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Geo-Spatial Exploration of Tuberculosis in Samarinda Ulu Sub-District, Samarinda City, East Kalimantan

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Abstrak

Penelitian ini bertujuan untuk memberikan gambaran distribusi dan pola spasial kasus tuberkulosis (TB) di Samarinda Ulu, yaitu kecamatan dengan persentase kasus TB terdeteksi tertinggi kedua di Kota Samarinda. Belum ada penelitian sebelumnya yang berfokus pada distribusi dan pola spasial kasus TB di Samarinda. Studi ini menggunakan pendekatan deskriptif-analitis, dengan memanfaatkan data sekunder dari formulir TB03-SO tahun 2023. Total sampel mencakup 323 kasus TB. Aplikasi Google Maps digunakan untuk menentukan koordinat kasus berdasarkan alamat responden. Analisis spasial dilakukan menggunakan perangkat lunak QGIS dengan teknik overlay, buffer, dan Nearest Neighbor Average. Hasil menunjukkan bahwa kasus TB di Samarinda Ulu terdistribusi dalam pola terkelompok atau "clustered" (NNI<1), dengan kluster terbentuk terutama di daerah yang padat penduduk. Hasil analisis spasial juga menunjukkan bahwa sebagian besar kasus TB menyebar melalui kontak erat dengan kasus indeks. Desa Teluk Lerong Ilir muncul sebagai "hotspot" TB, dengan konsentrasi kasus tertinggi. Studi ini menyarankan penguatan pengawasan TB berbasis spasial dan intensifikasi deteksi dini serta mempromosikan program pendidikan kesehatan berbasis komunitas di daerah yang padat penduduk. Ini akan memungkinkan institusi kesehatan untuk lebih menargetkan daerah berisiko tinggi dan meningkatkan strategi pencegahan dan pengendalian TB.

Abstract

This research investigates the spatial distribution of tuberculosis (TB) cases in Samarinda Ulu, a sub-district with the second-highest percentage of detected TB cases in Samarinda City. Despite the availability of geographic analysis tools, no prior studies have focused on this area. The study uses a descriptive-analytical, cross-sectional approach, utilizing secondary data from the TB03-SO form for 2023. The total sample includes 323 TB cases, with Google Maps used to locate case coordinates based on respondents' addresses. Spatial analysis was conducted using QGIS software with overlay, buffer, and nearest neighbor analysis techniques. Results shows that TB cases in Samarinda Ulu are distributed in a clustered pattern (NNI<1), with clusters forming primarily in densely populated areas. The spatial analysis results also indicate that the majority of TB cases spread through close contact with index cases. Teluk Lerong Ilir Village emerges as a TB "hotspot," with the highest concentration of cases. This study suggests strengthening spatial-based TB surveillance and intensifying control efforts, such as enhancing early detection and promoting community-based health education programs in highly populated areas. This would allow health institutions to better target high-risk regions and improve TB prevention and control strategies.

INTRODUCTION

Tuberculosis (TB) is a preventable disease that is usually curable (World Health Organization, 2023b). However, in 2022, tuberculosis was the second leading cause of death in the world caused by a single infectious agent, after COVID-19, and it resulted in nearly twice as many deaths as HIV/AIDS. Every year, more than 10 million people are diagnosed with tuberculosis (World Health Organization, 2023b). This indicates that tuberculosis remains a significant public health issue globally, including in developing countries such as India, Indonesia, and China.

Mycobacterium tuberculosis, the bacillus that causes tuberculosis, is dispersed through the air by TB patients. It is believed that a quarter of the world's population has contracted tuberculosis (World Health Organization, 2023a). About 90% of all cases of tuberculosis (TB) occur in adults, with men accounting for a greater proportion of cases than women. The death rate from tuberculosis is significant (about 50%). With therapies now suggested by WHO (a 4–6 months course of anti-TB medications), roughly 85% of people with TB can be cured (World Health Organization, 2023a).

