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Spatiotemporal dynamics and environmental risk factors in the spread of COVID-19 within urban slum settlements

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ABSTRACT

Background: This study examines the spatial-temporal dynamics and environmental risk factors that influence COVID-19 transmission in urban slums. Although the pandemic has had widespread social, economic, and environmental impacts throughout Indonesia, its effects have been particularly severe in slum communities, where residents face structural vulnerabilities such as high population density, poor sanitation, and limited access to health services. **Methods**: This study is based on a comprehensive review of accredited international and national journal publications. By synthesizing multidisciplinary evidence, the study identifies key factors driving infection patterns in urban slums, particularly those related to environmental conditions, population density, mobility, and socioeconomic inequality. The analysis also highlights the role of geospatial approaches in mapping transmission clusters and tracking temporal shifts in COVID-19 spread. **Findings:** The review shows that the geospatial and temporal patterns of COVID-19 transmission in slums are strongly influenced by environmental risks—such as inadequate housing ventilation, poor waste management, and limited access to clean water—combined with highly dense living conditions. These factors collectively increase the rate of transmission and create persistent disease hotspots. These findings also emphasize that targeted interventions, spatially informed policies, and community-centered strategies are essential for effectively reducing infection risk and strengthening local resilience. **Conclusion**: Future research should explore the application of geospatial methodologies to assess the complex interactions between environmental vulnerability and disease transmission in slum settings. These insights are essential for designing context-sensitive interventions to promote community health resilience and inclusive urban development. Strengthening spatial evidence and integrating it into policy frameworks can help protect vulnerable populations and build healthier, more equitable urban environments. **Novelty/Originality of this article:** This study offers a novel contribution by synthesizing spatiotemporal perspectives with environmental risk analysis to specifically examine COVID-19 transmission within urban slum settlements—an area that remains underexplored in existing Indonesian research.

KEYWORDS: COVID-19; Jakarta special capital region; slums area.

1. Introduction

Jakarta is the capital city of Indonesia with an area of 664 km^2 which has a population density greater than other cities in Indonesia of 15,900 people/km^2 (Martinez & Masron, 2020). The development of the city resulted in an increase in the population from 2015-2017 by 10.18 million people to 10.37 million people. This illustrates the population movement of 269 people per day or 11 people per hour to Jakarta, causing the population density in the capital city to increase (Sari & Winarso, 2007). The number of poor people in the capital city of Jakarta in 2018 reached 20,870 people (BPS DKI Jakarta, 2019). Of the total area of the capital city of Jakarta, 49.47% is used as housing and residential areas where 5.4% is slums consisting of 392 neighborhood association/*rukun warga* (RWs) (Fitria & Setiawan, 2014).

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Slums are dwellings with uninhabitable quality and have the characteristics of high population density with limited land area, low building quality, low access to basic services, prone to social and environmental diseases, and endanger the survival of their residents (Fitria & Setiawan, 2014; Friesen et al., 2020; Kyriazis et al., 2020). Indonesia is one of the countries that has slums (Friesen et al*.,* 2020). There are 186 RWs in the slum category with the largest percentage in North Jakarta (37%) (Cities Alliance, 2013). These slums grow in various locations including coastal areas (the majority in North Jakarta), railway banks (the majority in Central Jakarta and North Jakarta), toll road access (the majority in North Jakarta) and watersheds (the majority in West Jakarta) (Cities Alliance, 2013; Fitriyanto et al., 2019).

People living in slum areas live poorly. The difficulty of obtaining access to basic services and sanitation such as clean water, low handwashing with soap, and very minimal toilet ownership (Brito et al., 2020; Ilesanmi et al., 2020; Miller & Spoolman, 2016). Social and economic conditions that are far from welfare and poor environmental conditions such as frequent flooded houses, inadequate building ventilation, and living close to garbage dumps cause people in slums to live with poverty and susceptible to disease.

The extraordinary occurrence of COVID-19 in various countries and status as a pandemic caused by Severe Acute Respiratory Syndrome Coronavirus-2 known as SARS-CoV-2 which is classified as a highly pathogenic zoonotic virus was first discovered in animal markets in the Wuhan region, China at the end of 2019 and spread rapidly throughout the country (Djalante et al., 2020; Nghiem et al., 2020). The number of COVID-19 sufferers reached more than 290 million as of September 2020, making it a global pandemic that threatens public health (Al-Rohaimi & Al Otaibi, 2020; Liu et al., 2020; Saglietto et al., 2020; Yuan et al., 2020). The pandemic disaster that occurred in almost all countries also attacked Indonesia. Based on data from the Ministry of Health and National Disaster Management Agency/*Badan Nasional Penanggulangan Bencana (BNPB)* in Purnama & Susanna (2020), the cases reported in the first 1 month of the SARS-CoV-2 virus entering Indonesia were 6,760 infected people, 590 people died and 747 people recovered. As of November 27, 2020, in Jakarta special capital region/*Daerah Keistimewaan (DKI) Jakarta* Province, there were 131,525 people infected, 120,194 recovered, and 2592 people died (Geospatial Information Agency, 2020).

