Journal of Communicable Diseases
Volume 57, Issue 2 - 2025, Pg. No. 150-168
Peer Reviewed & Open Access Journal

Research Article

Trends and Correlations of Major Infectious Diseases in Indonesia Before and After the COVID-19 Pandemic: A Comprehensive Seven-Year Analysis (2017–2023)

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DOI: https://doi.org/10.24321/0019.5138.202551

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How to cite this article:
Sari S M P, Utomo B, Adnyana I M D M, Sari M, Adiwinoto R P. Trends and Correlations of Major Infectious Diseases in Indonesia Before and After the COVID-19 Pandemic: A Comprehensive Seven-Year Analysis (2017–2023).J Commun Dis. 2025;57(2):150-168.

Date of Submission: 2025-02-21
Date of Acceptance: 2025-05-25

A B S T R A C T

Background: The coronavirus disease 2019 (COVID-19) pandemic has profoundly impacted healthcare systems worldwide, potentially altering the epidemiological patterns of other infectious diseases. However, comprehensive analyses of these changes in Indonesia are limited.

Objective: This study aimed to investigate the trends and correlations of major infectious diseases in Indonesia before and after the COVID-19 pandemic.

Methods: This retrospective study analysed national surveillance data from 2017 to 2023 and examined seven major infectious diseases: tuberculosis, HIV/AIDS, pneumonia, hepatitis, diarrhoea, leprosy, and COVID-19. Statistical analyses included Pearson's correlation coefficient and principal component analysis (PCA) to identify disease interaction patterns and temporal trends.

Results: Disruptions occurred across diseases during the pandemic peak (2020), with reductions ranging from 16.5% (HIV) to 35.9% (leprosy). Tuberculosis cases doubled from to 2021-2023 (397,377-821,200), while HIV/AIDS showed increasing trends and mortality rates (1.64-22.27%). PCA revealed two components explaining 82.84% of the variation, with respiratory and vector-borne diseases clustering separately. Tuberculosis and HIV showed a strong correlation (r=0.87, p=0.011), while COVID-19 correlated negatively with endemic diseases, notably diarrhoea (r=-0.77, p=0.043).

Conclusions: COVID-19 disrupted Indonesia's infectious disease landscape, with varied recovery patterns, indicating healthcare adaptation and ongoing challenges. This underscores the need for improved surveillance and integrated post-pandemic disease management.

Keywords: Communicable diseases, COVID-19, Disease outbreaks, Health service accessibility, Epidemiology

Introductions

The coronavirus disease 2019 (COVID-19) pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has fundamentally transformed global public health systems since its emergence in Wuhan, China, in late 2019.[1] This respiratory disease, characterised by its high transmission rate and potential for multiorgan complications, rapidly evolved into an unprecedented global health crisis.[2–4]

In response to this crisis, governments worldwide implemented stringent containment measures, including lockdowns and social restrictions.[5] These interventions, while primarily aimed at controlling COVID-19 transmission, have inadvertently influenced the epidemiology of other infectious diseases.[6,7] Evidence from various countries has demonstrated significant changes in infectious disease patterns during the pandemic.[8,9] For example, Japan reported a substantial decrease in Mycoplasma pneumoniae cases,[10] whereas Germany reported a 36% reduction in acute respiratory infections.[11] Further studies revealed dramatic declines in vector-borne (100%), droplet-transmitted (72.7%), and airborne diseases (66.7%).[12,13]

Despite the growing body of global evidence regarding shifts in infectious disease patterns during the COVID-19 pandemic, a significant knowledge gap exists in understanding these dynamics in Indonesia. This gap is particularly critical given Indonesia's unique geographical, demographic, and socioeconomic characteristics, which may influence disease transmission patterns differently from those of other nations.[3,4,14] To date, no comprehensive study has analysed the changes in infectious disease patterns before and after the COVID-19 pandemic in Indonesia. This study addresses this research gap by examining how the COVID-19 pandemic has influenced infectious disease trends in Indonesia, specifically investigating whether significant changes in disease prevalence and transmission patterns have occurred before and after the implementation of COVID-19 mitigation policies.

This study aimed to comprehensively analyse the trends and correlations of major infectious diseases in Indonesia before and after the COVID-19 pandemic. Through an analysis of seven years of Indonesian health surveillance data, this study seeks to answer these fundamental questions while providing insights for future health policy development. Understanding the changes in infectious disease trends can inform more effective disease control strategies and resource allocation in post-pandemic healthcare systems. Moreover, this study's findings can contribute to the global literature on the indirect impacts of pandemic mitigation measures on infectious disease epidemiology while helping to develop more resilient public health strategies for future health crises.

Materials and Methods

Study design and setting

This study employed a retrospective design to analyse infectious disease trends in Indonesia from 2017 to 2023, with a specific focus on tuberculosis (TB), HIV, AIDS, pneumonia, hepatitis, diarrhoea, leprosy, and COVID-19. This approach enabled a comprehensive evaluation of epidemiological patterns across the prepandemic (2017–2020) and postpandemic (2021–2023) periods.[15]

Data collection and search strategy

Data were collected from official government sources, primarily the Indonesian Ministry of Health (https://www.kemkes.go.id/) database and provincial health offices. The research systematically accessed the Ministry of Health's main portal for annual health profile reports from 2017 to 2023. The search focuses on chapters related to infectious diseases, specifically tuberculosis, HIV/AIDS, pneumonia, hepatitis, diarrhoea, leprosy, and COVID-19. Additional data were obtained from the Directorate General of Disease Prevention and Control (P2P) (https://p2p.kemkes.go.id/) for specific disease control programs and surveillance reports. For COVID-19 data, researchers utilised the dedicated COVID-19 dashboard maintained by the Ministry of Health, which provides both real-time and historical data on cases, mortality rates, and recovery rates (https://covid19.go.id/). All the data collected were systematically recorded to ensure the transparency and reproducibility of the study. The data were stored in a structured format (spreadsheet).

Data extraction, synthesis, and analysis

Data extraction and synthesis followed a systematic approach using standardised worksheets that recorded key variables, including disease type, time periods (years), and epidemiological indicators, including cases, deaths, the case fatality rate (CFR), the treatment success rate (TSR), and the case stratification rate (CNR). The prepandemic data covered 2017–2020, whereas the post-pandemic data covered 2021–2023. Statistical analysis was performed via GraphPad Software, LLC for MacOS Version 10.3.1 (464), which incorporates eight pairs of observations for each disease comparison.

Pearson correlation (r) was performed to analyse the relationships among the eight infectious diseases from 2017–2023, with the significance level set at $p<0.01$ (99% confidence interval). The visualisation results used a correlation matrix heatmap with a blue–red colour

ISSN: 0019-5138
DOI: https://doi.org/

gradation, where dark blue indicates a strong positive correlation (1.0) and dark red indicates a strong negative correlation (-1.0).

Principal component analysis (PCA) was performed to reduce the dimensionality of the data and identify the main patterns of variation in the dataset. PCA was performed by extracting principal components with eigenvalues >1.0, calculating the percentage variance explained, performing scree plot analysis, and performing varimax rotation by retaining two principal components. Loading plots (displaying the relationships between variables) and biplots (displaying the relationships between variables and observations) were created to visualise disease relationships and temporal patterns, with loading values ≥ 0.5 considered significant with a confidence level of 99%.

Ethical Approval

This study was approved by the Health Research Ethics Commission of the Faculty of Medicine at Universitas Airlangga (protocol number 69/EC/KEPK/FKUA/2024).

