Assessment of infectious diseases trends using syndromic surveillance system at the Pohnpei State Hospital, Federated States of Micronesia.

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Assessment of infectious diseases trends using syndromic surveillance system at the Pohnpei State Hospital, Federated States of Micronesia

A thesis submitted to the Divine Word University for the partial fulfillment for the degree of Master of Public Health

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Assessment of infectious diseases trends using syndromic surveillance system at the Pohnpei State Hospital, Federated States of Micronesia

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Statement of Authorship and Sources

I hereby declare that the work herein now submitted as a final research report is the result of my own investigations. This paper contains no material which has been accepted for the award of any degree or diploma in any university. To the best of my knowledge and belief, this paper contains no material previously published by any other person except where due acknowledgement has been made.

Signature:  **Date:** 1st of August, 2022.

CERTIFICATE

This is to certify that the dissertation on "***Assessment of infectious diseases trends using syndromic surveillance system at the Pohnpei State Hospital, Federated States of Micronesia***" submitted by ***Rodney Londari Itaki***, in Partial fulfillment of the requirements for the award of the Degree of **Master of Public Health** is an original research work carried out by him under my supervision. It is certified that the work has not been submitted anywhere else for the award of any other diploma or degree of this or any other University.

Date:

Place:

Signature of Supervisor

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SUMMARY

Introduction

Syndromic surveillance is a method of monitoring the trends of infectious diseases. Public health authorities use syndromic surveillance to detect and respond to increased infectious diseases to investigate and control potential outbreaks. Although the International Health Regulation mandates all countries to have surveillance systems to monitor infectious diseases that can cross international borders, many small island countries in the Pacific have been unable to fulfil their international obligations. The inability of Pacific Island governments to have well-functioning infectious disease surveillance systems was because most of the surveillance systems recommended are expensive to implement and maintain. In 2010, the World Health Organisation (WHO) proposed a simplified surveillance system called the Pacific Syndromic Surveillance System (PSSS) and implemented it in 23 Pacific Island countries. Presently, all state health departments in the Federated States of Micronesia (FSM) use PSSS for the surveillance of six infectious disease syndromes.

Several infectious disease syndromes under surveillance in the FSM have been identified as potentially climate sensitive. These syndromes include diarrhoea, influenza-like illnesses (ILI), febrile illnesses and leptospirosis. Almost all of these infections are associated with rainfall, either directly or indirectly. Therefore, assessing the association between the trends of these infections and rain can be helpful in monitoring, planning and responding to seasonal spikes in infections due to local weather patterns. Furthermore, global climate change is translating to extreme local weather conditions. Strengthening syndromic surveillance of diseases will make health systems responsive and adapt to the emerging health impacts of climate change.

Objectives of the study

The objective of this study was to answer two research questions:

1. What is the trend of infectious disease syndromes using the syndrome surveillance system at Pohnpei State Hospital during 2020 and 2021?

2. What is the association or relationship between rainfall and the infectious disease syndromes at the Pohnpei State Hospital during 2020 and 2021?

Study method

The Pohnpei Hospital started using an electronic syndromic surveillance system in 2019 as part of a more extensive programme to digitise health records. The electronic surveillance system automatically generates weekly syndromic surveillance reports that are cleaned and analysed routinely by the public health surveillance team. This research used a retrospective longitudinal study design to retrieve and clean the 2020 and 2021 syndromic surveillance datasets for Pohnpei State Hospital. The cleaned datasets were analysed to determine the syndromic trends and evaluate any association with rainfall. Rainfall data for Pohnpei in 2020 and 2021 were obtained from the National Oceanic and Atmospheric Administration, an agency of the national government of the FSM.

Results

Results of the study showed the syndromes were equally distributed among males and females. Diarrhoea and ILI accounted for more than 90% of all syndromes in 2020 and 2021. Diarrhoea accounted for 43.2% of all syndromes in 2020, but in 2021 this figure increased by 14.6% to 57.8% of all syndromes. Influenza-like illness accounted for 54.3% of all syndromes in 2020, but in 2021 this figure decreased by 20.2% to 34.1% of all syndromes. More than 90% of the diarrhoea and ILI cases were reported in children aged 0 to 10 years. The frequency of diarrhoea appeared to be constant throughout the year, with a weekly average of 20 patients, whereas ILI had five to six in a year. However, there was no predictable pattern when examining the ILI trends for 2020 and 2021. Linear regression analysis showed there might be a negative relationship between rainfall and ILI, with a correlation coefficient of about 20%. However, this phenomenon was observed only when the 2020 dataset was analysed. Regression analysis of the 2021 dataset did not show a negative relationship between rainfall and ILI. Another interesting observation was that the evaluation of the 2021 dataset using regression analysis revealed rain to be statistically significant with prolonged fever, albeit with only a 10%

correlation coefficient. The relationship between rainfall and the other syndromes was not significant. The frequency of SARI cases rose from only two cases in 2020 to 10 cases in 2021, reflecting a 500% increase.

Conclusions

The results of this study answered the two research questions, and some conclusions can be made. Diarrhoea and ILI were the most frequent infectious syndromes reported using the syndromic surveillance system in Pohnpei for 2020 and 2021. Children aged 0 to 10 years were the most commonly affected, accounting for more than 90% of syndromes reported. The diarrhoea trend throughout the years of the study showed a steady and stable frequency of cases. However, the ILI trend showed a seasonal pattern with five to six spikes in 2020 and 2021. Although the evaluation of trends suggests a negative relationship between rain and ILI syndrome, this phenomenon was only observed in the 2020 dataset. The other syndromes do not show any association with the volume of rainfall in Pohnpei.

Recommendations

Four recommendations can be made based on the results. Firstly, health promotional programmes must include awareness and education messages to reduce the frequency of diarrhoea and ILI syndromes in the hospital. Secondly, a more detailed cohort study of the syndromes supported by laboratory testing will provide more detailed information to confirm the results of this study. The design of this study did not permit laboratory testing or retrieval of laboratory tests to correlate with syndrome trends. Thirdly, the electronic syndromic surveillance system used at the Pohnpei State Hospital needs to be improved to ensure the system detects duplicate syndrome records if a patient presents more than once for the same clinical complaint. This will prevent a false increase in syndromes. The electronic syndromic surveillance system's default algorithm cannot detect duplicate records. Fourthly, additional weather indices such as temperature and humidity may be incorporated into the regression analysis to assess the relationship between weather and infectious disease syndromes. And lastly, the relationship between rainfall and syndromes in Pohnpei may not be linear. Therefore,

additional possible contributing variables will need to be considered to enable multiple variable analyses to elicit the nature of the relationship between syndromes and weather indices.

