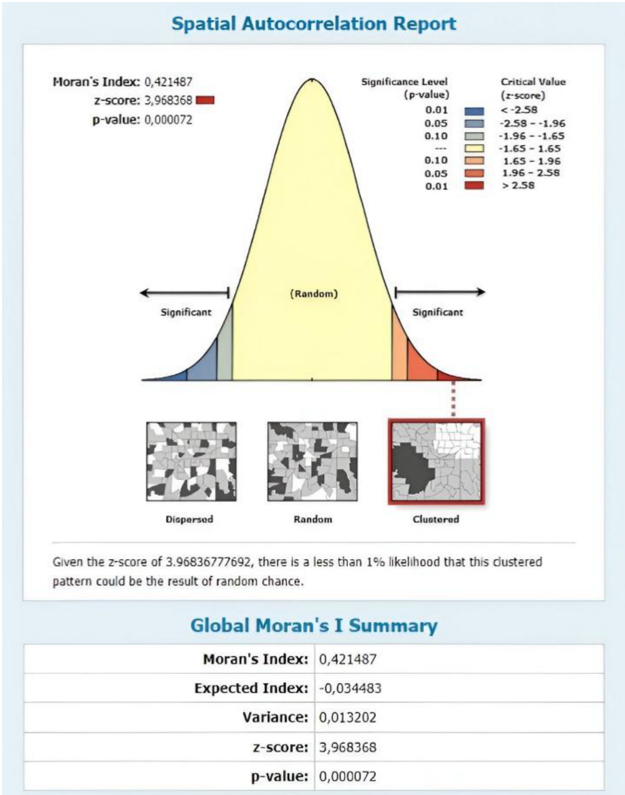

Figure 5. Moran's Index Analysis Result of Unspecified Amoebiasis in Bandung City from January to June 2024

Based on **Figure 5**, the expected value is -0.03, while the MI value is 0.42, indicating that the autocorrelation exceeded the expected value. The z-score of 3.96 falls within the cluster curve (z-score > 2.58) and is positive. With a p-value of 0.000 at a 5% significance level, the null hypothesis is rejected and the alternative hypothesis is accepted. This finding suggests that the incidence of unspecified amoebiasis in a given location is spatially correlated with diarrhea incidence in neighboring locations.

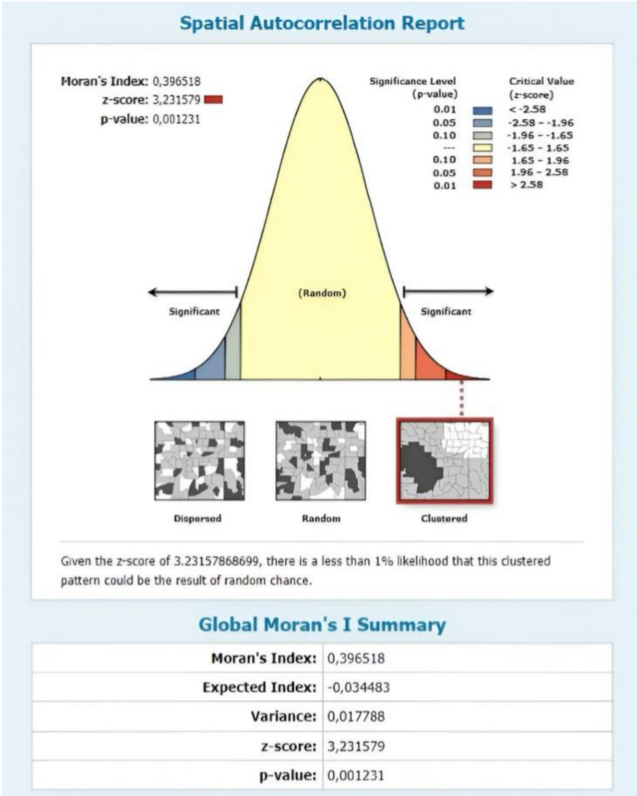

Figure 6. Moran's Index Analysis Result of Mild or Some Dehydration by Age in Bandung City from January to June 2024

Based on **Figure 6**, the expected value is -0.03, while the MI value is 0.39, indicating that the autocorrelation exceeded the expected value. The z-score of 3.23 falls within the cluster curve (z-score > 2.58) and is positive. With a p-value of 0.001 at a 5% significance level, the null hypothesis is rejected and the alternative hypothesis is accepted. This finding suggests that the incidence of mild or some dehydration by age in a given location is spatially correlated with diarrhea incidence in neighboring locations.