Results

Tuberculosis

During the prepandemic period (2017–2020), the number of TB cases initially increased from 425,089 cases in 2017 to a peak of 566,623 cases in 2018, followed by a slight decline to 543,874 cases in 2019. The onset of the pandemic in 2020 corresponded to a substantial decrease to 351,936 cases, representing a 35.3% reduction from the previous year. However, the post-pandemic period (2021–2023) exhibited a marked upward trajectory, with cases increasing from 397,377 in 2021 to 821,200 in 2023, more than doubling the case count. The CNR per 100,000 people demonstrated parallel trends, increasing from 169 in 2017 to 214 in 2018 before declining sharply to 130 during the 2020 pandemic. The post-pandemic periods showed substantial recovery and improvement in case detection, with the CNR reaching 298.8 by 2023, the highest recorded during the study period. The case-finding percentages exhibited notable fluctuations, with prepandemic levels ranging from 43.8% to 67.6% (2017–2019), followed by a significant drop to 41.7% in 2020. The post-pandemic period showed a remarkable improvement in case detection efficiency, reaching 77.5% by 2023. The high treatment success rates throughout the study period demonstrate the resilience of Indonesia's TB treatment programmes despite the challenges of the pandemic. Tuberculosis (TB) surveillance data trends from 2017 to 2023 are shown in Figure 1.

HIV/AIDS

The analysis of HIV/AIDS trends in Indonesia from 2017 to 2023 reveals distinct patterns across the prepandemic and post-pandemic periods. During the prepandemic period (2017–2020), the number of HIV cases moderately fluctuated, starting at 48,300 cases in 2017, slightly decreasing to 46,659 in 2018, and then increasing to 50,282 cases in 2019. The onset of the COVID-19 pandemic significantly declined to 41,987 cases in 2020, representing a 16.5% reduction from the previous year. The immediate post-pandemic period initially further decreased to 36,902 cases in 2021, followed by a substantial increase to 52,955 cases in 2022 and 57,299 cases in 2023, marking the highest recorded cases during the study period. HIV/AIDS surveillance data trends from 2017 to 2023 are shown in Figure 2.

AIDS cases followed a different trajectory, showing a gradual decline from 10,488 in 2017 to 7,036 in 2019 during the prepandemic period. The pandemic period slightly increased to 8,639 cases in 2020, followed by a decrease to 5,750 in 2021. However, the post-pandemic period witnessed a dramatic surge, with the number of cases rising to 9,341 in 2022 and nearly doubling to 16,410 in 2023, representing the highest number of AIDS cases in the study period. The mortality rate of AIDS patients was relatively stable during the prepandemic period, ranging from 1.03% to 1.09% (2017–2019). A gradual increase began during the pandemic, from 1.31% in 2020 to 1.61% in 2021. The most striking change occurred in the post-pandemic period, with mortality rates increasing marginally to 1.64% in 2022 before increasing dramatically to 22.27% in 2023, representing a more than thirteenfold increase from the previous year. This unprecedented increase in mortality rates suggests significant challenges in the HIV/AIDS healthcare delivery system during the post-pandemic period and warrants immediate attention from public health authorities.

Pneumonia

In the prepandemic era (2017–2020), pneumonia cases gradually declined from 511,434 cases in 2017 to 468,172 cases in 2019, followed by a sharp decrease to 309,838 cases in 2020, representing a 33.8% reduction coinciding with the onset of the COVID-19 pandemic. The case-finding rate exhibited a similar pattern, declining from 51.2% in 2017 to 34.8% in 2020. The post-pandemic period (2021–2023) initially showed a continued decrease to 278,261 cases in 2021, marking the lowest point in the study period, before demonstrating a recovery trend, with an increase of 386,724 cases in 2022 and 416,435 cases in 2023. However, the case-finding rates remained relatively low in the post-pandemic period, ranging from 31.4% to 38.8%, suggesting persistent challenges in pneumonia surveillance and detection. The case fatality rate (CFR)

ISSN: 0019-5138
DOI: https://doi.org/

showed notable fluctuations throughout the study period. The prepandemic period began with a relatively high CFR of 0.34% in 2017, which decreased substantially to 0.08% in 2018 and then gradually increased to 0.16% by 2020. During the post-pandemic period, the CFR remained relatively stable, remaining at 0.16% in 2021 before slightly decreasing to 0.13% by 2023. The number of deaths showed a similar pattern, with a significant decrease from 1,752 deaths in 2017 to 425 deaths in 2018, followed by a relative stability ranging from 444 to 522 deaths annually during the subsequent years. These trends suggest that while case detection and reporting were significantly affected by the pandemic, mortality management remained relatively stable in the post-pandemic period. Trends in pneumonia Cases and the case fatality rate (CFR) from 2017 to 2023 are shown in Figure 3.

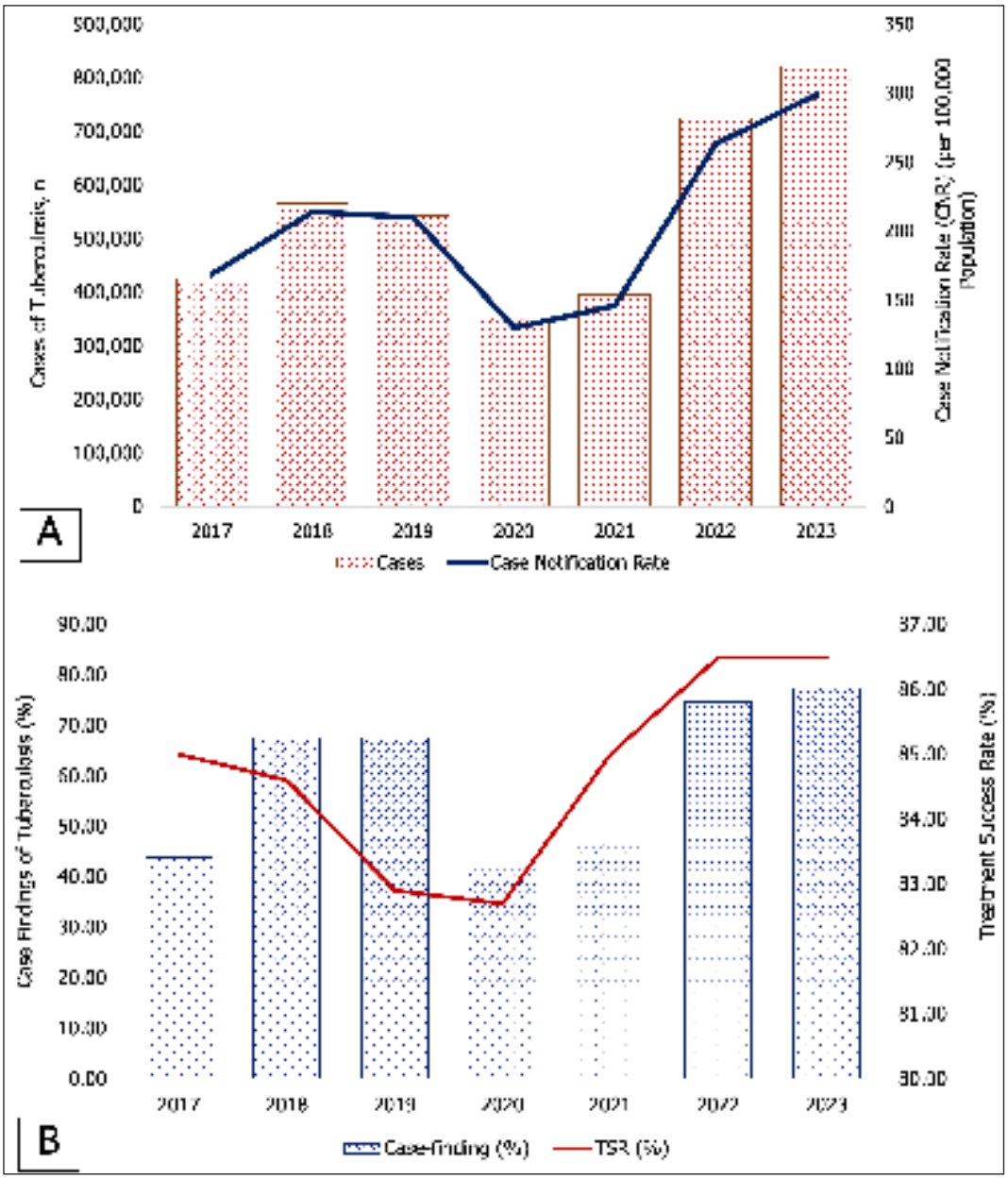

Figure 1.Tuberculosis (TB) surveillance data trends from 2017–2023. Remarks: Panel A illustrates the number of TB cases (dotted bars) and case notification rate (CNR) per 100,000 people (blue line). Panel B depicts two key TB programme indicators: the case-finding percentage (dotted bars) and the treatment success rate (TSR) (red line)