Thirty high TB burden countries accounted for 87% of the world's TB cases in 2022 and two-thirds of the global total was in eight countries: India (27%), Indonesia (10%), China (7.1%), the Philippines (7.0%), Pakistan (5.7%), Nigeria (4.5%), Bangladesh (3.6%) and the Democratic Republic of the Congo (3.0%) (World Health Organization, 2023a). As per the Global Tuberculosis Report 2023, Indonesia's predicted 2022 TB incidence rate was 385 per 100,000 people, indicating a rise from 2021's TB incidence rate of 354 per 100,000 population. In contrast, 49 people died from tuberculosis for every 100,000 people in 2022 (Kementerian Kesehatan RI, 2024)

In East Kalimantan in 2021, Samarinda City (1,465 cases), Balikpapan (1,166 cases), and Kutai Kartanegara (713 cases) had the greatest prevalence of tuberculosis (Dinas Kesehatan Provinsi Kalimantan Timur, 2022). The number of TB cases detected in Samarinda City in 2023 reached a total of 2,571 cases, with the Samarinda Ulu sub-district recording the second highest case detection percentage at 16.18%, after the Sungai Kunjang Sub-district, which reached 17.59% (Dinas Kesehatan Provinsi Kalimantan TImur, 2024).

Numerous factors, such as person characteristics (age, gender, income level, education level, etc.), home ambient elements, habits, contact history, and so forth, are risk factors for tuberculosis (TB) disease (Chandra et al., 2024). Slums, congested areas, and restricted access to hygienic and healthful living practices are the main causes of tuberculosis cases (Noykhovich et al., 2019). According to estimates, one person with pulmonary tuberculosis can infect ten to fifteen persons nearby(World Health Organization, 2023a). As a result, interaction with TB patients poses a significant danger for the spread of TB. Furthermore, a dense population in metropolitan settings increases the likelihood of interaction and hastens the spread of tuberculosis (Ardiyanti et al., 2021). For efficient tuberculosis control, access to healthcare services, particularly medical professionals, is also essential. Samarinda Ulu Sub-district is one of the most densely populated areas in Samarinda City (Badan Pusat Statistik Kota

Samarinda, 2023a). The Samarinda Ulu Sub-district itself has four community health centers, but they are not evenly distributed geographically compared to the relatively large area of the sub-district.

Socio-environmental factors significantly influence the transmission and prevalence of tuberculosis (TB). Time spent in densely populated, crowded living conditions, poor sanitation, poorly ventilated districts where tuberculosis cases who may be contagious frequent is a good indicator of socio-environmental risk (Cahyaningrum & Setiyadi, 2024). Most tuberculosis transmission in high-incidence areas happens in both the general community and homes (Coleman et al., 2022). According to Mohidem et al. (2021), environmental factors are a crucial part of the epidemiological triangle of tuberculosis disease and have a significant impact on the disease's development (Mohidem et al., 2021). Environmental factors, such as air quality and climate, also contribute to TB incidence. Poor ventilation in living and working environments can lead to prolonged exposure to TB bacteria in the air, increasing the risk of infection. Climate conditions such as humidity and temperature may influence the survival of TB bacteria in the environment, although this relationship requires further investigation (Krishnan et al., 2022). When combined with epidemiological analysis and data reinforcement, area-based surveillance may be able to define the precise distribution of tuberculosis cases (Tanjung et al., 2021).

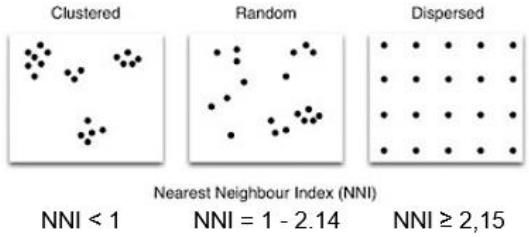
To effectively address the spatial dynamics of TB transmission, geographic-based surveillance and Geographic Information Systems (GIS) have become essential tools in TB epidemiology (Tuntun et al., 2023) Geographic-based surveillance involves the collection and analysis of spatial data related to TB cases, allowing public health officials to track disease patterns and identify high-risk areas (Chandra et al., 2024). GIS is a powerful tool that enhances this surveillance by visualizing and analyzing the spatial distribution of TB cases in relation to socio-demographic and environmental factors. Through mapping and spatial analysis, GIS can identify TB hotspots, enabling targeted interventions in areas with high transmission rates (Brooks et al., 2022). It also helps in understanding how environmental conditions, such as proximity to health facilities, urbanization, and population density, contribute to the spread of TB.