Keywords

Syndromic surveillance, infectious disease trends, Federated States of Micronesia, Pohnpei, infectious disease syndrome and rainfall, COVID-19, Coronavirus Disease 2019, ILI, Influenza-like illness, diarrhoea.

Acronyms

CBEWS – Climate-based early warning system

CHC – Community health centre

COVID-19 – Coronavirus Disease 2019

DWU – Divine Word University

EHR – Electronic health record

EpiNet - Epidemiology network

FSM – Federated States of Micronesia

HINARI – Health Inter-Network Access to Research Initiative

IHR – International Health Regulations

ILI – Influenza-like illness

NOAA – National Oceanic and Atmospheric Administration

PDHSS – Pohnpei Department of Health and Social Services

PICTs - Pacific Island countries and territories

PNG – Papua New Guinea

PSSS – Pacific Syndromic Surveillance System

SARI – Severe acute respiratory illness

UNICEF – United Nations International Children's Emergency Fund/United Nations Children's Fund

WHO – World Health Organisation

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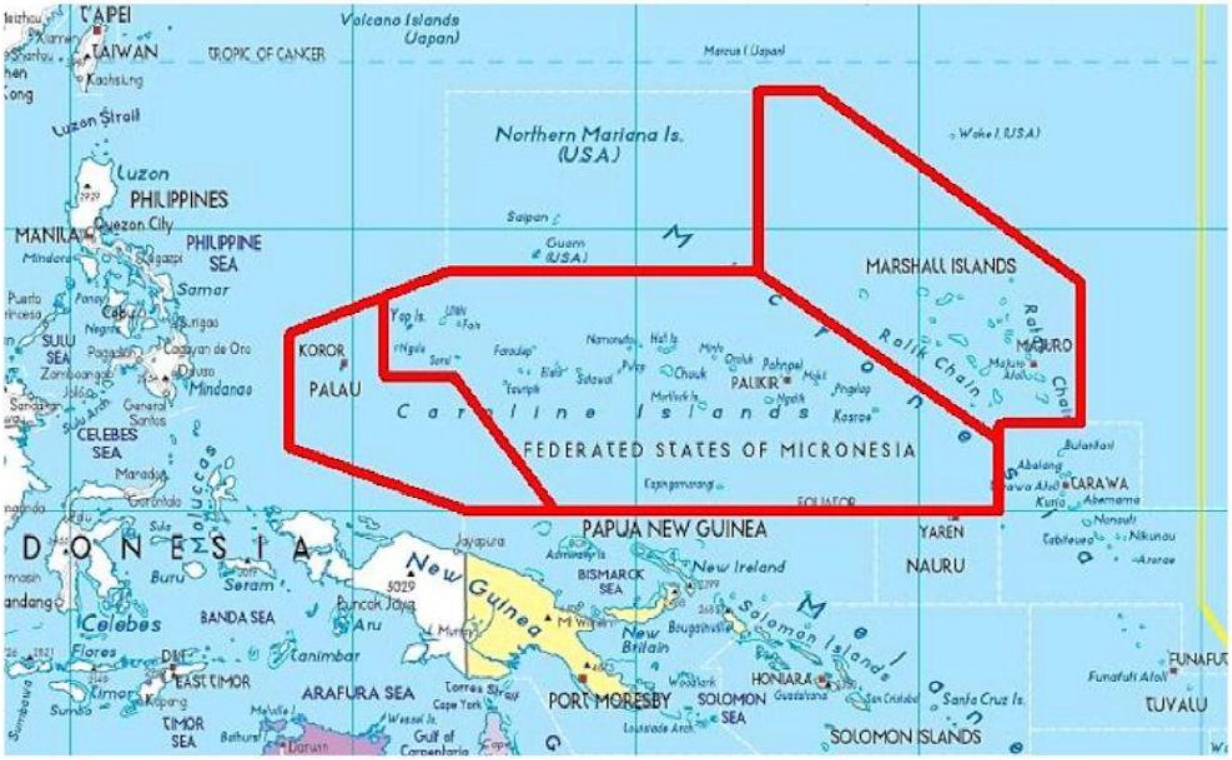
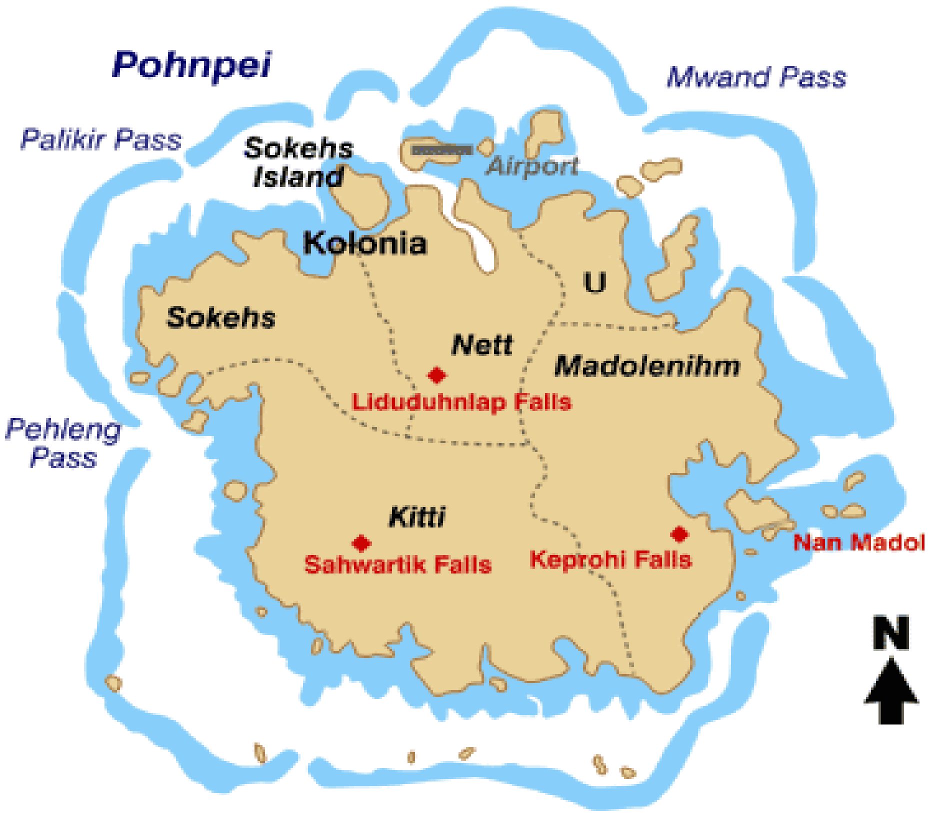


Map of Federated States of Micronesia (Source: Google images).