ISSN: 0019-5138
DOI: https://doi.org/

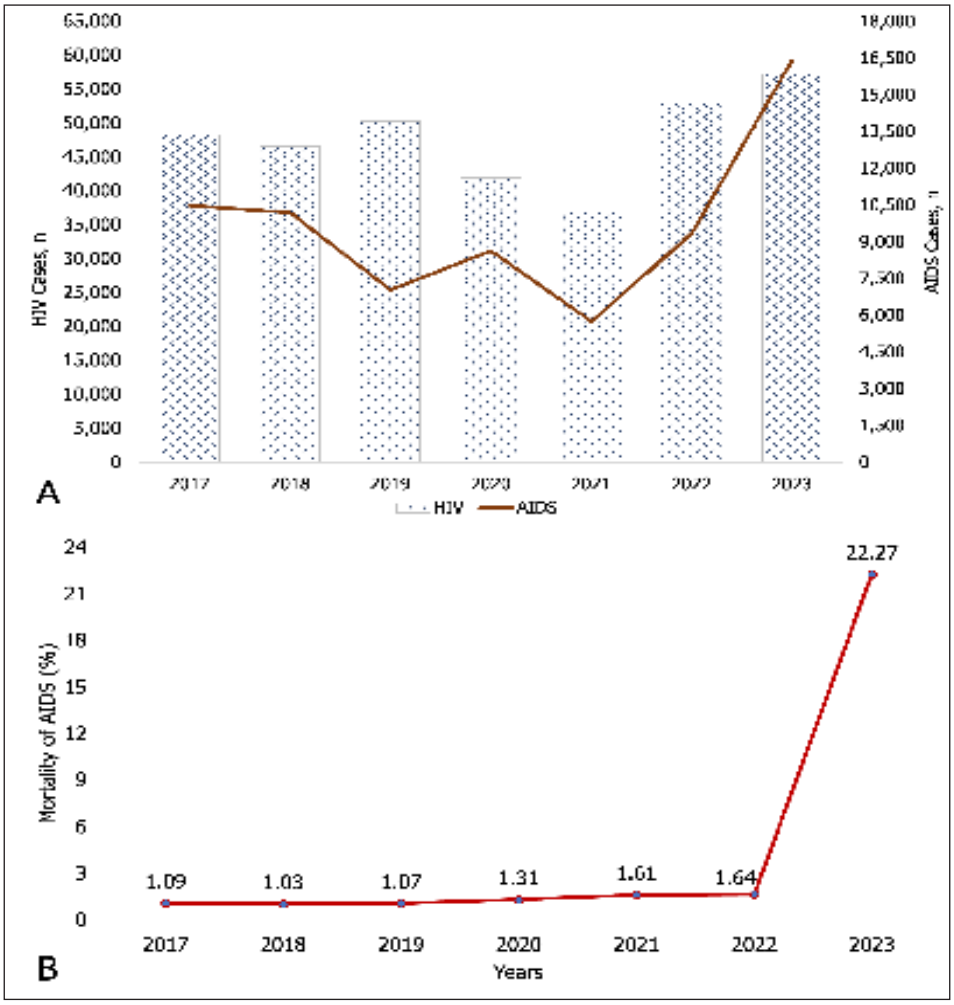

Figure 2.HIV/AIDS surveillance data trends from 2017 to 2023. Remarks: Panel A shows the number of HIV (dotted bars) and AIDS cases (brown line). HIV cases fluctuated, with a declining trend from 2017–2021, followed by an increase through 2023. AIDS cases show an increasing trend from 2021 to 2023. Panel B illustrates the mortality rate of AIDS patients, showing a dramatic increase from 1.64% in 2022 to 22.27% in 2023. Prior to 2022, the mortality rate had remained relatively stable at between 1.03% and 1.61%.

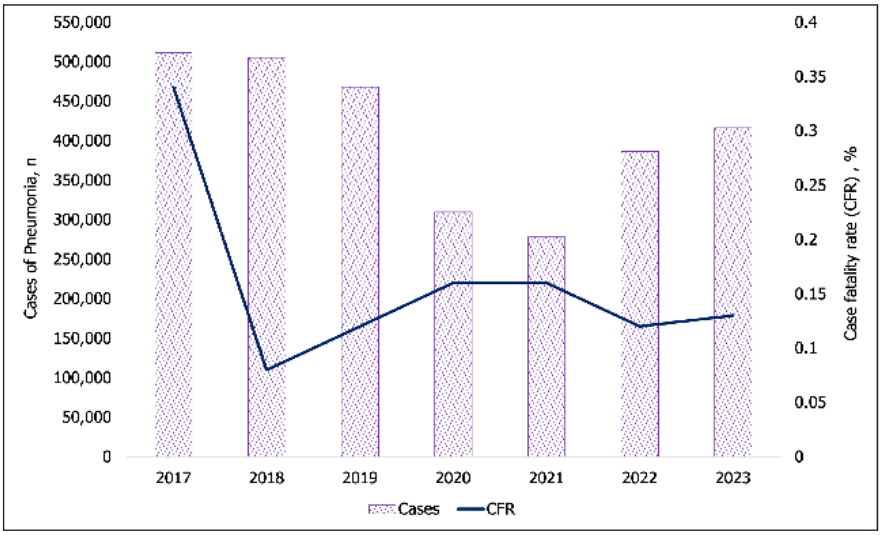

Figure 3.Trends in Pneumonia Cases and the Case Fatality Rate (CFR) from 2017–2023. Remarks: The graph illustrates the annual pneumonia cases (bars) and corresponding case fatality rates (lines) over a seven-year period.

ISSN: 0019-5138
DOI: https://doi.org/

Hepatitis

The analysis of hepatitis B/C cases during pregnancy in Indonesia from 2017 to 2023 revealed a distinctive pattern of disease burden across the prepandemic and post-pandemic periods. During the prepandemic era (2017–2020), there was a substantial increase in reported cases, increasing from 12,946 in 2017 to 30,965 in 2018, followed by a further significant increase to 46,064 in 2019. This sharp upward trend suggests that the screening and detection systems improved during this period. The onset of the COVID-19 pandemic corresponded to a slight decrease to 45,108 cases in 2020, representing a modest 2.1% reduction from the previous year. Trends in Hepatitis B/C Cases During Pregnancy, 2017–2023, are shown in Figure 4.

In the post-pandemic period (2021–2023), the data demonstrated a steady upward trajectory. The number of cases has increased from 47,550 in 2021 to 50,744 in 2022, followed by a marginal increase to 50,789 cases by 2023. This consistent upward trend in the post-pandemic period, with a total increase of 12.6% from 2020–2023, suggests resilient screening programmes and potentially improved access to antenatal care services, despite the pandemic's challenges. The overall trend from 2017–2023 shows a nearly fourfold increase in reported cases (from 12,946–50,789), with the most dramatic increase occurring in the prepandemic period between 2017 and 2019. The relative stability in case numbers during and after the pandemic period, particularly from 2022–2023 (only a 0.09% increase), might indicate either a plateau in disease prevalence or the attainment of optimal screening capacity in the Indonesian healthcare system. This pattern suggests the successful maintenance of hepatitis screening programmes during pregnancy despite healthcare system disruptions caused by the COVID-19 pandemic.

Diarrhoea

During the prepandemic era (2017–2019), the number of diarrhoeal cases remained relatively stable, with the number of cases ranging from 4.27 million in 2017 to 4.48 million in 2019, with a peak of 4.50 million cases in 2018. The percentage of cases during this period remained consistently above 60%, fluctuating between 60.4% and 62.93%, indicating robust surveillance and reporting systems. The onset of the COVID-19 pandemic marked a dramatic shift in this pattern, with cases dropping substantially to 3.25 million in 2020, representing a 27.5% reduction from the 2019 levels. The percentage of cases declined significantly to 44.4%. The impact continued into the early post-pandemic period, with cases further decreasing to 2.47 million in 2021, the lowest point in the study period, corresponding to a case percentage of 33.6%.