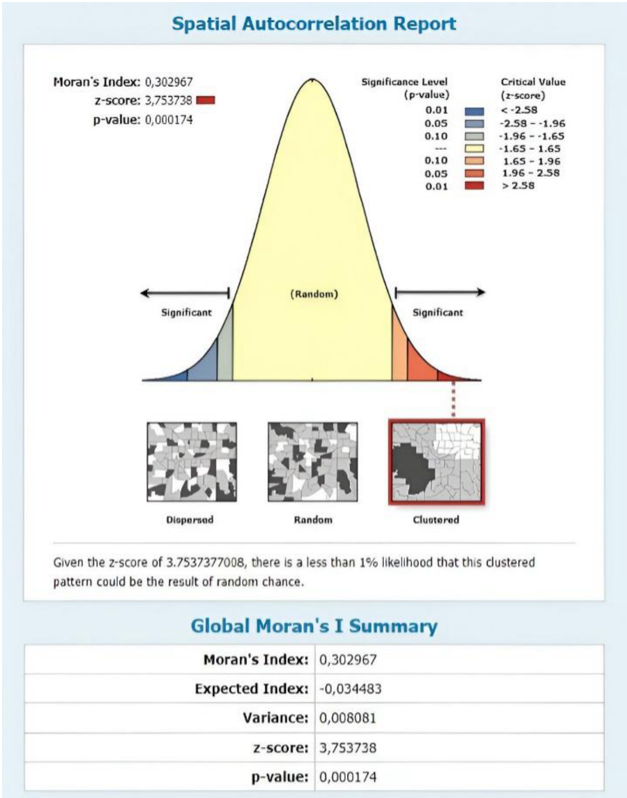

Figure 7. Moran's Index Analysis Result of Unspecified Dehydration Status by Age in Bandung City from January to June 2024

Based on **Figure 7**, the expected value is -0.03, while the MI value is 0.30, indicating that the autocorrelation exceeded the expected value. The z-score of 3.75 falls within the cluster curve (z-score > 2.58) and is positive. With a p-value of 0.000 at a 5% significance level, the null hypothesis is rejected and the alternative hypothesis is accepted. This finding suggests that the incidence of dehydration by age in a given location is spatially correlated with diarrhea incidence in neighboring locations.

DISCUSSION

The spatial distribution of diarrhea cases in Bandung City reveals significant clusters in high-incidence areas, such as Buahbatu (240 cases) and Rancasari (206 cases), which are concentrated in the central and southeastern parts of the city. In contrast, low-incidence areas, such as the northern and western parts of the city, show patterns that may be related to factors such as access to health services, sanitation quality, and population density. Based on the visualization results in Figure 1, the very high incidence area (dark red) in Babakan Ciparay highlights this area as high-risk, requiring more intensive public health interventions.

This clustering phenomenon has also been reported in several spatial epidemiology studies on diarrhea in developing countries. For example, a study in Bangladesh showed that areas with poor sanitation, high population density, and limited access to clean water had a significantly higher incidence of diarrhea compared to other areas.[32] Similarly, in urban India, spatial patterns showed that clusters of diarrhea incidence often appeared in slum areas with poor sanitation access, reinforcing the role of environmental factors in disease distribution.[33] Another study in Kenya found that poor access to clean water and sanitation facilities, combined with the rainy season, increased diarrhea incidence, especially in densely populated areas.[34]

In the context of Bandung City, this distribution pattern can be explained through a spatial epidemiological approach using analyses such as Moran's I to identify spatial autocorrelation and hot spot analysis to map high-risk areas in more detail. These findings are important for evidence-based public health planning, such as improving access to sanitation in high-incidence areas and strengthening community-based interventions. In addition, the influence of environmental factors, such as rainfall affecting contamination of water sources, needs further investigation to understand the causes of the uneven spatial distribution.[24,25,26]

The widespread occurrence of diarrhea in urban areas, including Bandung City, results from complex interactions between spatial, environmental, and socio-economic factors. Based on the findings of this study, areas with high incidence rates, such as Babakan Ciparay, Buahbatu, and Rancasari, exhibit significant spatial clustering patterns. These findings indicate that inadequate sanitation infrastructure, such as poor waste disposal systems and limited access to clean water, significantly contributes to the spatial distribution of diarrhea cases. For instance, the high number of cases in Babakan Ciparay (>200 cases) can be attributed to high population density and insufficient basic sanitation facilities. Similar conditions were observed in Buahbatu and Rancasari, with 240 and 206 cases, respectively, reflecting environmental challenges that exacerbate disease transmission in these areas.