COVID-19 transmission occurs from human to human through droplets (mouth and nasal cavity), aerosols (when sneezing), physical contact with COVID-19 patients, contact with surfaces containing COVID-19 and sharing goods (Rothan & Byrareddy, 2020). Droplets and aerosols containing SARS-CoV-2 enter the upper respiratory tract. The time needed to infect is a minimum of 5 days until showing symptoms. Although ideally 4-14 days is the incubation time required by SARS-CoV-2 (Al-Rohaimi & Al Otaibi, 2020; Rothan & Byrareddy, 2020). Patients with acute COVID-19 (80%) require intensive care such as oxygen supply. Severe infection from SARS-CoV-2 leads to the accumulation of large amounts of mucosa and fluid in the tissues of the pulmonary alveoli and results in decreased respiratory system performance (Al-Rohaimi & Al Otaibi, 2020).

In the Environment, SARS-CoV is found in groundwater, soil, and wastewater. SARS-CoV-2 in the environment is influenced by temperature, humidity, sun exposure and surface type (Tosepu et al., 2020). SARS-CoV-2 survived for 72 hours on stainless steel and plastic, 24 hours on cards, and 4 hours on copper, 4-5 days on wood and paper (at room temperature) and 2-3 days in wastewater (Lahrich et al., 2021). In wastewater, it takes 7-9 days to remove 99.9% of the coronavirus at 25% (Yeo et al., 2020). Various efforts to prevent the spread of COVID-19 have been implemented in various countries such as social-distancing, lockdowns, self-quarantine, and large-scale social restrictions (Bukuluki et al., 2020; Koh et al., 2020; Phuoc et al., 2020). However, people's non-compliance with the regulations imposed caused more and more people to be infected.

In various countries, the incidence of COVID-19 occurs in dense residential environments such as in Brazil (Brito et al*.,* 2020), in Africa (Ilesanmi et al., 2020) and in India (Malani et al*.,* 2020). Indonesia is one of the countries with a high population density so that SARS-CoV-2 can spread quickly and increase the number of COVID-19 infection cases in Jakarta. The COVID-19 pandemic in the capital city of Jakarta has an impact on all life settings (Brito et al., 2020). However, living conditions and urban morphology found in poor communities make informal settlements more vulnerable to COVID-19 infection compared to formal cities, where residents have the resources to follow health protocols that have been imposed by the Ministry of Health (Brito et al., 2020; Ilesanmi et al., 2020).

Analysis using Earth Observation (EO) can provide information about the earth's spatial order and bridge the spatial data gap (Kuffer et al., 2020). Satellite imagery data is available globally in a variety of resolutions and can be applied for different purposes. Temporally improved resolution of satellite imagery data also enables dynamic monitoring over days, weeks, months, and years. These satellite images can be used to identify disease outbreaks in larger units of space. For example, satellite imagery has been used to track Ebola disease in South Africa (Peckham & Sinha, 2017) and COVID-19 (Gupta et al., 2020). COVID-19 incident analysis studies using GIS and geospatial analysis can be a tool that can assist the government in making decisions, levels of importance, social mobilization and community response (Brito et al., 2020; Franch-Pardo et al., 2020). Based on the background that has been described, it is necessary to identify factors that accelerate the spread of COVID-19 infection in Jakarta special capital region/*Daerah Keistimewaan (DKI) Jakarta* slums. Geospatial analysis of the spread of COVID-19 and slums helps policymakers to create the right program or policy, so that the number of COVID-19 infections in slums can be suppressed.

2. Methods

The data used in writing this paper are international and national journals accredited by Scopus or Sinta. The journals reviewed include topics on the application of geospatial analysis of COVID-19 in Jakarta, geospatial analysis of slum areas, and factors related to the spread of COVID-19 in slum areas. The method carried out in this writing is a literature study method or desk research from various accredited international and national journals.

Furthermore, the author combines data and analyzes to produce a study related to geospatial analysis and changes in Jakarta's space during the COVID-19 pandemic. Modern geospatial analysis can assist in the community's infection response to COVID-19 by utilizing appropriate data on the location of residence of COVID-19 patients used to determine the potential spread of SARS-CoV-2 infection, population data, and the distribution of social and economic characteristics to determine the perspective of prevention and decision making (Brito et al., 2020; De Ridder et al., 2020). The data used in writing this paper include geospatial data of the city of Jakarta related to the COVID-19 pandemic and the latest COVID-19 infection case data.