The post-pandemic recovery phase (2021–2023) showed a gradual but consistent upward trend. The number of cases increased from 2.47 million in 2021 to 2.60 million in 2022 and further to 3.10 million in 2023, representing a 25.6% increase from the 2021 nadir. Similarly, the case percentage improved, increasing from 33.6% in 2021 to 42% in 2023. The failure to return to prepandemic levels by 2023 highlights the potential long-term impact of the COVID-19 pandemic on diarrhoeal disease surveillance and management systems in Indonesia. Trends in diarrhoeal cases and their percentage distribution across all age groups, 2017–2023 are shown in Figure 5.

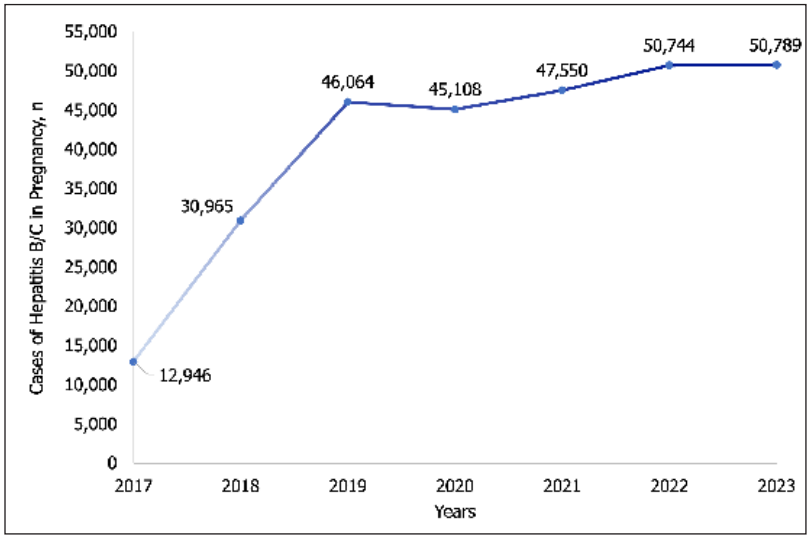

Figure 4.Trends in Hepatitis B/C Cases During Pregnancy, 2017–2023. Remarks: The graph depicts the annual number of reported hepatitis B/C cases among pregnant women over a seven-year period. The substantial increase in cases between 2017 and 2019 likely reflects improved screening and surveillance systems rather than an actual increase in disease incidence. The subsequent plateau suggests both consistent screening practices and a relatively stable prevalence of hepatitis among pregnant women

ISSN: 0019-5138
DOI: https://doi.org/

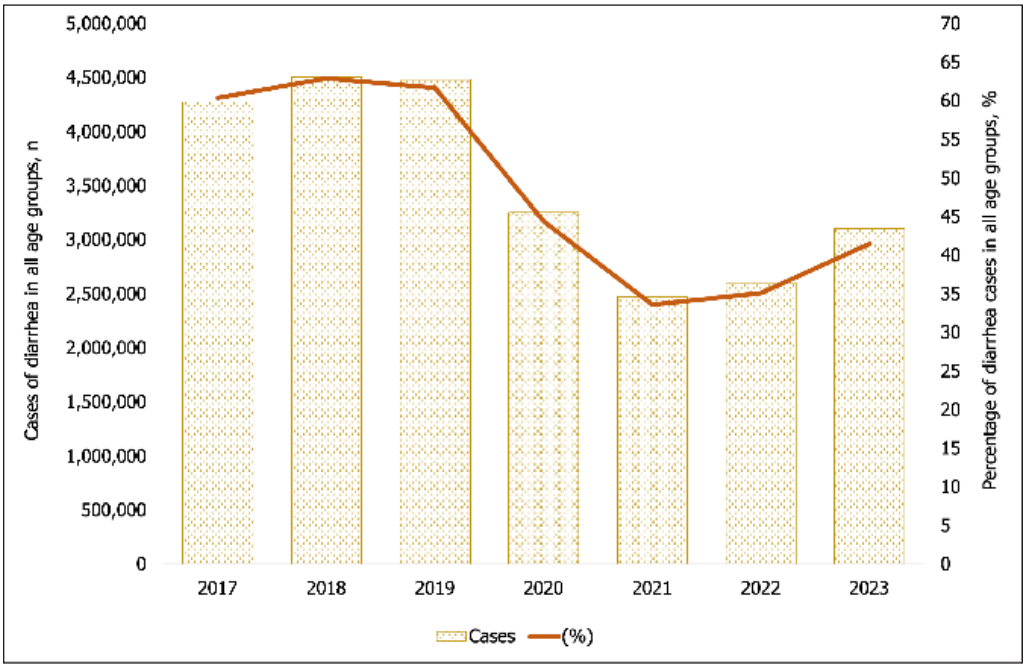

Figure 5.Trends in Diarrhoeal Cases and Their Percentage Distribution across All Age Groups, 2017–2023. Remarks: The graph depicts the annual number of diarrhoeal cases (bars) and their corresponding percentage distributions (lines) across all age groups over a seven-year period

Leprosy

During the prepandemic era (2017–2019), leprosy cases consistently increased, increasing from 15,910 cases in 2017 to 17,439 cases in 2019, with corresponding prevalence rates increasing from 6.1% to 6.5%. The case-finding rate remained stable at 0.7% during this period, indicating consistent surveillance. The onset of the COVID-19 pandemic marked a substantial disruption to this pattern, with cases dropping dramatically to 11,173 in 2020, representing a 35.9% reduction from the 2019 levels. Similarly, the prevalence rate decreased to 4.1%, whereas the case-finding rate declined to 0.5%. The immediate post-pandemic period slightly decreased, with cases reaching their lowest point of 10,976 in 2021, corresponding to a prevalence rate of 4.0%.

The post-pandemic (2021–2023) demonstrated a gradual but steady increase in case detection. The number of cases rose from 10,976 in 2021 to 12,612 in 2022 and further to 14,376 in 2023, representing a 31.0% increase from the 2021 nadir. The prevalence rate showed parallel improvement, increasing from 4.0% to 5.2% during this period. The case-finding rate also showed modest improvement, reaching 0.6% by 2023, although it did not return to prepandemic levels. Despite this recovery trend, both case numbers and prevalence rates remained below prepandemic levels, suggesting persistent impacts of the COVID-19 pandemic on leprosy surveillance and control programs in Indonesia. Trends in leprosy cases and prevalence rates, 2017–2023 are shown in Figure 6.

COVID-19

The analysis of COVID-19 trends in Indonesia from 2020–2023 revealed distinct patterns in disease burden, mortality, and case fatality rates (CFRs) throughout the pandemic period. The initial phase in 2020 recorded 743,198 cases, with 22,138 deaths, corresponding to a CFR of 2.98%. This relatively high CFR during the early pandemic phase likely reflects the limited testing capacity and initial adaptation of the healthcare system to the novel pathogen. The year 2021 marked a significant escalation in the impact of the pandemic, with cases increasing dramatically to 4,262,720, accompanied by 144,094 deaths. The CFR rose to 3.38%, the highest recorded during the study period, suggesting increased strain on healthcare resources and the emergence of more virulent variants. This surge continued until 2022, with cases peaking at 6,640,445, although the mortality rate remained stable at 144,094 deaths, resulting in a decreased CFR of 2.17%.

The year 2023 shows a marked decline in both cases and mortality, with 101,978 cases and 5,210 deaths recorded, representing the lowest figures since the onset of the pandemic. The CFR also decreased substantially to 1.32%, suggesting enhanced treatment protocols, widespread vaccination coverage, and possibly reduced virulence of circulating variants. The significant reduction in both absolute numbers and CFRs by 2023 suggests successful adaptation to and management of the pandemic, although continued vigilance remains essential. COVID-19 cases and mortality trends, 2020–2023 are shown in Figure 7.