Urban population density amplifies the risk of diarrhea transmission through direct or indirect human contact.[27] Areas with limited handwashing facilities and low public awareness of personal hygiene are more susceptible to food and water contamination.[28] The GIS mapping results from this study provide a visual representation of the interaction between social and environmental factors, highlighting regions with high disease transmission rates. This analysis underscores the importance of targeted, area-specific interventions to address the spread of diarrhea in urban settings.

GIS-based intervention recommendations are crucial for effectively tackling diarrhea cases. High-risk areas such as Babakan Ciparay should be prioritized for sanitation infrastructure improvements, including better waste disposal systems and increased access to clean water. Additionally, public health education programs should focus on these areas to raise awareness about hygiene and food safety. Localized campaigns leveraging GIS data can be effective as they can address the specific needs of each community.[29]

However, this study has several limitations that must be acknowledged. The reliance on data from a single hospital introduces potential bias, as it does not represent the entire population of Bandung City. Furthermore, the spatial resolution of the data may not capture micro-environmental factors, such as rainfall, temperature, or specific contamination sources, which could influence diarrhea incidence.[30] Future studies should integrate data from multiple healthcare facilities or public health agencies to improve the accuracy and representativeness of spatial analyses.

GIS analysis plays a critical role in public health planning, particularly in guiding resource allocation and designing disease prevention strategies.[31] By identifying high-risk areas such as Babakan Ciparay, Buahbatu, and Rancasari, policymakers can prioritize interventions in these regions. For example, public health budgets can focus on improving sanitation infrastructure in Babakan Ciparay, while hygiene education campaigns can be intensified in Buahbatu and Rancasari.

Furthermore, integrating GIS data into early warning systems can help detect and respond to potential outbreaks more quickly, ensuring more effective prevention and control measures.

Cross-sector collaboration, including government agencies, private sectors, and community organizations, is essential for implementing GIS-based strategies. For instance, public-private partnerships can support the construction of clean water facilities or sanitation technologies in high-risk areas, while community-based organizations can engage local residents in adopting sustainable hygiene practices. By leveraging the data and insights generated from GIS analysis, these collaborative efforts can enhance the precision and effectiveness of public health. This study has revealed the distribution pattern of diarrhea incidence in Bandung City, but limitations still exist in that it is necessary to examine a full-year dataset to account for seasonal variations in diarrhea incidence based on medical records. In addition, there is a need to identify environmental and behavioral factors in areas with the highest diarrhea cases.

RECOMMENDATION

This study highlights the importance of targeted interventions based on GIS insights to address diarrhea incidence in Bandung City. Key recommendations include improving sanitation infrastructure in high-risk areas like Babakan Ciparay, Buahbatu, and Rancasari by upgrading waste management systems and expanding access to clean water. Health education campaigns should focus on promoting hygiene practices, especially in vulnerable groups, and be delivered through local media and community leaders. Establishing real-time GIS monitoring will enable timely disease surveillance and resource allocation. Policymakers should integrate GIS findings into urban planning to prioritize sanitation improvements. Cross-sector collaboration among government agencies, NGOs, and community organizations is essential for implementing these strategies. Lastly, further research is needed to understand environmental factors and assess the effectiveness of interventions.

AUTHOR CONTRIBUTIONS

YWF conceptualization,, writing - original draft, validation, and methodology; SS data curation and visualization; MH writing - original draft; AAP writing - review & editing, formal analysis; BJP visualization data; D resource, investigation; RKD supervision and fundarising; MFR writing - original draft; YAS software and visualization.

ETHICAL CONSIDERATION

This study was approved by the Ethical Review Board of Universitas Santo Borromeus with an approval number 072/USTB/Etik/Has./VI/2024. All medical record data were anonymized before analysis to protect patients' privacy.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest associated with this study.

REFERENCES

1. Diarrhoeal disease [Internet]. 2024 [Cited 2024]. Available at: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease
2. Rafiuddin AT, Purwanty M. Factors Associated With The Incidence Of Diarrhea In Toddlers In The Working