Although spatial analysis can be used to gather data about tuberculosis in a given area, no studies have been conducted in Samarinda Ulu, Samarinda, Indonesia, to examine and analyze the tuberculosis cases' clustering. This research aims to identify, describe, and analyze the spatial distribution patterns of tuberculosis cases in the Samarinda Ulu Sub-district, Samarinda City, East Kalimantan. It is hope that this research could provide valuable insights for public health officials to develop targeted and evidence-based interventions, ultimately improving TB control and reducing the burden of the disease in Samarinda City.

METHOD

This is a descriptive-analytical study with a cross-sectional approach, using secondary data from the TB03-SO form for the year 2023 from Samarinda City Health Office. The population of this study consists of TB cases in the Samarinda Ulu Sub-district recorded in the TB03-SO form. The

sampling technique used is total sampling, with a sample size of 323 cases that are fully recorded in the TB03-SO form.



Then, main data in the form of case coordinates was gathered using secondary data which is respondent addresses. The GPS Essential and Google Maps apps were used to find the case coordinates. After that, this data was examined using the QGIS program to examine the spatial patterns of tuberculosis cases in the Samarinda Ulu District and to provide a spatial overview utilizing overlay, buffer, and nearest neighbor analysis approaches (which will generate nearest neighbor index = NNI). In addition, descriptive analysis was done on other secondary data in the form of frequency tables and narratives, including gender, age, and population density.

Figure 1. Percentage Distribution of Respondents Based on The Self-Reporting Questionnaire (SRQ-20) Score

Table 1. Respondent Characteristics

Variable	N (%)
Gender	
Male	158 (48.9)
Female	165 (51.1)
Age Group	
Toddler (≤ 5 Years Old)	36 (11.1)
Children (6-11 Years Old)	13 (4)
Adolescent (12-19 Years Old)	26 (8)
Adults (20-59 Years Old)	201 (62.2)
Elderly (≥ 60 Years Old)	47 (14.6)

RESULT AND DISCUSSION

The respondents in the study consisted of 323 tuberculosis patients, 165 of them were females (51.5%) and 158 of them were males (48.9%). The majority of respondents were adults (20-59 years old), totaling 201 individuals (62.2%).

Samarinda Ulu District, its relationship with population density, and where these cases form hot spots. In Figure 1, it is evident that the spread or distribution of TB cases in the Samarinda Ulu District forms a clustered pattern. This can be observed from the numerous cluster points that have formed. Then, in Figure 2, it can be seen that the majority of TB cases in the Samarinda Ulu District are located and clustered in densely populated areas. Figure 3 shows that the hot spot, or the place where TB cases are concentrated, is in the Teluk Lerong Ilir Village.