3. Results and Discussion

3.1 Analisis spasiotemporal COVID-19 di Jakarta special capital region

Epidemiology is a science that studies a disease and determines the cause of disease that focuses on the human population. In the epidemiology of COVID-19 disease, it discusses 3 basic components of epidemiology, namely the number of COVID-19 cases in DKI Jakarta, the transmission of the spread of the disease, and the factors causing COVID-19 (Nangi et al., 2019). Initially, the coronavirus was first discovered in a marine fish market in the Wuhan area of China. This virus attacks people in almost all countries (developed and developing) with more than 290 million cases until September 2020 so that Coronavirus infectious diseases 2019 or COVID-19 causes a global pandemic and poses a threat to public health (Arora et al., 2020; Asian Development Bank, 2020; Liu et al., 2020; Saglietto et al., 2020; Yuan et al., 2020).

COVID-19 transmission occurs from human to human through droplets (mouth and cavity), aerosols (when sneezing), physical contact with COVID-19 patients, contact with surfaces containing COVID-19 and sharing of goods even SARS-CoV-2 is categorized as airborne disease which means it can be transmitted through inhalation (Liu et al., 2020; Mandal et al., 2020; von Seidlein et al., 2020). Droplets and aerosols containing SARS-CoV-2 enter the upper respiratory tract. The time needed to infect is a minimum of 4 days until showing symptoms. Although ideally 4-14 days is the incubation time required by SARS-CoV-2. The vital target of this virus is respiratory and affects other organs such as the gastrointestinal tract, liver, and central nervous system in humans and animals (Lau & Chan, 2015; Liu et al., 2020; Rothan & Byrareddy, 2020). Patients with acute COVID-19 (80%) require intensive care such as oxygen supply. Severe infection from SARS-CoV-2 leads to the accumulation of large amounts of mucosa and fluid in the pulmonary alveoli tissue and results in decreased respiratory system performance (Al-Rohaimi & Al Otaibi, 2020).

Earth Observation (EO) data plays an important role in illustrating the determination of COVID-19 disease in space and is very useful in timely decision making and can save many lives (Brito et al., 2020; Franch-Pardo et al., 2020). In Indonesia, geospatial data on the spread of infected and reported communities has been provided through a COVID19.big.go.id *website* initiated by the Geospatial Information Agency of the Republic of Indonesia. Figure 1 illustrates the pandemic case that occurred in Jakarta special capital region/*Daerah Keistimewaan (DKI) Jakarta*.