Area Of Puuwatu Health Center, Kendari City. 1 2020; 3(1): 65–75. Available at: https://doi.org/10.36566/mjph/Vol3.Iss1/140
3. Dinas Kesehatan Kota Bandung. Bandung City Health Profile Year 2020 [Internet]. 2020. Available at: https://dinkes.bandung.go.id/download/profil-kesehatan-kota-bandung-2020/
4. Chu C, Rotondo-Trivette S, Michail S. Chronic diarrhea. Curr Probl Pediatr Adolesc Health Care 2020; 50(8): 100841. Available at: https://doi.org/10.1016/j.cppeds.2020.100841
5. Camilleri M, Sellin JH, Barrett KE. Pathophysiology, Evaluation, and Management of Chronic Watery Diarrhea. Gastroenterology 2017; 152(3): 515-532.e2. Available at: https://doi.org/10.1053/j.gastro.2016.10.014
6. Ferris A, Gaisinskaya P, Nandi N. Approach to Diarrhea. Prim Care 2023; 50(3): 447–59. Available at: https://doi.org/10.1016/j.pop.2023.03.010
7. Ryan MJ, Schloter M, Berg G, Kostic T, Kinkel LL, Eversole K, et al. Development of Microbiome Biobanks - Challenges and Opportunities. Trends Microbiol 2021; 29(2): 89–92. Available at: https://doi.org/10.1016/j.tim.2020.06.009
8. Rego R, Watson S, Gill P, Lilford R. The impact of diarrhoea measurement methods for under 5s in low- and middle-income countries on estimated diarrhoea rates at the population level: A systematic review and meta-analysis of methodological and primary empirical studies. Trop Med Int Health 2022; 27(4): 347–68. Available at: https://doi.org/10.1111/tmi.13739
9. Fan Y, Pedersen O. Gut microbiota in human metabolic health and disease. Nat Rev Microbiol 2021; 19(1): 55–71. Available at: https://doi.org/10.1038/s41579-020-0433-9
10. Raza O, Mansournia MA, Rahimi Foroushani A, Holakouie-Naieni K. Exploring spatial dependencies in the prevalence of childhood diarrhea in Mozambique using global and local measures of spatial autocorrelation. Med J Islam Repub Iran 2020; 34: 59. Available at: https://doi.org/10.34171/mjiri.34.59
11. Almasi A, Zangeneh A, Ziapour A, Saeidi S, Teimouri R, Ahmadi T, et al. Investigating Global Spatial Patterns of Diarrhea-Related Mortality in Children Under Five. Front Public Health [Internet] 2022 [Cited 2025]; 10. Available at: https://doi.org/10.3389/fpubh.2022.861629
12. Syukri M, Halim R. Spatial Analysis to Identify Hotspot of Diarrhea Among Children under Five Years in 154 Districts/Cities in Sumatera Island. Indonesian Journal of Global Health Research 2023; 5(1): 111–20. Available at: https://doi.org/10.37287/ijghr.v5i1.1777
13. Wahyudi T, Yuniar P, Rahmaniati M. Spatial Autocorrelation of Diarrhea Cases in West Java Province in 2023. Media Publikasi Promosi Kesehatan Indonesia (MPPKI) 2024; 7(9): 2368–76. Available at: https://doi.org/10.56338/mppki.v7i9.5973
14. Jandhyala SM, Talukdar R, Subramanyam C, Vuyyuru H, Sasikala M, Reddy DN. Role of the normal gut microbiota. World J Gastroenterol 2015; 21(29): 8787–803. Available at: https://doi.org/10.3748/wjg.v21.i29.8787
15. Yin J, Li Y, Han H, Ma J, Liu G, Wu X, et al. Administration of Exogenous Melatonin Improves the Diurnal Rhythms of the Gut Microbiota in Mice Fed a High-Fat Diet. mSystems 2020; 5(3): e00002-20. Available at: https://doi.org/10.1128/mSystems.00002-20
16. Gresse R, Chaucheyras-Durand F, Fleury MA, Van de Wiele T, Forano E, Blanquet-Diot S. Gut Microbiota