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DOI: https://doi.org/

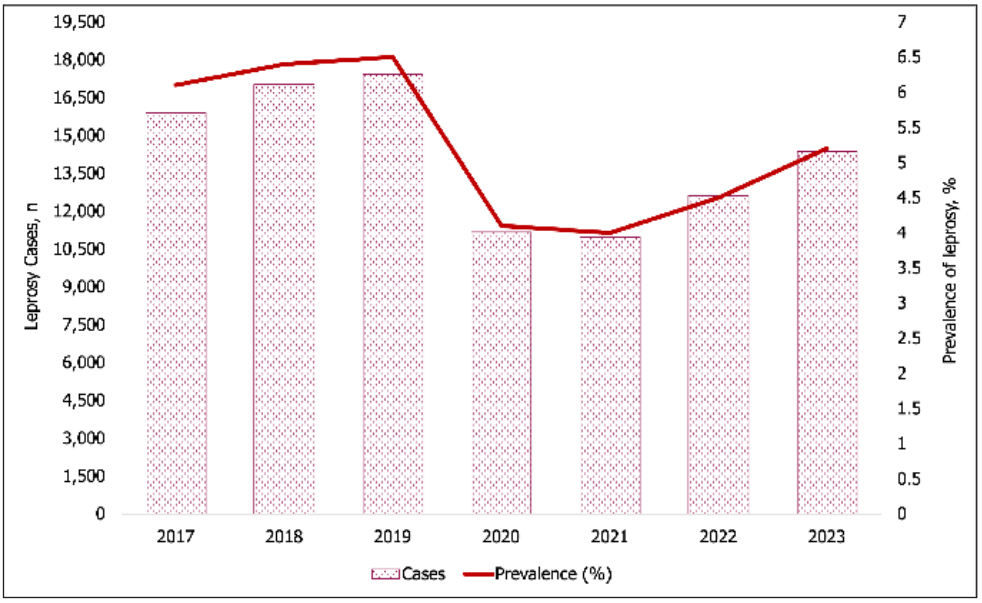

Figure 6.Trends in Leprosy Cases and Prevalence Rates, 2017–2023. Remarks: The graph presents the annual number of leprosy cases (bars) and corresponding prevalence rates (lines) over a seven-year period.

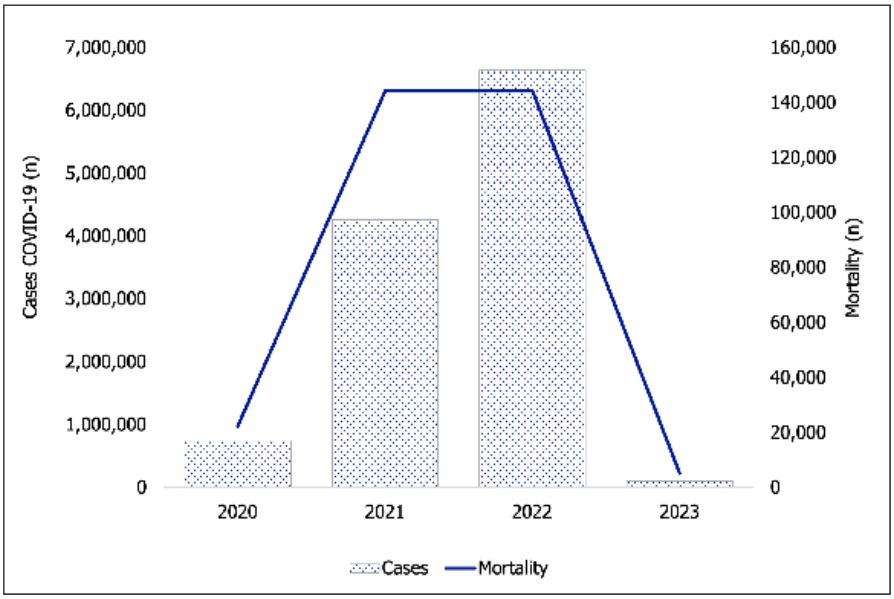

Figure 7.COVID-19 cases and mortality trends, 2020–2023. Remarks: The graph illustrates the trajectory of COVID-19 cases (bars) and mortality rates (lines) over a four-year period. The data demonstrate the evolution of the COVID-19 pandemic from its initial emergence through its peak and subsequent decline. The sharp decrease in both cases and mortality rates by 2023 suggests the effectiveness of public health interventions, vaccination programmes, and improved treatment protocols.

Correlation of infectious diseases in Indonesia over the last seven years

Based on the Pearson correlation (r) analysis of trends in eight infectious diseases in Indonesia from 2017–2023, several significant patterns of association were identified. Tuberculosis was strongly positively correlated with HIV (r=0.87, p=0.011) and AIDS (r=0.70, p=0.080) incidence, indicating coinfection or interrelated risk factors among the three diseases. Pneumonia was strongly positively correlated with leprosy (r=0.94, p=0.002) and diarrhoea (r=0.84, p=0.017) but negatively correlated with hepatitis (r=-0.64, p=0.119), suggesting the possibility of different transmission patterns or environmental risk factors for these diseases.

ISSN: 0019-5138
DOI: https://doi.org/

COVID-19 is negatively correlated with most other infectious diseases, especially diarrhoea (r=-0.77, p=0.043) and leprosy (r=-0.62, p=0.140), which may reflect the impact of public health interventions during the pandemic, such as large-scale social restrictions (PSBBs) and improved individual hygiene practices. Hepatitis was moderately negatively correlated with diarrhoea (r=-0.64, p=0.121) and pneumonia, suggesting possible differences in transmission pathways and affected populations. Statistical significance (p<0.01) was found in the correlations among tuberculosis-HIV, pneumonia-leprosy, pneumonia-diarrhoea, and COVID-19-diarrhoea. The correlation matrix of disease prevalence patterns from 2017–2023 are shown in Figure 8.

Principal component analysis (PCA) of infectious disease trends in Indonesia

Based on the results of principal component analysis (PCA), two principal components (PC1 and PC2) explained 82.84% of the total data variation, with PC1 contributing 50.69% and PC2 contributing 32.15%. These findings indicate that the two components are representative of the spread patterns of the studied infectious diseases. The loading plot results revealed that pneumonia, diarrhoea, and leprosy had strong positive loadings on PC1 (with loading values of 0.961, 0.868, and 0.933, respectively), indicating that these diseases have similar trend patterns. In contrast, COVID-19 and hepatitis had substantial negative loadings on PC1 (-0.731 and -0.588, respectively), indicating an opposite pattern to that of the first group. HIV and AIDS occupy an intermediate position, suggesting different dynamics in their transmission patterns and cases annually.

PC2 provided additional information, with tuberculosis showing the highest negative loading (-0.938), followed by HIV (-0.780) and AIDS (-0.690). This pattern indicates a unique characteristic in the trend of these three diseases that distinguishes them from other infectious diseases over the past seven years and during the COVID-19 pandemic. The biplots show that the samples were spread across four quadrants, indicating significant temporal variability in the prevalence of these diseases over the study period (2017–2023).

There was a significant increase, likely mediated by the COVID-19 pandemic, as well as a relatively significant peak increase from 20220–2023. Parallel analysis confirmed that the selection of the two principal components was appropriate, with the eigenvalues of PC1 (4.055) and PC2 (2.572) being above the values expected from random data. This finding strengthens the validity of the interpretation of observed patterns and underscores the complexity of the interactions between different infectious diseases in the context of the COVID-19 pandemic in Indonesia. The PCA results are shown in Figure 9.