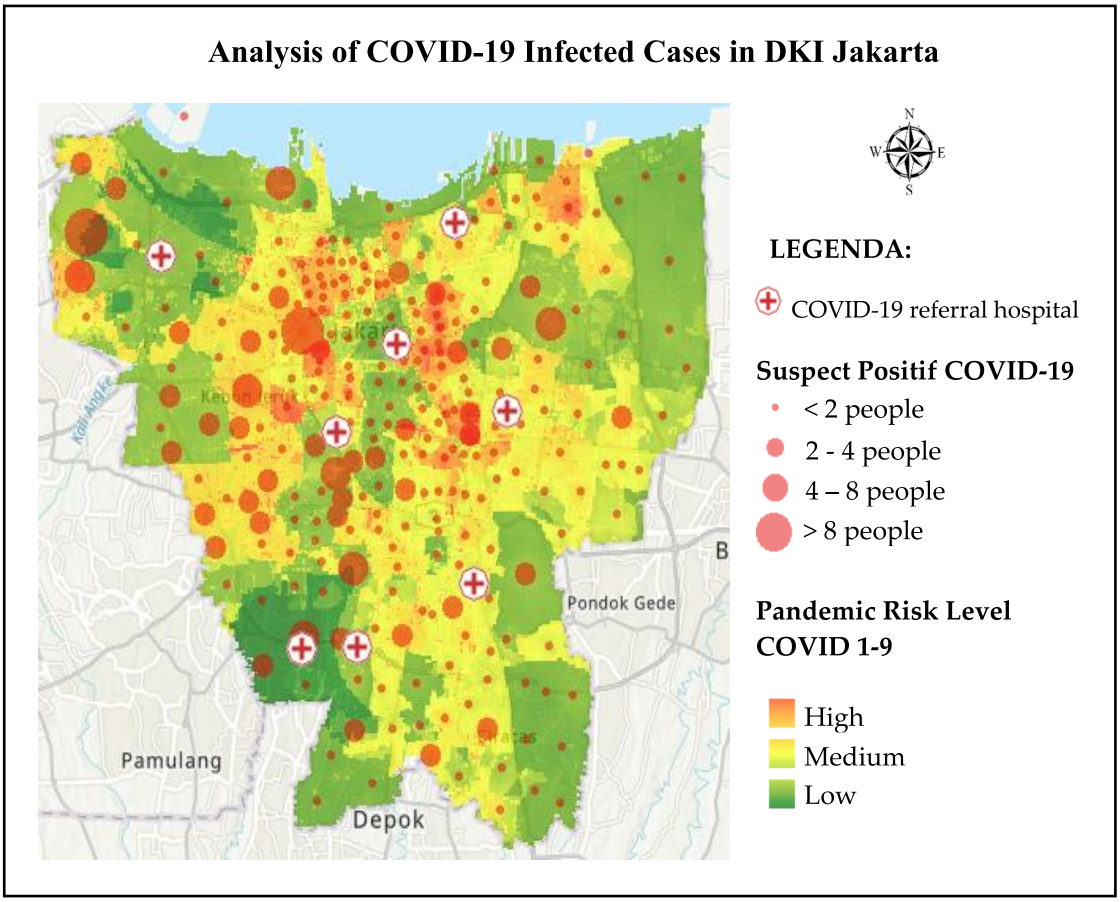


Fig. 1. Map of analysis of COVID-19 infected cases in Jakarta special capital region (Geospatial Information Agency, 2020)

Geospatial analysis is considered very important for transparency regarding the distribution of infected communities in Jakarta as one of the main keys to an effective response. However, the President on the contrary admitted not to create a sense of panic and unrest in the community, so that the government's handling was silent, including the location of people infected with COVID-19 (Almuttaqi, 2020). Thus, the gap between the central and local governments has caused government confusion in handling COVID-19.

Geospatial analysis displayed on the COVID19.big.go.id website should not be classified based on the category of the number of suspects in an area, but rather the location point where positive humans are infected with COVID-19, so that it will be easier to identify possible spread.

In the picture above, many cases of COVID-19 infection occur in Central Jakarta. Central Jakarta is the center of urban society where the majority of economic and business activities are located in the region. During the pandemic, community accessibility has been limited by stay-at-home, work from home (WHF), and student learning from home policies known as the implementation of Large-Scale Social Restrictions/*Pembatasan Sosial Berskala Besar* (PSBB) and Transitional PSBB in Jakarta special capital region/*Daerah Keistimewaan (DKI) Jakarta* from April 10 to July 30, 2020 to prevent mass transmission in the community (Darmawan & Atmojo, 2020; Son et al., 2020; Setyawan & Lestari, 2020). PSBB in Jakarta Special capital region has been regulated in Jakarta special capital region Governor Regulation Number 33 of 2020 concerning the Implementation of PSBB in Handling COVID-19. Initially, PSBB was considered effective because of a decrease in the number of cases of 3.2% to 4% (Yazid & Palani, 2020). However, the policy has not been optimal due to several factors such as the distribution of information technology infrastructure has not been evenly distributed, not all sub-districts or kelurahan have prepared technology-based documentation systems, and not all agencies are ready to provide information technology-based services (Darmawan & Atmojo, 2020). According to the author's observation, information technology-based services at the sub-district level are not optimal. So during the pandemic, people still come to sub-districts and sub-districts to exchange information. The existence of the transitional PSBB has caused an increase in the incidence rate and positivity rate of COVID-19 in Jakarta Special capital region/*Daerah Keistimewaan (DKI) Jakarta*. Community movements have increased, especially in public places, shopping centers, and workplaces (Saputra & Salma, 2020). The COVID-19 pandemic in Indonesia certainly affects human survival from 3 aspects, namely social, economic, and environmental.

3.1.1 Social

During the pandemic, some individuals developed an uncontrolled fear of the coronavirus. There are several studies that show people who have been exposed experience fear of illness suffered and fear of transmitting it to family members (Jeong et al., 2016). Other studies have shown that pregnant women and the elderly are at risk for developing a fear of becoming infected or transmitting the virus to others. The tragic effects associated with widespread anxiety in the pandemic period are lower perceived social support such as feeling lost, limited freedom, and boredom (Lee & You, 2020). Stress, boredom, social isolation, and frustration are caused by the inhibition of daily activities, resulting in loss of social activities so that these factors predict suicide (Engel-Yeger et al., 2016; Gunnell et al., 2020).