Dysbiosis in Postweaning Piglets: Understanding the Keys to Health. Trends Microbiol 2017; 25(10): 851–73. Available at: https://doi.org/10.1016/j.tim.2017.05.004
17. Torres-Fuentes C, Schellekens H, Dinan TG, Cryan JF. The microbiota-gut-brain axis in obesity. Lancet Gastroenterol Hepatol 2017; 2(10): 747–56. Available at: https://doi.org/10.1016/S2468-1253(17)30147-4
18. Carvalho S, Magalhães M de AFM, Medronho R de A. Analysis of the spatial distribution of dengue cases in the city of Rio de Janeiro, 2011 and 2012. Rev Saude Publica 2017; 51: 79. Available at: https://doi.org/10.11606/S1518-8787.2017051006239
19. Iryanto AA, Firmansyah YW, Widyantoro W, Zolanda A. Spatial Patterns of Environmental Sanitation Factors as Determinants of Toddlers' Diarrhea in Pauh District, Padang City in 2021. JURNAL KESEHATAN LINGKUNGAN 2022; 14(2): 71–81. Available at: https://doi.org/10.20473/jkl.v14i2.2022.71-81
20. Firmansyah YW, Setiani O, Darundiati YH, Joko T, Raharjo M. Water Pollution Index and The Distribution of Waterborne Diseases on The East Flood Canal, Semarang City : An Analysis Spatial. Jurnal Aisyah : Jurnal Ilmu Kesehatan 2021; 6(3): 569–78. Available at: https://doi.org/10.30604/jika.v6i3.701
21. George CM, Perin J, Neiswender de Calani KJ, Norman WR, Perry H, Davis TP, et al. Risk Factors for Diarrhea in Children under Five Years of Age Residing in Peri-urban Communities in Cochabamba, Bolivia. Am J Trop Med Hyg 2014; 91(6): 1190–6. Available at: https://doi.org/10.4269/ajtmh.14-0057
22. Ghosh K, Chakraborty AS, Mog M. Prevalence of diarrhoea among under five children in India and its contextual determinants: A geo-spatial analysis. Clinical Epidemiology and Global Health 2021; 12: 100813. Available at: https://doi.org/10.1016/j.cegh.2021.100813
23. Azanaw J, Malede A, Yalew HF, Worede EA. Determinants of diarrhoeal diseases among under-five children in Africa (2013–2023): a comprehensive systematic review highlighting geographic variances, socioeconomic influences, and environmental factors. BMC Public Health 2024; 24(1): 2399. Available at: https://doi.org/10.1186/s12889-024-19962-0
24. Wenzl HH. Diarrhea in chronic inflammatory bowel diseases. Gastroenterol Clin North Am 2012; 41(3): 651–75. Available at: https://doi.org/10.1016/j.gtc.2012.06.006
25. Corgneau M, Scher J, Ritie-Pertusa L, Le DTL, Petit J, Nikolova Y, et al. Recent advances on lactose intolerance: Tolerance thresholds and currently available answers. Crit Rev Food Sci Nutr 2017; 57(15): 3344–56. Available at: https://doi.org/10.1080/10408398.2015.1123671
26. Zhong Y, Priebe MG, Vonk RJ, Huang C-Y, Antoine J-M, He T, et al. The role of colonic microbiota in lactose intolerance. Dig Dis Sci 2004; 49(1): 78–83. Available at: https://doi.org/10.1023/b:ddas.0000011606.96795.40
27. Clasen T, Pruss-Ustun A, Mathers CD, Cumming O, Cairncross S, Colford JM. Estimating the impact of unsafe water, sanitation and hygiene on the global burden of disease: evolving and alternative methods. Trop Med Int Health 2014; 19(8): 884–93. Available at: https://doi.org/10.1111/tmi.12330
28. Prüss-Ustün A, Wolf J, Bartram J, Clasen T, Cumming O, Freeman MC, et al. Burden of disease from inadequate water, sanitation and hygiene for selected adverse health outcomes: An

updated analysis with a focus on low- and middle-income countries. Int J Hyg Environ Health 2019; 222(5): 765–77. Available at: https://doi.org/10.1016/j.ijheh.2019.05.004
29. Alsan M, Goldin C. Watersheds in Child Mortality: The Role of Effective Water and Sewerage Infrastructure, 1880 to 1920. Journal of Political Economy 2018; 127. Available at: https://doi.org/10.1086/700766
30. Dangour AD, Watson L, Cumming O, Boisson S, Che Y, Velleman Y, et al. Interventions to improve water quality and supply, sanitation and hygiene practices, and their effects on the nutritional status of children. Cochrane Database Syst Rev 2013;(8): CD009382. Available at: https://doi.org/10.1002/14651858.CD009382.pub2
31. Fuller JA, Eisenberg JNS. Herd Protection from Drinking Water, Sanitation, and Hygiene Interventions. Am J Trop Med Hyg 2016; 95(5): 1201–10. Available at: https://doi.org/10.4269/ajtmh.15-0677
32. Chen J, Wan C-M, Gong S-T, Fang F, Sun M, Qian Y, et al. Chinese clinical practice guidelines for acute infectious diarrhea in children. World J Pediatr 2018; 14(5): 429–36. Available at: https://doi.org/10.1007/s12519-018-0190-2
33. Shane AL, Mody RK, Crump JA, Tarr PI, Steiner TS, Kotloff K, et al. 2017 Infectious Diseases Society of America Clinical Practice Guidelines for the Diagnosis and Management of Infectious Diarrhea. Clin Infect Dis 2017; 65(12): e45–80. Available at: https://doi.org/10.1093/cid/cix669
34. Navaneethan U, Giannella RA. Mechanisms of infectious diarrhea. Nat Clin Pract Gastroenterol Hepatol 2008; 5(11): 637–47. Available at: https://doi.org/10.1038/ncpgasthep1264