Figures 1, 2, and 3 illustrate the pattern of TB case distribution in the

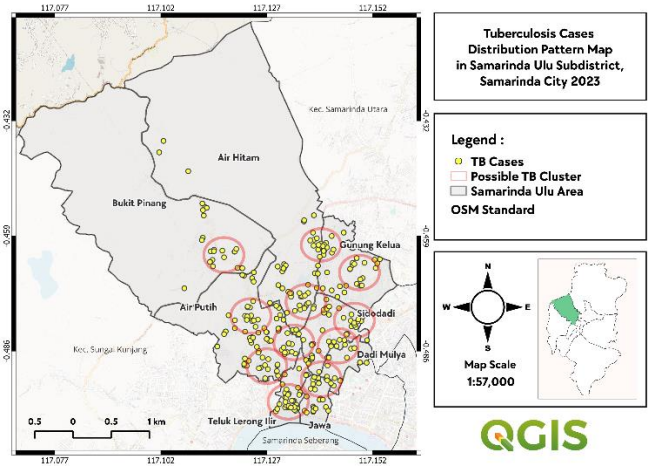


Figure 1. TB Distribution Pattern

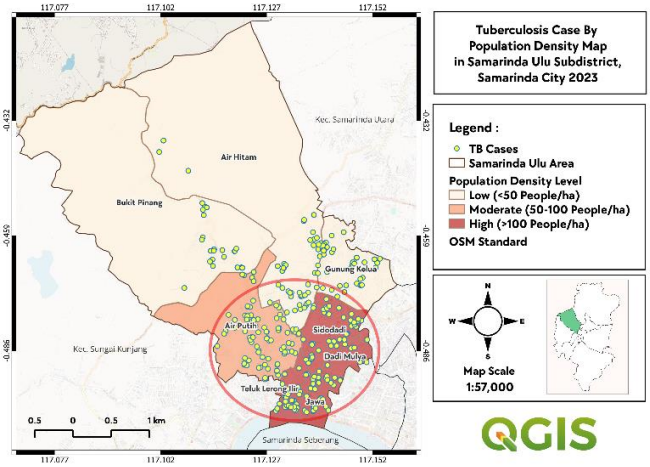


Figure 2. TB and Population Density

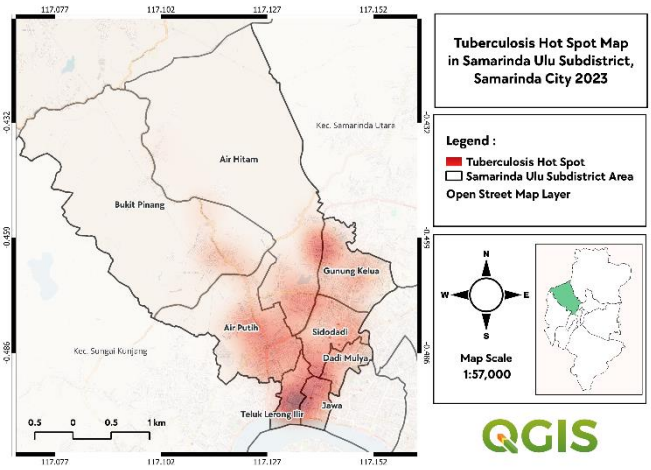


Figure 3. TB Hot Spot

Table 2 shows that Air Putih Village has the highest number of TB cases, whereas Air Hitam Village has the highest incidence rate (IR). Furthermore, the table also shows that 4 (50%) of the villages in the Samarinda Ulu District, namely Dadi Mulya, Jawa, Sidodadi, and Teluk Lerong Ilir, have a high population density (>100 people/ha). In addition, the results of the nearest neighbor index (NNI) analysis show that all neighborhoods have an NNI value of less than 1 (NNI<1), which means that TB cases in all neighborhoods form a clustered pattern.

Table 2. TB Cases, Population Density, and Pattern by Village

Village	TB Cases		Population Density		Nearest Neighbor Analysis	
	Numbers	IR per 10.000	People/ha	Category	Index (NNI)	Pattern
Air Hitam	58	36	35	Low	0.62	Clustered
Air Putih	79	26	63	Moderate	0.51	Clustered
Bukit Pinang	26	22	30	Low	0.66	Clustered
Dadi Mulya	25	20	120	High	0.77	Clustered
Gunung Kelua	36	26	26	Low	0.78	Clustered
Jawa	26	22	129	High	0.82	Clustered
Sidodadi	36	15	113	High	0.79	Clustered
Teluk Lerong Ilir	37	28	132	High	0.92	Clustered
Samarinda Ulu	323	24	81	Moderate	0.48	Clustered

Figures 3 and 4 illustrate the relationship between the index cases and the distance to healthcare facilities with the distribution of TB cases. Figure 3 shows that the majority of TB contact cases occur within the contact range of the index cases, although there are some clusters of cases outside the contact range of the index cases. Similarly, Figure 4 indicates that most TB cases occur within the reach of primary healthcare facilities, but there are still clusters of cases that lie outside the reach of primary healthcare facilities.