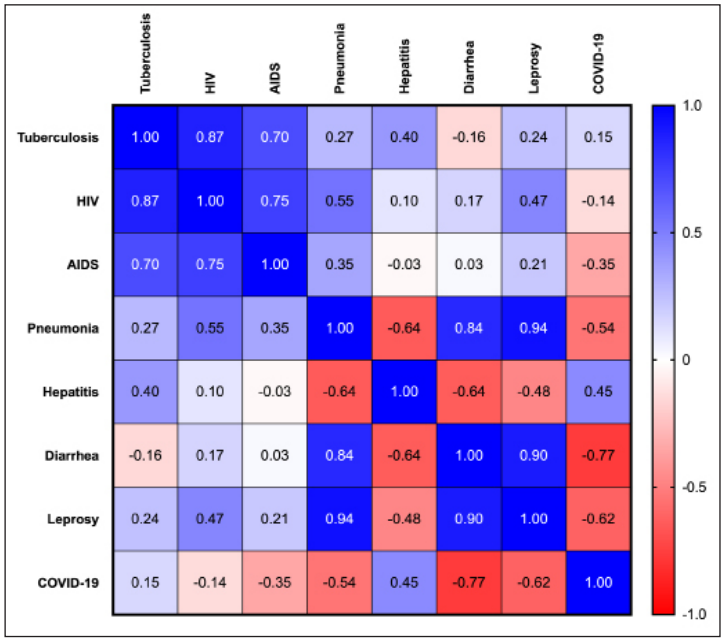

Figure 8.Correlation matrix of disease prevalence patterns, 2017–2023. Remarks: The heatmap presents correlation coefficients between eight major diseases via a blue-red colour gradient, where dark blue indicates a strong positive correlation (1.0) and dark red represents a strong negative correlation (-1.0). The strong positive correlation between HIV and tuberculosis aligns with known coinfection patterns, whereas the negative correlations with COVID-19 might reflect changes in disease reporting and healthcare access during the pandemic

ISSN: 0019-5138
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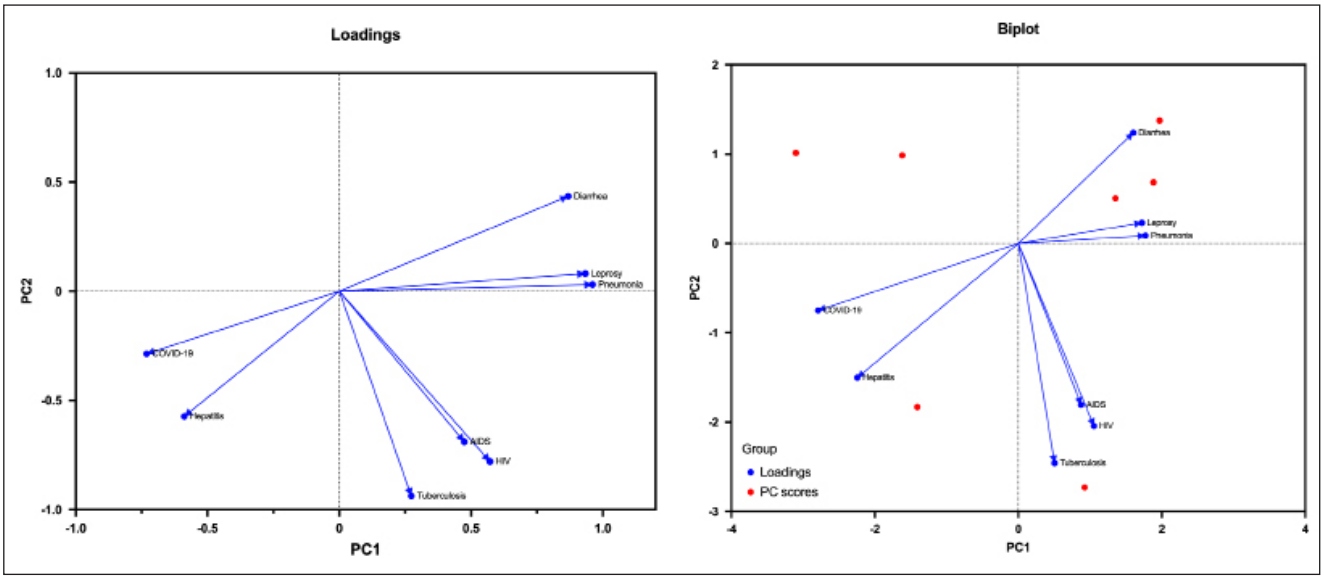

Figure 9.Principal component analysis (PCA) of disease patterns. Remarks: The figure comprises two related plots that show the PCA results of the disease relationships. The left panel displays the loading plot, whereas the right panel presents the biplot with both loadings and PC scores. PCA visualisation effectively demonstrated the underlying structure of disease relationships, explaining the primary sources of variation in the dataset. The clustering patterns suggest potential shared risk factors or transmission dynamics among the grouped diseases

Discussion

Tuberculosis before and after the COVID-19 pandemic

The significant increase in TB cases and case notification rates (CNRs) after the pandemic (2021–2023) aligns with the findings of Falzon et al. [16] and Utomo et al. [17] who predicted a potential surge in TB cases following pandemic-related disruptions. The initial decline in cases in 2020 (35.3% reduction) mirrors the global patterns observed by the WHO, where TB notifications decreased by 18% globally during the early pandemic phase.[18,19] This disruption was attributed to healthcare resource reallocation and reduced access to TB services during the lockdowns.[20]

The remarkable improvement in case-finding percentages from 41.7% in 2020 to 77.5% in 2023 suggests the successful implementation of adaptive strategies in Indonesia's TB control programs.[21] This improvement corresponds with the findings of Ledesma et al. [22] who documented enhanced TB surveillance systems and innovative case-finding approaches in high-burden countries post-pandemic. The integration of digital health solutions and community-based screening programmes is likely to have contributed to this success, as supported by evidence from similar interventions in other Southeast Asian countries.[23–25]

The sustained treatment success rate (TSR) throughout the study period (82.7–86.5%) demonstrates the resilience of Indonesia's TB treatment infrastructure. This stability during crisis periods aligns with the theoretical framework of health system resilience proposed by Sari et al.[26] and Yeboah et al.[27], emphasising the importance of maintaining essential health services during emergencies. The slight improvement in the TSR after the pandemic (86.5% from 2022–2023) suggests the successful adaptation of treatment protocols and patient support systems. However, the substantial increase in cases (821,200 in 2023) raises concerns regarding TB transmission dynamics during the pandemic. Jeong & Min.[28] and Comella-del-Barrio et al.[29] suggested that lockdown measures and increased indoor congregation may have enhanced TB transmission in household settings. Additionally, the economic impact of the pandemic likely exacerbated the social determinants of TB, including poverty and malnutrition.[30]

The improved case notification rates after the pandemic (298.8 per 100,000 in 2023) may reflect both enhanced surveillance and a true increase in the TB burden. This finding supports the "perfect storm" hypothesis proposed by Saunders and Evans,[30] where pandemic-related factors create conditions favourable for TB transmission while simultaneously disrupting control efforts. The findings of this study highlight the need for sustained investment in TB control programmes and the importance of resilience in the health system. The successful recovery and improvement in case detection after the pandemic demonstrate the potential for health systems to adapt and strengthen during crises, as theorised in the adaptive health system framework.[31,32]

ISSN: 0019-5138
DOI: https://doi.org/

HIV/AIDS before and after the COVID-19 pandemic

The observed fluctuation in HIV cases during the prepandemic period, followed by a significant decline during the early pandemic (16.5% reduction in 2020), aligns with the global patterns documented by Mude et al.[33], who reported widespread disruptions in HIV testing services during the COVID-19 lockdown. The subsequent increase in HIV cases post-pandemic (57,299 cases in 2023) suggests improved case detection and possibly increased transmission, which is consistent with the findings of Suchacz et al.[34] regarding the impact of delayed diagnoses during pandemic restrictions. The dramatic surge in AIDS cases after the pandemic (16,410 cases in 2023) and the unprecedented increase in mortality rates (22.27% in 2023) can be explained by multiple mechanisms. Hung et al.[35] documented how COVID-19 disrupts the HIV care continuum, leading to delayed diagnosis and treatment initiation. This disruption, combined with the "syndemic framework" proposed by Ojukwu et al.[36], suggests that the intersection of COVID-19 and HIV/AIDS has created compounded vulnerabilities in affected populations.