Map of Pohnpei showing the four municipalities on the island of Pohnpei. (Source: Google images).

Chapter 1 Introduction to the study

1.1 Introduction to the chapter

This chapter discusses the phenomenon under investigation, sketches the background of the study, outlines the problem statement and describes the significance of this research. The chapter concludes with a summary of this section.

1.2 Phenomena under investigation

A syndromic surveillance system detects, reports and responds to disease trends. When used to monitor infectious diseases, syndromic surveillance can help detect predefined disease signal thresholds and serve as an early warning system. For example, syndromic surveillance studies in many Asian and South American countries monitor seasonal trends in diarrhoea and influenza-like illnesses (Ghazani et al., 2018; Paesi & Magrini, 2015). In India and other Asian countries with a monsoonal season, monitoring leptospirosis using a syndromic surveillance system revealed an association with weather parameters such as rainfall, humidity and temperature, which assisted in planning public health response to disease trends (Ehelepola et al., 2021; Pawar et al., 2018; Saadi et al., 2021; Victoriano et al., 2009). Therefore, monitoring contagious diseases using syndromic surveillance systems helps predict seasonal changes, helping to prepare for increases in disease presentation at hospitals or responding to outbreaks.

Selected infectious disease syndromes in the Federated States of Micronesia (FSM) have been declared potentially climate sensitive. McIver et al. (2015) suggested that febrile illnesses, leptospirosis, diarrhoea and influence-like illnesses (ILI) are potential climate-sensitive infections. The authors also highlighted the need for further detailed study into assessing these infectious disease syndromes to have accurate data on the trends of infectious disease syndromes in the FSM.

1.3 Background of the study

The International Health Regulation (IHR) mandates member countries to establish legislation, policies and systems for the surveillance of infectious diseases that can cause outbreaks (Kool et al., 2012; Paterson et al., 2012). The IHR regulation ensures that every country has legislation to facilitate mandatory reporting of infectious diseases that have the potential to cross international borders. Unfortunately, countries in the Pacific have been unable to fulfil their IHR responsibilities because the recommended systems are copied from more developed countries and require laboratory testing of samples abroad, resulting in delayed responses to possible outbreaks (Craig et al., 2016). In 2010, a simplified surveillance system based on syndrome definitions that use clinical signs and symptoms was proposed and successfully trialled in three Pacific Island countries and later implemented in 21 Pacific Island countries (Craig et al., 2016; Kool et al., 2012).

The Pacific Syndromic Surveillance System (PSSS) was evaluated by World Health Organisation (WHO) experts two years after its implementation (Craig et al., 2016; Paterson et al., 2012). Paterson et al. (2012) used quantitative and qualitative methods to evaluate the PSSS in five Pacific Island countries. They found that it was simple, had government support, had well-defined roles and responsibilities, and had regular feedback to front-liners collecting data. The authors also reported that the system had well-defined case definitions and was integrated well into existing health information systems. Technical advice from external partners was readily available. In addition, Craig et al. (2016) found that the system was helpful for decision makers. The system's simplicity enabled Pacific Island countries to fulfil their IHR obligations, something many low-income countries have struggled to achieve (Craig et al., 2016). The system has also been helpful for outbreak monitoring in mass gatherings, such as during the 8th Micronesian Games in 2014 (White et al., 2018) and the 11th Festival of Pacific Arts (Hoy et al., 2016). However, there were still unresolved issues such as late data input, incomplete reporting, poor-quality data and unstable systems (Craig et al., 2016).

The Federated States of Micronesia is one of the 21 Pacific Island countries using the PSSS, and in 2019 the government began digitising its syndromic surveillance system. This transition was piloted at Pohnpei State Hospital and eventually rolled out to other states. When the WHO declared the pandemic, the National Health Department added severe acute respiratory illness (SARI) to the syndromic surveillance system to detect Coronavirus Disease 2019 (COVID-19).

1.4 Problem statement

The FSM government has identified several potential climate-sensitive infectious disease syndromes. However, accurate data on the trends of these syndromes are scanty. Analysing datasets generated by the electronic syndromic surveillance system at Pohnpei State Hospital can accurately show the trends of infectious disease syndromes under surveillance in the FSM.

1.5 Research question(s)

1. What is the trend of infectious disease syndromes using the syndrome surveillance system at Pohnpei State Hospital during 2020 and 2021?
2. What is the association between rainfall and the infectious disease syndromes at the Pohnpei State Hospital during 2020 and 2021?

1.6 The significance of the study

Many infectious diseases tend to coincide with seasonal rain. In areas where toilet practices are poor, heavy rain can lead to flooding with surface runoff containing faecal matter contaminating drinking water sources and causing diarrhoea outbreaks. On the opposite spectrum, extreme drought can also lead to diarrhoea when people consume contaminated water when their usual water sources dry up. Mosquitoes transmit many viral and parasitic infections, which can cause outbreaks of febrile illnesses two to three weeks after a rainy season when mosquito populations are large. Respiratory diseases, including the common cold and other influenza-like infections, tend to be more common in the colder parts of the year because common respiratory viruses favour colder temperatures. Therefore, analysing infectious disease surveillance data contributes to public health planning. In addition, analysing surveillance data can show trends over time and indicate the periods of the year when these infections associated with high rainfall occur so that health facilities can allocate resources to accommodate the increases. Such data can also inform public awareness and be used in preventive messages.

The results of this study will have three public health benefits for the FSM. Firstly, it will contribute to a gap in baseline knowledge about trends in infectious disease syndromes in the

State of Pohnpei. Secondly, evidence from this study will inform government policies and contribute to health service planning. Finally, the results of this study will provide primary data on potentially climate-sensitive infectious syndromes and could lead to the development of integrated surveillance systems that combine weather and syndromic surveillance variables. Governments could use the integrated systems within climate change initiatives for ongoing monitoring programmes to manage the impacts of climate-sensitive infections on health.

1.7 Researcher's role and position in the study

The researcher is a general practitioner at the Pohnpei State Hospital and is a final year MPH student at Divine Word University (DWU). The researcher is also the EpiNet clinical team lead and works closely with the public health team to investigate potential outbreaks detected by the syndromic surveillance system. The researcher was responsible for downloading, cleaning and analysing the datasets used in this research project.