3.1.2 Economy

The economic impact felt by Indonesia due to the COVID-19 pandemic includes a decrease in imports, inflation, losses in the tourism sector, and increasing poverty rates (Nicola et al., 2020; Yamali & Princess, 2020). The increase in prices of several commodities such as oil can have a negative effect on the economy in Indonesia (Akhmad et al., 2019). Every 10% price reduction in crude palm oil will have an impact on the Indonesian economy by 0.08% and coal (-0.07%) (Nasution et al., 2020). Meanwhile, according to the Indonesian Ministry of Finance, it estimates that economic growth in 2020 can reach -0.04% (Suryahadi et al., 2020). Average per capita income is estimated to decrease from -1.17% to -2.88% if economic growth in Indonesia in 2020 is projected at 4.2% and -3%, respectively. However, the decline will be higher by -4.16%, -5.44% and -5.72% when economic growth in 2020 experiences delays of 2.1%, 1.2%, and 1% respectively (Suryahadi et al., 2020). If Indonesia experiences a cessation of activities for 1 month, it will cause national losses of Rp 923 trillion (Hadiwardoyo, 2020). The poverty rate in Indonesia will also increase in line with the economic slowdown. Before the COVID-19 outbreak hit, in September 2019, the poverty rate in Indonesia reached 9.22%, which means 24.8 million people live below the poverty line. When growth in 2020 is projected to reach 4.2% or 3%, the poverty rate will increase to 9.7% and 10.7% respectively. Meanwhile, if there is a slowdown of 2.1%, 1.2%, and 1%, then the poverty rate will jump by 11.4%, 12.2% and 12.4% (Suryahadi et al., 2020).

3.1.3 Environment

The environment in which humans live is also affected. Although there is known to be a reduction in various pollutants in the air and carbon footprint, it is due to a reduction in human activities. When the world returns to normal, air pollution will occur again (Ibn-Mohammed et al., 2021). The use of disposable medical equipment during the pandemic has increased significantly. Germany, the United States, Switzerland, China, and Ireland are exporters of medical equipment-related goods such as personal protective equipment in the form of medical masks, paper bed sheets, surgical gloves, syringes, and others to more than 20 countries (OECD, 2020). The global pandemic due to this infectious disease contributes to environmental issues. More than two hundred tons (4x the usual amount of municipal waste) of medical waste was generated from the handling of COVID-19 in Wuhan, China. Medical waste has the potential to have health impacts for those who have direct contact with waste such as garbage collectors, cleaners, and medical staff (Bashir et al., 2020).

The increase in plastic waste apart from hospital waste has increased. Consumers prioritize hygiene for many needs, one of which is in terms of packaging (both for food delivery and shopping for home needs). Public perception of the reuse of plastic cups and bags is turning into a threat of disease transmission, while the majority of plastic products are made from non-biodegradable materials (Patrício Silva et al., 2020; Vanapalli et al., 2020). The ability of the coronavirus to survive in plastic is longer (3 days) than paper (3 hours) and clothes (2 days) (Taylor et al., 2020). The increase in food and daily necessities shopping through online increased by 92.5% and 44.5% in South Korea during the pandemic. An increase in online shopping of 12-57% also occurred in Vietnam, India, China, Italy, and Germany in the same period (Vanapalli et al., 2020).

3.2 Factors causing the spread of COVID-19 in slums

The COVID-19 pandemic in Indonesia, especially the capital city of Jakarta, has an impact on all life settings (Brito et al., 2020). However, the living conditions and urban morphology found in poor communities make residents more vulnerable to COVID-19 infection compared to formal cities, where residents have the resources to follow health protocols that have been imposed by the Ministry of Health (Brito et al., 2020; Ilesanmi et al., 2020). In the capital city of Jakarta, there are 186 neighborhood association/*rukun warga* (RWs) in the slum category with the largest percentage in North Jakarta (68%), East Jakarta (38%), and Central Jakarta (37%) (Cities Alliance, 2013). These slums grow in various locations including coastal areas (the majority in North Jakarta), railway banks (the majority in Central Jakarta and North Jakarta), toll road access (the majority in North Jakarta) and watersheds (the majority in West Jakarta) (Cities Alliance, 2013; Fitriyanto et al., 2019). Figure 2 describes the distribution of slums by RW and location.

From Figure 2, it can be seen that slums are mostly located in Central Jakarta and North Jakarta. This is because these areas, especially Central Jakarta, are densely populated and the center of government, which provides a source of income for the community. People living in slums, usually located within or on the outskirts of the city, are difficult to access and generally underestimate the pandemic situation (Brito et al., 2020; Fitriyanto et al., 2019). Therefore, it is possible that COVID-19 infections spread in slum areas. The spread of COVID-19 infections among communities in slum areas has been studied by Brito et al. (2020), in Salvador, Brazil, Ilesanmi et al. (2020) in Africa and Malani et al. (2020) in India. There are several environmental, economic, and social factors in slum areas that make communities vulnerable to COVID-19 infection. These factors include poor basic services, high population density, livelihood issues, poor living conditions, increased waste accumulation, and limited access to social assistance (Bashir et al., 2020; Brito et al., 2020; Cities Alliance, 2013).