The striking increase in mortality rates warrants particular attention. Previous research identified several contributing factors in similar settings, including reduced access to antiretroviral therapy during lockdowns, delayed healthcare-seeking behaviour due to fear of COVID-19, and a compromised immune system, increasing the vulnerability of HIV patients to COVID-19 complications.[37–41] The theoretical framework of "cascading health system failures" proposed by Dui et al.[32] helps explain how initial pandemic-related disruptions led to downstream effects on HIV/AIDS outcomes. These findings highlight the urgent need to strengthen HIV/AIDS services in the post-pandemic era, with particular attention given to mortality prevention strategies. The results also emphasise the importance of maintaining essential health services during future public health emergencies.[42–44]

Pneumonia before and after the COVID-19 pandemic

The substantial decline in pneumonia cases during the early pandemic period (33.8% reduction in 2020) aligns with the findings of Tang et al.[45], who reported similar reductions in reported respiratory infections worldwide. However, this decrease likely reflects reduced healthcare access and testing capacity rather than true disease reduction, as suggested by To et al.[46] in their analysis of respiratory disease surveillance during the COVID-19 pandemic. The subsequent increase in cases after the pandemic (416,435 cases in 2023) indicates an improvement in detection systems, although they have not reached prepandemic levels. The persistently low case-finding rates postpandemic (31.4–38.8%) represent a concerning trend.

Elson et al.[47] and Ghafari et al.[48] identified similar challenges in respiratory disease surveillance, attributing them to sustained healthcare system disruptions and changing healthcare-seeking behaviours. This aligns with the "healthcare system resilience framework" proposed by Borghi et al.[49], which suggests that system recovery requires both infrastructure restoration and behavioural readjustment. The evolution of case fatality rates (CFRs) presents an interesting pattern, with a dramatic improvement from 2017 (0.34%) to 2018 (0.08%), suggesting the successful implementation of treatment protocols. The subsequent stabilisation at moderate levels (0.13–0.16%) during and after the pandemic indicates resilient critical care systems, supporting Poroes et al. [31] findings regarding the adaptability of essential healthcare services during crises.

The current challenges focus on rebuilding pneumonia surveillance systems while maintaining improved mortality outcomes. Elson et al.[47] emphasised the importance of integrated respiratory disease surveillance post-COVID-19, which is particularly relevant given the potential overlap in symptoms and detection methods. The theoretical framework of "systematic healthcare strengthening" proposed by Poroes et al.[31] provides a roadmap for simultaneous improvement in case detection and outcome management.

Hepatitis before and after the COVID-19 pandemic

The dramatic increase in cases during the prepandemic period (12,946–46,064 cases between 2017 and 2019) aligns with the findings of Khetsuriani et al.[50], who documented improved hepatitis screening coverage in maternal health services across Southeast Asia. This increase likely reflects enhanced surveillance systems rather than increased disease prevalence, supporting the "healthcare capacity building theory" proposed by Rastogi et al.[51] regarding the development of screening programmes in middle-income countries. The remarkable resilience of hepatitis screening programmes during the pandemic period, as evidenced by stable case numbers (45,108 in 2020 to 50,789 in 2023), corresponds with the observations of Dionne-Odom et al.[52] Their research highlighted how integrated maternal health services maintained essential screenings despite COVID-19 disruptions.[53–56] This success supports the "essential service preservation framework" developed by Neill et al.[57] and Junaid et al.[58], which demonstrates how critical healthcare services can be maintained during public health emergencies.

The post-pandemic plateau in case numbers (50,744 in 2022 and 50,789 in 2023) presents an interesting phenomenon. Kondili et al.[59] suggested that this pattern might represent the achievement of optimal screening coverage rather than true disease stabilisation. Martyn et al. [60] further argued

ISSN: 0019-5138
DOI: https://doi.org/

that such plateaus often indicate a need for targeted interventions in hard-to-reach populations. Current challenges focus on maintaining screening momentum while improving treatment access. Alfaray et al.[61] emphasised the importance of linking screening to care, which is particularly relevant given Indonesia's geographic challenges. The "cascade of care model" proposed by Chu et al.[62] provides a framework for optimising the screening-to-treatment pipeline in the postpandemic era.

Diarrhoea before and after the COVID-19 pandemic

The analysis of diarrhoeal disease trends in Indonesia from 2017–2023 revealed complex patterns influenced by the COVID-19 pandemic, demonstrating important implications for public health surveillance and intervention strategies. The substantial number of prepandemic cases (averaging 4.4 million annually from 2017–2019) aligns with the findings of Friedel and Cappell,[63] who documented similar disease burdens in comparable Southeast Asian settings. The high case percentages during this period (>60%) suggest effective surveillance systems, supporting the "comprehensive disease-monitoring framework" proposed by Hardhantyo et al.[64] and Hu et al.[65] The dramatic decline in cases during the pandemic (27.5% reduction in 2020) mirrors the global patterns observed by Adu et al.[66] and Morse et al.[67], who attributed such reductions to both improved hygiene practices and reduced access to healthcare. This phenomenon aligns with the "dual impact theory" presented by Sachs et al.[68], suggesting that pandemic-related behavioural changes simultaneously affect disease transmission and detection rates.

The postpandemic recovery trajectory, while showing improvement (25.6% increase from 2021–2023), remained significantly below the prepandemic level. Junaid et al.[58] identified similar patterns in other endemic diseases, attributing this to persistent changes in healthcare-seeking behaviours and surveillance system disruptions. The "new normal adaptation framework" proposed by Nawaz et al.[69] helps explain this sustained impact on disease-reporting patterns. Current challenges focus on rebuilding surveillance capacity while maintaining the beneficial hygiene practices adopted during the pandemic. Clark et al.[70] emphasised the importance of integrated disease surveillance systems that can adapt to changing public health landscapes. The persistently lowercase percentages (42% in 2023 vs. 60.4% in 2017) suggest a need for targeted interventions to restore comprehensive disease monitoring.

Leprosy before and after the COVID-19 pandemic

The prepandemic increase in cases (15,910–17,439 between 2017 and 2019) aligns with the findings of da Paz et al.[71], who reported enhanced case detection in endemic regions due to improved surveillance systems. The stable case-finding rate of 0.7% during this period supports the "active case-finding paradigm" proposed by Kahawita [72], which emphasises the importance of systematic screening approaches in leprosy control. The dramatic decline in cases during the pandemic (35.9% reduction in 2020) mirrors the global patterns observed by Vidal et al.[73], who identified significant disruptions in leprosy services in endemic countries. This observation supports the "service disruption cascade theory" developed by Filip et al.[74], demonstrating how pandemic-related restrictions affect both healthcare access and disease surveillance mechanisms.

The post-pandemic recovery trajectory, while showing improvement (31.0% increase from 2021–2023), remains below the prepandemic level. Butala et al.[75] and Manyazewal et al.[76] identified similar patterns in other neglected tropical diseases, attributing this to lingering healthcare system disruptions and changing healthcare-seeking behaviours. The gradual improvement in prevalence rates (4.0% to 5.2%) suggests that Williams et al. Williams et al.[42] termed this "resilient recovery", where systems slowly rebuild while adapting to new challenges. The current challenges centre on rebuilding comprehensive surveillance systems while addressing the potential hidden disease burden. Mphande-Nyasulu et al.[77] emphasised the critical importance of enhanced case-finding strategies in the post-pandemic era, particularly given the risk of delayed diagnosis during the pandemic period.

COVID-19 before and after the pandemic

The analysis of COVID-19 trends in Indonesia from 2020–2023 presents a comprehensive picture of pandemic evolution, healthcare system adaptation, and public health response effectiveness.[78] The initial high CFR in 2020 (2.98%) aligns with the findings of Khairulbahri,[79] who documented similar patterns across Southeast Asian countries during early pandemic responses. This phenomenon supports the "healthcare system adaptation theory" proposed by Poroes et al.[31], which highlights how healthcare systems evolve in response to novel pathogens. The subsequent increase in the CFR to 3.38% in 2021 corresponds with observations by Dol et al.[80] regarding the impact of viral variants and healthcare system strains during peak transmission periods.