1.8 The dissertation guide

Chapter 1 introduces the phenomenon under study, presents a brief background to this research, and lists the research questions that this study set out to answer. The chapter discusses the possible contributions of the results to our understanding of the phenomenon.

Chapter 2 contains the literature review. This section reviews the literature on syndromic surveillance. The chapter begins with the origins and development of the syndromic surveillance system, highlights the importance of syndromic surveillance, and discusses some literature on the present use of syndromic surveillance in the context of climate change.

Chapter 3 describes the study methods. This chapter explains the electronic syndromic surveillance system and how the system generates datasets. Some limitations of the study methods are also discussed.

Chapter 4 presents and describes the results of this study.

Chapter 5 contains the discussion, focussing on the main results concerning the research questions.

Chapter 6 presents the study conclusions and some recommendations.

1.9 Summary of the chapter

Syndromic surveillance is a vital tool for disease surveillance. Health systems routinely monitor and respond to outbreaks through infectious disease syndrome surveillance. Unfortunately, countries in the Pacific region have been unable to successfully implement and effectively sustain infectious disease surveillance systems due to financial and capacity constraints and the system's complexity. The Pacific Syndromic Surveillance System has been in use in some small island countries in the Pacific, including the FSM, since 2010 because it is simple and cheap. This research aimed to assess the trends of six infectious disease syndromes using datasets generated by the electronic syndromic surveillance at the Pohnpei State Hospital. In addition, this research also evaluated the connection or link between the syndrome trends and rainfall.

Chapter 2 Literature review

2.1 Introduction to the chapter

Recently, considerable literature has grown around the theme of climate-sensitive infections. Diarrhoea and febrile illnesses have been linked to heavy rain or drought (Ghazani et al., 2018). At the same time, ILI syndromes have been associated with cold temperatures (Soebiyanto et al., 2015; Thongpan et al., 2020). Surprisingly, similar studies evaluating the association between weather and infectious disease syndromes within the Pacific region are scanty, even though this region is very vulnerable to the effects of climate change.

McIver et al. (2015) identified leptospirosis, diarrhoeal illnesses and respiratory illnesses as potential climate-sensitive infections in the FSM. The authors suggested that these infections may be linked to the rainfall pattern, similar to studies elsewhere (Ehelepola et al., 2019, 2021; Prasetyo et al., 2015, Watson et al., 2006). Furthermore, McIver et al. (2015) identified knowledge gaps in the data for these climate-sensitive infections across the four states of the FSM. The authors suggested that the most likely reason for the gaps in data was unreliable health information systems because of information technology or human skills capacity constraints. Hence, the authors concluded that the amount of data available for their assessment was inadequate and presented limited opportunities for further analysis. They recommended increased research on the epidemiology of climate-sensitive infectious diseases in the FSM to construct a climate-based early warning system for infectious diseases (McIver et al., 2015).

The introduction of an electronic infectious disease syndromic surveillance system at the Pohnpei State Hospital in 2019 presented an opportunity to commence a study to assess how rainfall and the syndromes under surveillance are associated. This literature review guided a research project aimed at evaluating the correlation between rainfall and the trend of infectious diseases using the syndromic surveillance system at Pohnpei State Hospital. The following questions were used to guide this literature review: (1) What is the association between rainfall and diarrheal illnesses? (2) What is the association between rainfall and influenza-like illnesses, including COVID-19? (3) What is the association between rainfall and febrile illnesses? (4) What is the association between rainfall and leptospirosis? (5) How is climate change influencing rain-sensitive vector-borne infections?

2.2 Method of literature search and keywords

Google search, Google Scholar, HINARI from Research4life and PubMed were searched for relevant literature. The following keywords were used: syndromic surveillance, infectious disease outbreak, Pacific, Papua New Guinea, disease surveillance, infectious disease surveillance, climate change AND outbreak, climate change AND syndromic surveillance, climate change AND infectious disease outbreak and syndromic surveillance trend. The keywords were used in varying combinations and arrangements to maximise search output. This strategy was repeated with all keywords until all valid combinations were exhausted. All studies identified were added to the Mendeley library. Sometimes Mendeley search was used, and articles identified were added to the Mendeley library. Duplicate articles were identified and deleted. The abstracts were exported from Mendeley to a word document for further reviewing. Google search also produced conference presentations, web pages and reports. These results were included in the literature review. All non-English publications were excluded. Quantitative and qualitative literature, including peer review articles, government or non-government reports, opinions, web pages, consensus statements and conference proceedings, were included in the review. All the materials contained for the literature review were logged using Microsoft's Excel program. The abstracts were reviewed and used as guides for focused reading of specific literature. All the literature was summarised and used in writing the literature review.

2.3 Syndromic surveillance

Syndromic surveillance is a public health disease surveillance system that uses a set of predefined clinical signs and symptoms to detect specified diseases early. Even though the concept of an early warning public health system was known for some time, the Center for Disease Control and Prevention (CDC) in the United States of America fast-tracked its development, refinement and deployment when anthrax was detected in mail items in the country in 2001 (Henning, 2004).

Syndromic surveillance systems vary depending on the point of data collection and objective. For example, event-based syndromic surveillance is used in mass gatherings, while electronic methods detect infectious disease outbreaks using routine clinical data from outpatient or emergency departments (Henning, 2004). Syndromic surveillance systems are, therefore, highly adaptable and suitable for rapid deployment. These characteristics of syndromic surveillance systems have allowed this form of public health surveillance to serve many needs.

The advantages and disadvantages of a syndromic surveillance system depend on the type of surveillance used. For example, event-based surveillance is deployable rapidly but is labour intensive and not scalable (Henning, 2004). Electronic surveillance systems allow them to be scalable, data is standardised, and data mining can be done but have the disadvantage of being potentially expensive (Henning, 2004). Before implementing syndromic surveillance systems, health authorities need to consider their surveillance systems' objectives, advantages, and weaknesses.