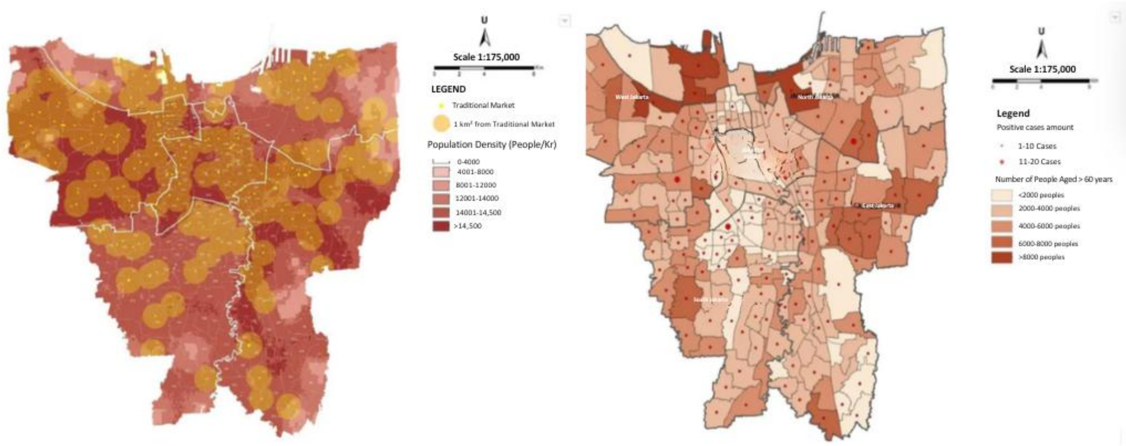
The problem for people living in slums is the low access to basic services such as access to clean water, inadequate sanitation, and handwashing with soap (Brito et al., 2020; Ilesanmi et al., 2020; Miller & Spoolman, 2016). So it is very difficult to comply with health protocols. The availability of clean water in Jakarta Special capital region is only available 18 m^3, while the need for clean water reaches 28 m^3. Thus causing disparities in access to clean water, especially in communities in slums (Cities Alliance, 2013; Moonlight et al., 2020). In meeting the needs of clean water, in general, housewives in slums buy water from mobile clean water selling agents using carts. During a pandemic like this, these activities are still ongoing, even though sellers do not use Personal Protective Equipment (PPE). This increases the risk of human-to-human transmission of COVID-19 (Parikh et al., 2020). People who have difficulty getting access to clean water will use river water that has a high pollutant load, smells, and brownish in color which is at risk of various diseases (Kooy et al., 2018; Liu et al., 2020).

Fig. 2. Map of slum area distribution in Jakarta special capital region (Cities Alliance, 2013)

Various studies have found the presence of corona virus in wastewater that has been treated and discharged into water bodies (Ahmed et al., 2020; Amoah et al., 2020; Liu et al., 2020; Mandal et al*.,* 2020). If people use river water as their daily needs, there will be unconscious contact with the corona virus and cause infection in the community. This can be the cause of asymptomatic patients in Jakarta Special capital region/*Daerah Keistimewaan (DKI) Jakarta*. Poor sanitation is exacerbated by bad behavior such as not washing hands with soap which is still low in Jakarta Special capital region (Brito et al., 2020; Purnama & Susanna, 2020) and the behavior of throwing garbage into empty land and thrown directly into the river (Fitria & Setiawan, 2014).

3.2.1 Residential environment

Jakarta is one of the provinces with a high level of density. With an area of 664 km2, the capital city must accommodate a population of 15,900 people/km^2 (Martinez & Masron, 2020). Population density affects people's vulnerability to COVID-19 infection (Mishra et al., 2020). The increasing use of land in Jakarta which is used for industrial development, settlements, offices, and road access triggers population density. Thus, people with low incomes are forced to build houses with limited materials and forms of houses near the workplace and cause slums to develop to reach 1,024.52 Ha (Caesandra et al., 2020; Fitria & Setiawan, 2014; Parris, 2016). In Jakarta, many people live in poor environmental conditions such as inadequate indoor ventilation, frequent flooding, and living in areas with poor levels of air pollution (Brito et al., 2020). Figure 3 describes a map of the distribution of population density and COVID-19 cases in Indonesia.



(a) (b)

Fig. 3. (a) Map of population density in Jakarta special capital region (b) Map of the distribution of positive COVID-19 cases in Jakarta
(Irawati, 2020)

Since the transmission of COVID-19 disease can be through the air, the structure of the airflow in buildings can determine the acceleration or deceleration in the spread of SARS-CoV-2 infection. Buildings with good ventilation design help prevent transmission of the spread of diseases spread through indoor air media (Lipinski et al., 2020; Qian & Zheng, 2018). Vice versa, poor ventilation systems can accelerate the transmission of disease spread such as the incident at the Price of Wales Hospital in Hong Kong causing an outbreak of SARS nosocomial disease occurred in 2003 due to poor ventilation design (Li et al., 2005). Slum communities generally have one room for a family of 4 or more people. This causes air circulation that is too narrow (CNN Indonesia, 2020; Islam et al., 2020). Airborne viruses occur when a pathogenic agent leaves its source and spreads through various routes of transmission to susceptible humans. Distribution through droplets and air is a frequent distribution route. Droplets that are released in the air are at a height of about 2 meters from the ground and will settle on the floor within 3-6 seconds with a horizontal distance of 1.5 m at room air temperature and relative humidity of less than 60%, while droplets with a smaller diameter will still evaporate in the air within 3-6 seconds and if exposed to vulnerable groups will cause infection (Lipinski et al., 2020).