The dramatic case surge in 2022 (6,640,445 cases) while maintaining stable mortality rates demonstrates what Burau et al.[81] termed "healthcare resilience capacity", where systems maintain effectiveness despite an increased burden. This observation supports the "adaptive response framework" developed by Poroes et al.[31], suggesting that healthcare systems can optimise responses through experience and resource allocation. The significant reduction in both cases and the CFR by 2023 (1.32%) reflects successful public health interventions and population

ISSN: 0019-5138
DOI: https://doi.org/

immunity development. Charrier et al.[82] and Shattock et al.[83] identified similar patterns in other countries, attributing improvements to vaccination programmes and enhanced clinical protocols. The current situation, a transition from a pandemic to an endemic phase, emphasises the need for continued surveillance and response capabilities.[84]

Correlation of infectious diseases in Indonesia over the last seven years

The pattern of correlation found between tuberculosis, HIV, and AIDS reflects the complexity of infectious disease interactions in Indonesia, which requires further treatment. The strong positive correlation between these three diseases (TB-HIV-AIDS) is in line with global findings of immunodeficiency syndromes that increase susceptibility to opportunistic infections.[85] This phenomenon is reinforced by previous studies showing that TB-HIV coinfection remains a significant public health challenge in developing countries, with higher mortality rates than single infections.[86,87]

The negative correlation between COVID-19 and most other infectious diseases, particularly diarrhoea and leprosy, indicates the indirect impact of pandemic control policies, such as large-scale social restrictions (PSBBs), over the past three years. This finding is consistent with global studies reporting significant reductions in the transmission of various infectious diseases during periods of social restriction that have a direct impact on reducing case reports and increasing the risk of an explosion of these diseases in the aftermath of the COVID-19 pandemic.[88] Improved hygiene practices, mass mask wearing, and clean and healthy living behaviours have been shown to have protective effects against various respiratory and enteric pathogens.[67,89] These conditions taught better social and health practices than did the years before the pandemic (2017–2020).

The strong associations between pneumonia and leprosy and diarrhoea raise questions about the underlying socioeconomic factors. Recent research suggests that environmental conditions and access to health services play important roles in the comorbidity of these diseases in resource-limited settings.[90,91] These findings emphasise the importance of a holistic approach to infectious disease control, especially in the post-pandemic era, to avoid an increase in and re-explosion of cases that impact public health.[92,93]

Principal component analysis (PCA) of infectious disease trends in Indonesia

Findings from the PCA revealed complex dynamics in the patterns of spread and increase of infectious diseases in Indonesia during the period of 2017–2023. The clustering of diseases identified through loading patterns revealed significant interactions between different infectious diseases that reflect changes in the health system and people's behaviour during the COVID-19 pandemic (2020–2023). The first group, consisting of patients with pneumonia, diarrhoea, and leprosy, presented strong positive correlations, indicating that these diseases may be affected by similar risk factors. When individuals are infected with COVID-19, the clinical manifestations are different but generally lead to worsening of the respiratory system, which leads to inflammation, flu, diarrhoea, and fever. This is in line with the findings of Chiu et al. [94], who reported that changes in hygienic behaviours during the pandemic, such as the use of masks and increased handwashing habits, contributed to a simultaneous decrease in the incidence of respiratory infections and waterborne diseases.

The positioning of COVID-19 and hepatitis in contrast to the first group on PC1 suggests a "displacement effect," where the focus and health resources diverted to the COVID-19 response might affect surveillance and response to other infectious diseases. This phenomenon is consistent with the observations of Sonneveld et al.[95], who reported a significant decrease in the diagnosis and treatment of viral hepatitis during the peak of the pandemic in various developing countries. The unique patterns exhibited by tuberculosis, HIV, and AIDS in PC2 reflect the special challenges in managing these chronic diseases during the pandemic. Sari et al.[26] emphasised that disruptions in routine health services during lockdowns have a serious impact on the continuity of treatment for TB and HIV patients, which could have long-term implications for the control of these diseases. These findings are also supported by WHO data showing an increase in undetected TB cases during the pandemic.[22]

The post-pandemic implications of the observed patterns highlight the need for strengthened integrated surveillance systems and improved resilience of the health system. Chen et al.[96] and Cioboata et al.[97] emphasised the importance of implementing a "dual-track" strategy that allows health systems to respond to new infectious disease threats while maintaining essential services for endemic diseases. This finding is in line with the recommendations of the current study, which indicates the need for a more integrated approach to infectious disease control.[98]

Public health and clinical implications

The findings of this comprehensive analysis have significant implications for both public health policies and clinical practice. The observed post-pandemic surge in tuberculosis cases, coupled with improved case detection rates, underscores the urgent need for strengthened TB surveillance systems and enhanced integration of TB services with existing healthcare infrastructure. The dramatic increase in HIV/AIDS mortality rates demands

ISSN: 0019-5138
DOI: https://doi.org/

immediate attention, suggesting the need for targeted interventions to restore and improve the continuity of HIV care, particularly in vulnerable populations. The persistently lower-case detection rates for pneumonia and diarrhoeal diseases indicate potential gaps in surveillance systems, necessitating innovative approaches to disease monitoring and reporting in the post-pandemic era. The successful maintenance of hepatitis screening programmes during the pandemic provides valuable lessons for preserving essential health services in future public health emergencies. The strong correlations identified between certain diseases, particularly TB-HIV-AIDS, emphasise the importance of integrated disease management approaches and comprehensive healthcare delivery systems. These findings suggest a need for policy reforms that prioritise health system resilience, sustainable disease surveillance mechanisms, and improved emergency preparedness protocols. In addition, the successful adaptation of certain health programmes during the pandemic offers valuable insights for developing more robust and flexible healthcare delivery systems in the future.

Limitations

The limitations of this study are the methodological and data constraints that may have affected the interpretation of the findings. The retrospective design and reliance on official government databases during the period of healthcare system disruption introduce potential reporting biases, particularly in capturing the true disease burden across remote and underserved areas. The seven-year timeframe (2017–2023), while providing valuable insights into pandemic impacts, may be insufficient to fully understand long-term disease patterns and the complete ramifications of COVID-19. Additionally, the inability to account for critical confounding factors such as socioeconomic disparities, healthcare accessibility, and regional infrastructure variations limits the depth of analysis. The correlation findings, although revealing significant disease associations, cannot establish causal relationships, necessitating cautious interpretation of the interplay between different infectious diseases.

Conclusion

This comprehensive analysis of infectious disease trends in Indonesia from 2017–2023 reveals the significant impacts of the COVID-19 pandemic on disease patterns and healthcare delivery systems. This study demonstrated substantial disruptions in disease surveillance and treatment programmes during the pandemic, followed by varying patterns of recovery across different diseases. Correlation analysis and PCA revealed important interactions between different infectious diseases, suggesting the need for integrated approaches for disease control and prevention. This study underscores the importance of maintaining essential health services during public health emergencies and suggests the need for innovative approaches to disease surveillance and control in the post-pandemic world. Future research should focus on developing more robust and integrated disease surveillance systems while addressing the identified gaps in healthcare delivery and monitoring.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Source of funding: None

Author's Contribution: Conceptualization: SMPS, IMDMA, Methodology: BU, IMDMA, Software: SMPS, IMDMA, Validation: BU, RPA, MS, Formal analysis: SMPS, IMDMA, Investigation: SMPS, RPA, Resources: MS, RPA, Data Curation: BU, IMDMA, Writing - Original Draft: SMPS, BU, IMDMA, Writing - Review & Editing: BU, IMDMA, RPA, Visualization: IMDMA, Supervision: BU, Project administration: MS

Declaration of Generative AI and AI-Assisted Technologies in the Writing Process: None

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ISSN: 0019-5138
DOI: https://doi.org/