The original intent of syndromic surveillance systems was to detect bioterrorism, but over the years, its application has evolved into other aspects of public health surveillance (Henning, 2004). Syndromic surveillance systems are disease-focused and automated, but the systems' sensitivity to detect syndromes depends on many factors. Specifically, the nature of case definitions used in describing syndromes in syndromic surveillance systems affects the sensitivity and positive predictive value of the case or syndrome definitions. For example, a study by Guasticchi et al. (2009) showed 90% sensitivity for coma but only 22% for haemorrhagic diarrhoea. In the same study, the positive predictive value of syndromes ranged between 99.3% and 20% (Guasticchi et al., 2009). The sensitivity of syndromic surveillance to detect waterborne outbreaks is also highly variable and depends on multiple variables such as environmental and other health factors (Hyllestad et al., 2021). Therefore, syndromic surveillance systems can potentially detect many false signals. This apparent disadvantage is offset by system automation enabling faster response because a delay can be costly both in material terms and in lives lost, particularly in low-resource settings. Furthermore, emergency departments using syndromic surveillance for COVID-19 have shown that having a syndromic surveillance system that detects many false positives can be an advantage in a pandemic (Hughes et al., 2020). The ongoing review of syndrome definitions, regular refresher training of physicians who report syndromes, and the assessment of syndromic trends can improve the accuracy of syndromic surveillance systems.

2.4 Syndromic surveillance in Pacific Island countries and territories

The International Health Regulation (IHR) mandates member countries to establish legislation, policies and systems for the surveillance of infectious diseases that can cause outbreaks and potentially cross international borders (Kool et al., 2012; Paterson et al., 2012). The IHR regulation ensures that every country has its list of infectious diseases required by law for monitoring. Unfortunately, countries in the Pacific have been unable to fulfil their IHR responsibilities because the recommended systems are replicated from more developed countries and require laboratory testing of samples abroad, resulting in delayed responses to possible outbreaks (Craig et al., 2016). In 2010, a simplified surveillance system based on syndrome definitions that use clinical signs and symptoms was proposed and successfully trialled in three Pacific Island countries and later implemented in 21 Pacific Island countries (Craig et al., 2016; Kool et al., 2012).

These 21 countries in the Pacific region currently use PSSS. This simplified syndromic surveillance is affordable and sustainable. Furthermore, this initiative has enabled small island countries in the Pacific to fulfil their IHR obligations. The Pohnpei State Hospital uses the PSSS to monitor and respond to disease outbreaks. In 2019 the Pohnpei State Department of Health and Social Services digitised the syndromic surveillance system. This improvement to the syndromic surveillance system is aimed at overcoming some challenges such as late data input, incomplete reporting and poor-quality data (Craig et al., 2016).

Surveillance of communicable diseases in Papua New Guinea (PNG) is done primarily through the National Health Information System (NHIS). The NHIS is intended for routine data collection from health facilities for monitoring and evaluating health system indicators (Cibulskis & Hiawalyer, 2002). The PNG NHIS is not suitable for detecting potential outbreaks early. Other surveillance systems used in PNG include the hospital-based system for monitoring measles and polio and event-based surveillance systems, which are not structured but rely on health workers to report unusual cases on ad hoc bases (Rosewell et al., 2013). The inability of the PNG public health surveillance systems to detect outbreaks early was well illustrated in how the first cases of cholera in a remote part of Morobe Province in 2009 were reported to provincial health authorities (Rosewell et al., 2011). To close this gap, a mobile phone-based syndromic surveillance system, similar to the one trialled in other Pacific Island countries, was piloted in PNG in 2010 (Rosewell et al., 2013). The results of the trial showed that the syndromic surveillance system produced reports in 2.4 days (compared to 84 days in the existing system), was 70% complete (compared to 40% in the existing system) and 95% sensitive (compared to 26% in the existing system) (Rosewell et al., 2013). Despite the reported advantages, the mobile phone-based syndromic surveillance system was neither integrated into the existing NHIS of PNG nor accepted for use as an adjunct surveillance system for detecting outbreaks early. Effective syndromic surveillance systems depend on close working relationships between clinicians and public health teams; a feature observed to be lacking in PNG (Rosewell et al., 2013). Although the authors did not highlight the estimated initial investment and ongoing operational costs of the mobile phone-based syndromic system if it were to be used in PNG nationally, financial constraints could have prevented its adoption by the PNG national health department.

2.5 Association between rainfall and infectious disease syndromes using syndromic surveillance

Studies assessing the association between rainfall and diarrhoea have shown mixed results. A review by Ghazani et al. (2018) showed that high precipitation was associated with an increased incidence of diarrhoea in some places, while low rainfall correlated with increased diarrhoea cases in others. Both low and high rainfall patterns are linked to increased diarrhoea cases. This is not surprising since heavy flooding and drought can lead to diarrheal outbreaks. Extreme rainfall or drought may influence environmental factors, especially drinking water sources. For example, severe drought led to outbreaks of diarrheal illnesses and eye infections in the Marshall Islands in 2013 (Marshall Islands Ministry of Health, 2020). Other studies assessing seasonal diarrhoea suggest that rainfall may influence the seasonal presence of rotavirus, directly influencing the seasonal trend in diarrhoea cases (Levy et al., 2008; Nath et al., 1992; Sumi et al., 2013). Where rotavirus presence is not seasonal, diarrhoea seems to have no relation to rainfall (Prasetyo et al., 2015).

Rainfall as a single factor may not be linked to cases of diarrhoea but requires the added multiplying effect of other weather factors, such as temperature or humidity (Levy et al., 2008; Sumi et al., 2013). As one review showed, a one-centimetre increase in rainfall plus an increase in temperature of one degree Celsius was associated with a 10% reduction in the incidence of rotavirus (Levy et al., 2008) and thereby affecting the trend of diarrhoea cases. Water and sanitation were common themes in most of the studies assessing the link between rainfall and diarrhoea cases. Indeed, regardless of weather changes, the critical risk factor appears to be water and sanitation practices (Njuguna et al., 2016). Assessing rainfall and cases of diarrhoea is crucial because data linking rainfall patterns to seasonal diarrhoea trends can be used to develop prediction models, which can be integrated into health promotional tools for public health interventions.

Small island nations are particularly vulnerable to climate change. Increased rainfall can also affect the habitat of vectors and influence the trend of infectious diseases (McIver et al., 2015). Assessing the correlation between rainfall and the trend of febrile illnesses can provide the evidence needed to plan for outbreaks that may arise because of changes in local weather patterns. Common febrile infections associated with a rainy season include dengue, leptospirosis and enteric fever (Iyer et al., 2019; Pawar et al., 2018; Pineda-Cortel et al., 2019). Rainfall variation can also influence hepatitis E virus infection (Tricou et al., 2020). Most studies show a positive correlation between rainfall, dengue, and leptospirosis, with two to three weeks of lag time (Alshehri, 2013; Blanco & Romero, 2016; Flamand et al., 2014; Khairunisa et al., 2018; Premdas et al., 2019). Furthermore, these trends appear to have seasonal variations following the rainy or monsoon seasons (Palihawadana et al., 2014; Salam, 2019). On the other hand, some studies do not correlate rainfall and dengue fever or leptospirosis (Jorge et al., 2017; Tasanee et al., 2015). Environmental factors, such as soil conditions, could also contribute to leptospirosis (Dao Thi Minh & Rocklov, 2014; Ehelepola et al., 2019, 2021). The difference could be due to reasonable vector control or good environmental management of dengue vectors in these countries.