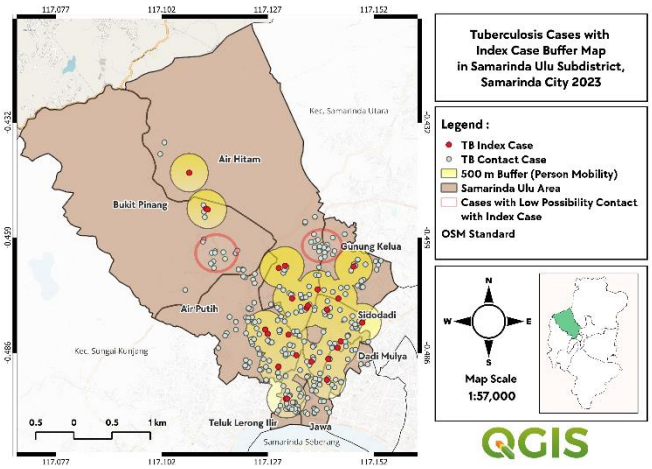


Figure 4. TB Index Case Buffer

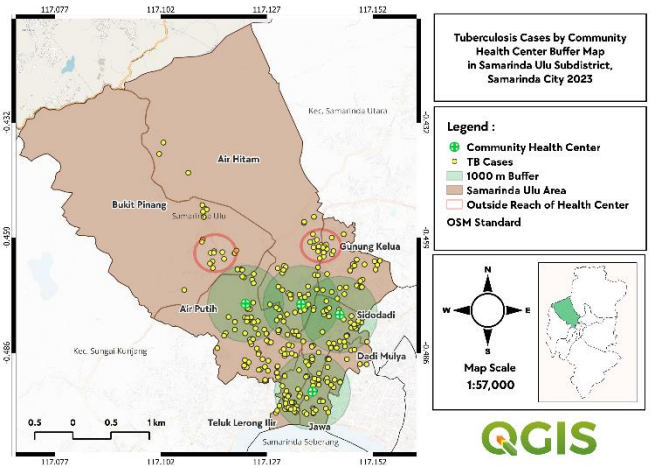


Figure 5. TB and Health Facility Buffer

The Samarinda Ulu District has an area of 22.12 km² with a population of 133,111 people in 2022, showing an increase compared to the previous year, which had a population of 131,774 in 2021. With this area and population, the population density in the Samarinda Ulu Sub-district reached 6,017 people per km² in 2022, also an increase from the previous year, which was 5,957 people per km² in 2021. This shows that the area has a reasonably high population density, with this sub-district being the second most densely populated area after the Samarinda Seberang Sub-district (Badan Pusat Statistik Kota Samarinda, 2023b).

The map indicates that TB cases are concentrated in a number of sub-districts, including Teluk Lerong Ilir (Figure 8), Dadi Mulya (Figure 7), and Sidodadi (Figure 6), which are the most densely populated sub-districts in the Samarinda Ulu District (Badan Pusat Statistik Kota Samarinda, 2023a). The spatial analysis results also indicate that the TB case Hot Spot is located in Teluk Lerong Ilir, which is the most densely populated area in the Samarinda Ulu District and even one of the sub-districts with the highest population density in the city of Samarinda (Badan Pusat Statistik Kota Samarinda, 2023b).

This study is also in line with Zhang, et al. (2020), where population is consistently positively correlated with the number of tuberculosis cases (Zhang et al., 2020). Total population and population density are proven to have a spatial effect on the number of tuberculosis cases (Smith et al., 2018). This finding is also in line with previous findings that show statistically significant fires and spatial clusters occur in sub-districts with a high population (Lasari et al., 2023)(Fahdhienie et al., 2024). A higher population will lead to a higher level of population density. The denser and faster the population growth of an area, the more likely it is to have health problems (Cahyaningrum & Setiyadi, 2024).

Figure 6. The condition of the settlement in Sidodadi village, Samarinda Ulu District, using Google Earth layer captures.

Figure 7. The condition of the settlement in Dadi Mulya village, Samarinda Ulu District, using Google Earth layer captures.

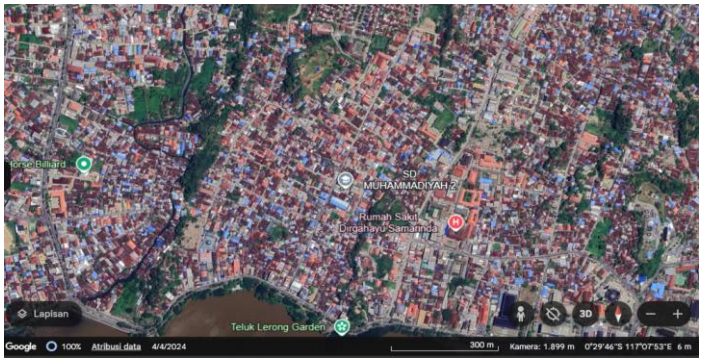


Figure 8. The condition of the settlement in Teluk Lerong Ilir village, Samarinda Ulu District, using Google Earth layer captures.