In addition to poor ventilation, not all residents have sanitary facilities such as toilets. So that there are several public toilets that are used for many other residents as well as bathing and washing facilities that must be used together (CNN Indonesia, 2020; Parikh et al., 2020). The use of bathroom facilities for washing, bathing, and defecating simultaneously allows for the risk of transmission and the difficulty of maintaining distance between people (in some places, there are more than 20 families using the facilities simultaneously). In some studies, SARS-CoV-2 RNA was found in feces and sputum (Han et

al., 2020; Sethuraman et al., 2020). Toilet guards and cleaners do not use PPE, making them a group that is very vulnerable to COVID-19 infection (Parikh et al., 2020).
In addition to sanitation problems, slum houses in Jakarta are often flooded, especially in Jakarta City (Harifa et al., 2017). Flooding occurs due to obstruction of hydrological processes in urban areas. The hydrological system in urban areas is a series of soil types, topography, land use and slope length that have a relationship between one element and another so as to form a unity that mutually affects the balance of water management (Parris, 2016; Septriana et al., 2020). Other factors of flooding in Jakarta include the geomorphology of Jakarta City, land subsidence, climate change and rainfall, drainage capacity as well as population factors and land use change (Harifa et al., 2017; Marfai & Khasanah, 2012; Septriana et al., 2020). Several studies have revealed the presence of coronavirus in treated wastewater discharged into water bodies (Ahmed et al., 2020; Amoah et al., 2020; Liu et al., 2020; Mandal et al., 2020). This allows the existence of disease carrier vectors, one of which is SARS-CoV-2 and can infect communities in flooded areas (Parikh *et al.*, 2020).

Fig. 4. (a) Physical condition of light slum settlement building (b) Physical condition of heavy slum settlement building (c) Slum settlement conditions close to garbage disposal
(Fitria & Setiawan, 2014; CNN Indonesia, 2020)

Poor solid waste management has the potential to spread disease vectors for people in slums (Brito et al., 2020). Undeniably, societal changes in the consumption of plastics and other packaging are changing. It is known that the amount of waste generated from purchasing products and food online is increasing (Aldaco et al., 2020; Mofijur et al., 2021). This is a challenge for waste managers, because medical waste is increasing and has more potential to spread disease than domestic waste, finally medical waste management is prioritized and causes neglect of domestic waste (Fan et al., 2021). This problem causes domestic waste to be buried, one of which is near slums and causes pollution to the environment (Rume & Islam, 2020). In fact, in the environment SARS-CoV-2 can still be found and has the potential to infect through groundwater, wastewater, and soil. SARS-CoV-2 in the environment can be affected by temperature, humidity, sun exposure, and surface type. SARS-CoV is able to live on several surfaces such as iron and plastic waste for 3 days, 24 hours on cards, 4 hours on copper, 4-5 days on wood and paper, and 2-3 days in wastewater (Lahrich et al., 2021; Mofijur et al., 2021). The results of liquid waste management are usually flowed into river bodies and allow it to be used as agricultural irrigation. Poor liquid waste management allows SARS-CoV-2 to be present in the water and contact with soil where the virus is more likely to survive. This is a risk to public health as a result of contamination of water bodies with viruses that can contaminate the soil and enter through the human body through the consumption of agricultural products (Lahrich et al., 2021; Liu et al., 2020).

3.2.2 Access to health information and services

Access to information and health services is one of the vital points in preventing the spread of disease. The following is a geospatial analysis that illustrates the range of access in the form of hospitals for people infected with COVID-19. The reach of COVID-19 referral hospitals has been geospatially documented by the Geospatial Information Agency of the Republic of Indonesia. This is as information for the surrounding area to get access to health services for people infected with COVID-19. However, geospatial data on COVID-19 referral hospitals has not been updated. On the map above, there are 8 COVID-19 referral hospitals and close range (0-5 km) in Central Jakarta (Geospatial Information Agency, 2020). With the increasing incidence of COVID-19, the need for health services such as laboratories and hospitals has increased. This has led to an increase in the number of COVID-19 referral hospitals to 52 units which have been stipulated in Governor's Decree Number 494 of 2020. Then, the Governor of Jakarta special capital region/*Daerah Keistimewaan (DKI) Jakarta* renewed the number of COVID-19 referral hospitals regulated in the Regulation of the Governor of the special capital region of Jakarta Number 987 of 2020 that there are 90 hospitals as health services for people infected with COVID-19. The capacity of the COVID-19 special ICU room until now there are 528 beds with an occupancy rate of 83% (Saputra & Salma, 2020).