It is well established that malaria positively correlates with rainfall, showing parasite density fluctuation with rainfall (Odongo-Aginya et al., 2005). Unfortunately, similar correlation studies are lacking in PNG and other Pacific countries, although infections such as dengue, malaria and other mosquito-borne infections are common. Febrile and diarrheal illnesses have been identified as climate-sensitive diseases in the Pacific (McIver et al., 2015). Still, climate change's potential infectious disease-related health impacts remain under-researched. Therefore, disease surveillance systems in small island nations need strengthening to be adaptable to monitor infectious disease trends. Routine surveillance data must be evaluated regularly to gather reliable evidence to help plan for climate change-related shifts in disease trends.

Influenza-like and other respiratory illnesses generally have seasonal trends. Within the context of climate change, respiratory illnesses' seasonal trends may change due to the changing weather patterns. In the FSM, ILIs have been identified as climate-sensitive diseases (McIver et al., 2015). Evidence suggests that ILIs and other respiratory diseases, such as pneumonia, are influenced by temperature and humidity (Chen et al., 2014; Kim et al., 2016; Nakapan et al., 2012; Thongpan et al., 2020). Respiratory syncytial virus, a common cause of ILIs, appears more active in colder months (Watson et al., 2006). A study in PNG assessing pneumonia in children under five years of age showed that the risk of pneumonia is variable between rainy and drier months of the year (Kim et al., 2016). The variation in risk was also observed across the different provinces studied (Kim et al., 2016). This observation suggests that the correlation between rainfall and childhood pneumonia in PNG may be geography specific. Rainfall appears to influence ILIs and respiratory illnesses, but the available research assessing the correlation between weather parameters and ILIs suggests that the relationship may not be linear (Basray et al., 2021). Other factors, such as human activity that affects the environment and social activities that are shaped by weather conditions, may determine seasonal trends of respiratory diseases in a community. Other social and economic statuses of the community could also add to the risk of respiratory illnesses regardless of the time of the year. Nevertheless, it is important to continue surveillance of ILI trends because this knowledge contributes to planning vaccination campaigns such as influenza vaccines.

Leptospirosis is a frequent cause of febrile illness in the FSM and is commonly associated with dogs, pigs and rats (Colt et al., 2014). The condition typically presents as a febrile illness with joint aches and pain, and outbreaks can sometimes occur one to two weeks after heavy rainfall. A study in India showed that leptospirosis infection has a seasonal trend (Premdas et al., 2019), but similar correlation studies have not been done in the FSM. Similar observations showing leptospirosis peaking up to one month after heavy rainfall have also been reported in other tropical countries where this infection is common (Premdas et al., 2019). However, observing trends and patterns does not generate sufficient information that can be used for developing strategies aimed at reducing the infectious disease-related health impacts of climate change. Accurate forecasting models that combine meteorological factors with infectious disease trends are needed. Indeed, many such studies have been performed, including predictive models for leptospirosis (Pawar et al., 2018). A study in India correlating monthly rainfall to monthly leptospirosis infection showed a predictable trend (Pawar et al., 2018). Still, their forecasting model showed 80% variability. Their models could not accurately predict the occurrence of leptospirosis for July and August 2011 but accurately predicted the number of leptospirosis cases for August 2013 and August 2014 (Pawar et al., 2018). The results suggest forecasting models for climate-sensitive infectious diseases may need to include multiple meteorological and geographical factors in the statistical models for better predictive accuracy. The study's prediction model did not include other elements, such as oxygen and iron concentrations in the soil, water and soil pH, human activities and cyclone data. These elements influence leptospirosis transmission and may have affected the accuracy of the statistical models (Pawar et al., 2018).

Infectious diseases transmitted by mosquitoes are sensitive to rainfall. Dengue and lymphatic filariasis, two mosquito-borne infections, are endemic in the FSM, and the frequency of these infections is related to rainfall (McIver et al., 2015). Kosrae, a state of the FSM, has experienced periodic dengue outbreaks in the past. The sporadic outbreaks were most likely related to the vector population's rise and fall. However, until 2013, no reliable data existed on the dengue vector population in Kosrae (Noda et al., 2013).

Understanding the local variation of mosquito populations with rainfall will enhance the environmental management of dengue. Mosquito populations tend to increase and decrease following the volume of rain. Therefore, ongoing surveillance of febrile syndromes and integration with weather monitoring systems can effectively detect potential early signals of an outbreak. Efforts to eliminate lymphatic filariasis in the FSM are ongoing, but intense transmissions still occur in some areas. The small outer atoll islands of the FSM have a high concentration of lymphatic filariasis (Pretrick et al., 2017). In addition to mass drug administration to eliminate lymphatic filariasis, controlling mosquito breeding sites is a proven preventive strategy.

2.6 Association between meteorological variables and COVID-19

There is some evidence suggesting that weather variables may influence COVID-19 transmission. For example, a study in Pakistan used Spearman rank correlation analysis to assess the correlation between COVID-19 and meteorological factors such as temperature, humidity and rainfall (Basray et al., 2021). That study showed variation in the correlation across different cities in Pakistan. Humidity was negatively associated with COVID-19 in all towns except Karachi, where it was positively related (Basray et al., 2021). Rainfall was positively associated with COVID-19 in all cities studied except in the cities of Islamabad and Peshawar (Basray et al., 2021). However, other studies do not confirm or show similar results, and there have been calls for robust research designs to examine the relationship between COVID-19 and weather factors (Zaitchik et al., 2020). These studies need to identify the intermediate factors and type of relationship (linear or nonlinear) that weather has with these intermediate factors and how they combine to influence COVID-19 disease dynamics.

Although the weather may influence COVID-19 transmission, other factors may be involved. Among the key issues that need to be considered include data quality, identifying non-environmental factors, and mapping the COVID-19 distribution in time and space within the context of what phase of the epidemic is being assessed (Zaitchik et al., 2020). It has also been recommended that COVID-19 predictive models should factor in the current understanding of disease transmission dynamics (Zaitchik et al., 2020). As in all infectious diseases associated with climate change, it is possible that the relationship between COVID-19 and meteorological factors will vary between tropical and temperate regions of the world. Socioeconomic and cultural practices will also play a role. Predictive models would need to consider all these factors.