The results of the spatial analysis also show that the majority of TB contact cases occur within the contact range of the index cases. The high number of contact points within this 500-meter buffer indicates a high potential for transmission. The transmission will likely originate from interactions at contact points, including household contacts or contact with people nearby. Contact interaction refers to the contact between active TB patients and vulnerable clients. There is a relationship between the duration of contact with the index TB patient and the occurrence of TB, as well as an increased risk of latent TB (Reichler et al., 2020). These findings highlight the ongoing significance of contact investigations as a public health prevention strategy to disrupt transmission and carry important implications for efforts to eradicate TB. This highlights the importance of preventive measures and quick interventions in the immediate environment to minimize the transmission of TB.

The high humidity in Samarinda, which has an average humidity of above 80% throughout the year 2023 (Badan Pusat Statistik Kota Samarinda, 2024), may potentially have an impact on this spread. A risk factor for PTB was discovered to be the abnormally high relative humidity (Mohidem et al., 2021). The likelihood of contracting pulmonary tuberculosis increases with increasing relative humidity because of the stronger Brownian motion of gas molecules, longer residence time of Mycobacterium tuberculosis in the air, and other factors (Nie et al., 2022).

The majority of TB cases, according to the map, seem to be localized within a 1-kilometer radius around the health facility, suggesting that this area has quite good access to medical facilities for both diagnosis and treatment. However, this high concentration suggests that more needs to be done to prevent and control tuberculosis in locations near medical facilities. As a primary healthcare facility, the community health center is essential to the early diagnosis and treatment of tuberculosis cases (Nurhayati et al., 2024). Accessibility improvements and the provision of sufficient healthcare services for the entire community in the Samarinda Ulu District are essential components of effective public health policies.

Additionally, the Nearest Neighbor Analysis results for the spatial analysis show that the distribution pattern of tuberculosis cases in Samarinda Ulu District is clustered. Dense populations and high levels of interaction with vulnerable groups can cause patterns of tuberculosis transmission to become concentrated or clustered in particular places ((Gde Trishia Damayanti et al., 2024). According to contact inquiry employing active discovery tactics, close contacts and home contacts with tuberculosis (index case) can happen, particularly in settings with a high population density. This is consistent with

the circumstances of closely spaced, closely packed homes that may be seen in a number of neighborhood locations, as figures 6, 7, and 8 illustrate.

Pathogen lineages and sociodemographic risk variables both had an impact on clustering and continued transmission. To determine more precise targets for TB therapies, greater research utilizing WGS-based cluster analysis that takes into account additional variables like area of residence, comorbidities, or human genetic characteristics might be beneficial (Miyahara et al., 2020). Research noted by Shaweno, et al. (2021), indicated that the impact of population migration and closeness is one of the causes of TB clustering, making adjacent areas with high TB case counts more vulnerable (Shaweno et al., 2021). According to a different study carried out in China, the reason for the clustering of cases is that nearby areas or subdistricts with similar geographical features linked to the development and transmission of diseases cause the same incidence (Alene et al., 2021)

Mycobacterium tuberculosis infection and illness are more likely to occur in close quarters of patients with infectious tuberculosis. Study from Reichler, et al. (2018), had indicated that recently exposed close acquaintances have relatively high rates of TB. Furthermore, they have presented significant new evidence from the contemporary era to show that tuberculosis among contacts who have been exposed is not spread equally over the first two years following exposure, but rather that the majority of cases occur shortly after exposure and are already apparent at the time of contact investigation (Reichler et al., 2018). These results highlight the significance of conducting contact investigations as soon as index cases are identified, as a public health intervention to identify new cases of active tuberculosis and take action to stop transmission.

CONCLUSION

The spatial analysis's findings show that the distribution of tuberculosis cases in the Samarinda Ulu District is clustered, with many clusters emerging throughout the district, especially in densely populated areas. The spatial analysis results also indicate that the majority of TB cases spread through close contact with index cases. Teluk Lerong Ilir village is a TB Hot Spot where TB cases are most concentrated in a specific area around the village. It is recommended that health institutions strengthen the geographical/spatial-based TB surveillance system and implement more intensive TB control strategies in densely populated areas, such as enhancing early detection and community-based health education programs, because of majority of TB cases are within the coverage area of the community health center.

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