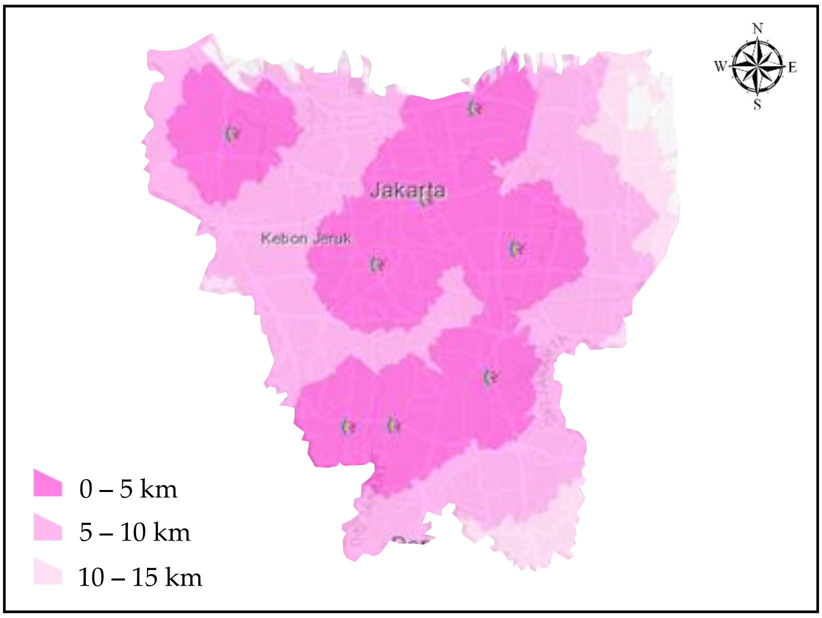


Fig. 5. COVID-19 referral hospital coverage analysis
(Geospatial Information Agency, 2020)

The problem faced by people in slums is not the problem of distance to health services. However, the poor do not make use of these health care facilities. The majority of these facilities are used by people with better economic conditions. The ignorance of people in slums about how to access health services also affects the use of health service facilities (Basir, 2012).

3.2.3 Social and economic conditions

Various efforts to prevent the spread of COVID-19 have been implemented in various countries such as social-distancing, lockdown, self-quarantine, and large-scale social restrictions/*Pembatasan Sosial Berskala Besar* (PSBB) (Bukuluki et al., 2020; Koh et al., 2020; Phuoc et al., 2020). High population density in slums makes it less likely to implement physical distancing policies, by maintaining a minimum distance of 2 meters from other humans (Brito et al., 2020; Gibson & Rush, 2020; Ilesanmi et al., 2020). The dependence of the community with other communities in making a living so decided to ignore the PSBB imposed in Jakarta.

Low socioeconomic conditions make it impossible for people in slums to provide sanitizers, disinfectants, and soap (Pereira et al., 2020). The majority of slum dwellers make a living as laborers and micro-traders with incomes between IDR 1,100,000 – IDR 2,500,000 per month (Corburn et al., 2020; Fitria & Setiawan, 2014). Due to the COVID-19 pandemic, many companies such as manufacturing have stopped operating and caused thousands of workers from various sectors to be forced to become unemployed (Ibn-Mohammed et al., 2021; Nicola et al., 2020). This has caused poverty in Indonesia to increase due to COVID-19 (Suryahadi et al., 2020). Moreover, the composition of people in slums who are not native to Jakarta special capital region/*Daerah Keistimewaan (DKI) Jakarta* residents or migrants is not recorded and does not get social assistance from the government, causing people to have to leave their homes to seek income (CNN Indonesia, 2020). The attention of some governments in providing information intended specifically for the public is considered lacking. Therefore, the local government initiated and created handwashing facilities in washing areas, shared toilets, and markets.

4. Conclusions

The COVID-19 pandemic in Indonesia has had an impact on three aspects: social, economic, and environmental. People living in slum areas are vulnerable to COVID-19 infection. Factors such as low accessibility to basic services (clean water, sanitation facilities, and soap for hand washing), poor living conditions, low access to information and health services, social and economic conditions, and previous medical history put people living in slum areas at high risk of SARS-CoV-2 infection. The available geospatial analysis can be used as a consideration in deciding policies and programs, especially for communities in slum areas. Policies that need to be developed include outbreak mitigation plans in slum settlements, providing basic access services, and creating waste management strategies in slum settlements. For further research, three aspects of social, economic, and environmental factors in slum settlements can be analyzed using geospatial analysis to determine the interventions that can be carried out in slum settlements.

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