2.7 Summary of the chapter

Many infectious diseases are associated with rainfall, either increasing or decreasing soon after a rainy season. This literature review examined studies evaluating the link between rainfall and febrile illnesses, diarrhoea, ILIs and COVID-19. Such research is crucial because monitoring climate-sensitive infections help to plan for managing the health impacts of climate change. Climate-sensitive infections are linked to the environment and seasonal changes in the local weather. Systemic surveillance of infectious syndromes aids the assessment of trends and can serve as an early warning system. Combining syndromic surveillance trends with meteorological variables can provide evidence to inform policy development, health promotion and health service planning. Such approaches will strengthen health systems to be more responsive, resilient and adaptable to climate change.

The evidence reviewed suggests that although rainfall may be associated with infectious disease syndromes, the relation is complex with the interplay of multiple factors. Although growing research suggests rain may be positively associated with diarrhoea, ILIs and febrile illnesses, other studies do not show this connection. The positive association is more evident in regions with distinct seasonal rainfall, such as monsoon seasons. What has emerged from this review is that although infectious syndromes may correlate with rainfall season, other weather variables such as temperature and humidity should also be factored in the analysis. Environmental factors such as soil parameters and geographical terrain may also influence infection trends. The present state of research in this area is still poorly understood and presents opportunities for more research.

2.8 Conclusion

Many infectious diseases are seasonal, coinciding with the rainy season. Analysing infectious disease surveillance data trends can show trends over time and indicate the periods of the year when these infections associated with high rainfall are expected, enabling public health preparedness. The link between climate change and variation in disease trends has multifactorial roots. Therefore, combining meteorological variables such as rainfall, temperature or humidity with syndromic surveillance data can reveal associations between weather and infectious disease syndromes. However, research evidence suggests that the association between rainfall and infectious disease trends is multifactorial and geography-specific. Conclusions from studies in one geographical region cannot be applied globally, and further research is needed to examine this phenomenon locally. Locally generated research evidence is better suited for informing local policy and public health practices.

Chapter 3 RESEARCH DESIGN

3.1 Introduction to the chapter

This study aimed to assess the trends of infectious disease syndromes using the syndromic surveillance system and to determine any association with rainfall. This chapter describes the quantitative methods used in data sampling and analysis to answer the research questions.

The specific objectives of the study were to:

1. determine the frequency and distribution of six infectious disease syndromes using the syndromic surveillance system's dataset for 2020 and 2021 from the Pohnpei State Hospital's electronic health record system,
2. determine the monthly variation in the six syndromes in Pohnpei State during 2020 and 2021, and
3. investigate any association between the six syndromes and rainfall in Pohnpei during 2020 and 2021.

3. 2 Study site

The researcher conducted this study in the Pohnpei State Hospital, Department of Health and Social Services, Pohnpei State, in the Federated States of Micronesia (FSM). The hospital has 100 beds. The hospital's catchment population is approximately 40,000 to 45,000. Primary care, specialist clinical services (surgical, paediatrics, gynaecology, obstetrics) and other support services (pathology, radiology, physiotherapy, pharmacy) are available.

3.3 Study design

This study employed a retrospective cohort study design. Routine syndromic surveillance datasets for 2020 and 2021 were retrieved from the hospital server and analysed.

3.4 Sample population and sampling strategy

The sample population was patients seeking doctors' consultation at the OPD and ER departments at the Pohnpei State Hospital during 2020 and 2021.

Inclusion criteria were:

1. All patients with an electronic health record of a clinical encounter and captured in the syndromic surveillance report generated by the EHR system. The syndromic surveillance datasets contained patients' hospital numbers, gender, dates of birth, municipality in which they lived, clinical encounter date and syndromic surveillance syndrome classification assigned by the treating physician.
2. Patients classified as PSS02, PSS03, PSS04, PSS05, PSS06 and PSS07 using the syndromic surveillance by the treating physician.

Exclusion criteria were:

1. Patients classified as PSS01 (not an infectious disease syndrome) in the syndromic surveillance system. These patients' signs and symptoms did not qualify as one of the infectious disease syndrome definitions.
2. Patients without electronic health records of a clinical encounter at the Pohnpei State Hospital during 2020 and 2021.
3. Patients treated for clinical conditions at other private hospitals or health dispensaries in Pohnpei.
4. Weekly syndromic surveillance reports that had incomplete data were excluded from the final analysis.

The datasets for this study are from a sample of patients classified into one of six infectious disease syndromes monitored using the syndromic surveillance system. Analysis of the datasets will enable generalisation to the general population of Pohnpei. Furthermore, this study assumes that the dataset sample is representative of all patients who had clinical encounters at health facilities in Pohnpei State during 2020 and 2021.

3.5 Data analysis

Rainfall data for 2020 and 2021 were cleaned and entered into an Excel file. Daily rainfall measurements were converted from inches to millimetres prior to further data manipulation and correlation analysis. The daily rainfall measurements were pooled to construct weekly and monthly tables in Excel.

Syndromic surveillance data for 2020 and 2021 were downloaded from the hospital server in PDF format and converted to Excel files. The Excel files contained the clinical encounter variables and syndrome classification. The clinical encounter variables included date of encounter, patient age, patient gender, syndrome classification and the municipality of residence. The Excel files were reviewed and cleaned. The cleaned datasets in Excel files were coded (see code book in Annex) and used in the analysis. Patients that had missing variables were removed from the study. A master list of all the clinical encounters was constructed in sequential order following the date of the clinical encounter and then pooled to construct weekly and monthly data tables. Separate tables for 2020 and 2021 datasets were created. The final data tables were used in the final analysis and for creating graphs.

The final weekly and monthly data in Excel files were used for assessing weekly and monthly trends. Excel was used to create line graphs using the independent and dependent variables to visualise syndrome trends. The independent variable was the time in weeks (week 1 to week 52) or months (month 1 to month 12) following the standard calendar year. The dependent variable was case frequency. The frequency and distribution of syndrome cases were visualised using bar charts and trends. The syndrome trends were visualised using line graphs.

Each clinical encounter variable (age, gender and municipality of residence) was the independent variable. The dependent variable was syndrome classification. The syndrome classifications were stratified by age, gender and municipality of residence to examine syndrome distribution. Excel was used to create bar graphs using the stratified syndrome classification data to visualise and describe the distribution of the different syndrome classifications stratified by age, gender or municipality of residence.

The clinical encounter date was used to match the daily syndrome clinical encounters with the corresponding rainfall measurements. This approach was used to create tables that had clinical encounter dates, patient clinical variables and corresponding rainfall measurements for that date of clinical encounter. The daily data tables were pooled to make weekly and monthly frequency tables of syndrome classification with corresponding rainfall measurements. The pooled weekly and monthly tables were then utilised for the regression analysis to evaluate the correlation between syndrome and rainfall. Linear regression analysis was done using Epi Info™ (version 7.2.4.0). Simple linear regression was employed to determine the relationship between syndrome frequency and rainfall. The independent variable was rainfall measurement in millimetres. The dependent variable was syndrome frequency.

Frequency rates and proportions were used to describe syndrome distribution and trends. Mode, median and interquartile range were used to describe the distribution of numerical variables. Linear regression analysis and visual inspection of graphs were used to evaluate the association between syndrome frequency and rainfall. The correlation coefficient (0.0-1.0) was used to assess the degree of correlation between syndrome frequency and rainfall. No correlation was defined as 0.0, and perfect correlation was defined as 1.0.

3.6 Ethical issues

Ethical clearance for this research was given by the Faculty of Medicine and Health Sciences, Divine Word University (FMHSRC approval number FRC/MHS/10-22).

The researcher informed the Pohnpei Department of Health and Social Services and the FSM National Health Department using prescribed forms for documentation and reporting. The FSM Internal Review Board (IRB) could not meet because of pressing government needs due to the ongoing COVID-19 activities in the FSM. Therefore, this study was exempted from IRB ethical review. The researcher is the clinical team lead for the Pohnpei EpiNet team and routinely reviews the syndromic surveillance data. Analysis of the datasets is also part of the routine operational review of public health syndromic surveillance data.

This study used secondary data that physicians generated from clinical encounters at the OPD and ER departments of Pohnpei State Hospital. There was no direct contact with patients in this study. No patient was interviewed. No blood or other biological samples were obtained. All personal identification details on the datasets were removed. The datasets were stored on a password-protected Google drive. All information was used for routine reporting and research purposes. All datasets will be deleted after the study.

There is no conflict of interest to declare. This research did not use any external funding.

3.7 Limitations of the study methods

The electronic syndromic surveillance system does not give a unique identification number for each consultation visit or syndrome recorded. Every patient who goes to the Pohnpei State Hospital has a unique hospital registration number used every time a person visits the hospital for a test or consultation. Consequently, the system could not differentiate whether a syndrome was the initial consultation or a revisit for the same clinical complaint, resulting in possible duplication of syndromic records. For example, if someone had a fever and is recorded as PSS02 on day one and discharged with medicines, but on day three, if the fever was still present and that person returned for the same complaint, the system was unable to identify whether this consultation was a revisit of the same syndrome that was recorded earlier, thereby recorded as another PSS02 syndrome and ultimately creating duplicate syndromic data for that particular case.

This study used syndromic surveillance data from the state hospital only. Syndromic surveillance data generated by private health facilities and community health centres were not included in the datasets. The state hospital's information system is digitised, whereas all other public health facilities in Pohnpei still used paper-based systems at the time of this study. Therefore, the data in this study will represent clinical presentations at the state hospital only. However, because most patients with severe illnesses come to the main hospital (personal experience), it is assumed that the data will give a reasonably good representation of the infectious disease trend in Pohnpei.

Syndrome misclassification by physicians is another potential source of error. Physicians could misclassify a syndrome despite receiving training on the syndrome definitions. Such mistakes in classification are usually identified by the public health data analyst, who is required to contact the physician via phone to verify the classification and correct any errors.

3.8 Summary of the chapter

This study employed a longitudinal retrospective cohort design to analyse routine syndromic surveillance data from the Pohnpei State Hospital. This chapter further outlined the methods used for data collection and analytical methods employed in this study.

Chapter 4 Research findings

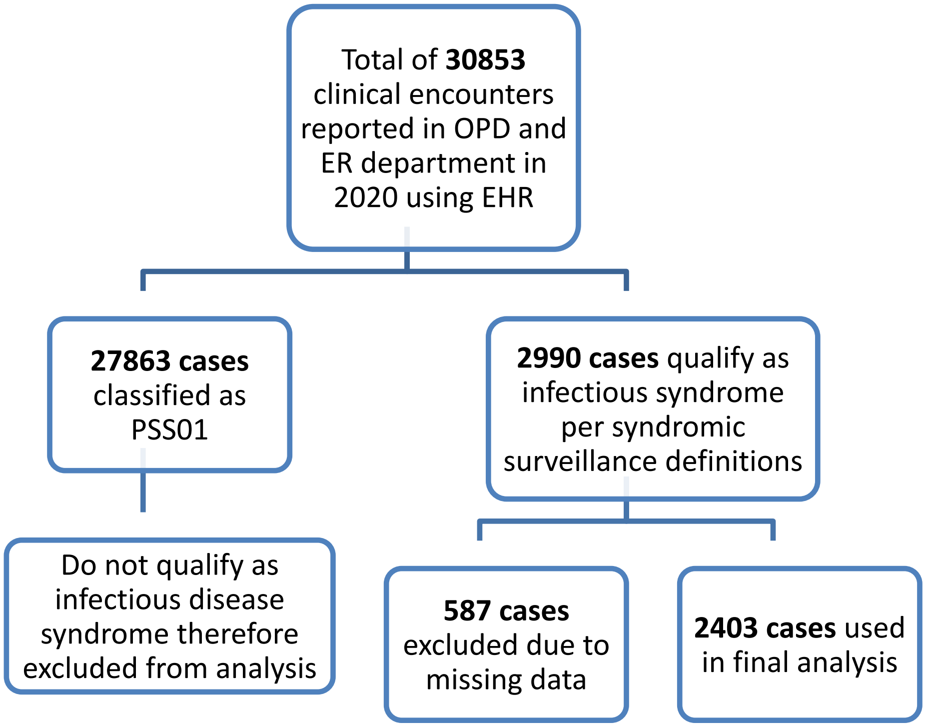
4.1 Introduction to the chapter

This chapter presents the results of the analysis. The sub-sections are categorised by each variable that was analysed. These variables are age, gender, municipality, week, month and the connection to rainfall. Within each syndrome analysis, the results of the 2020 dataset are first described, followed by the 2021 results.

4.2 Overall syndrome frequency

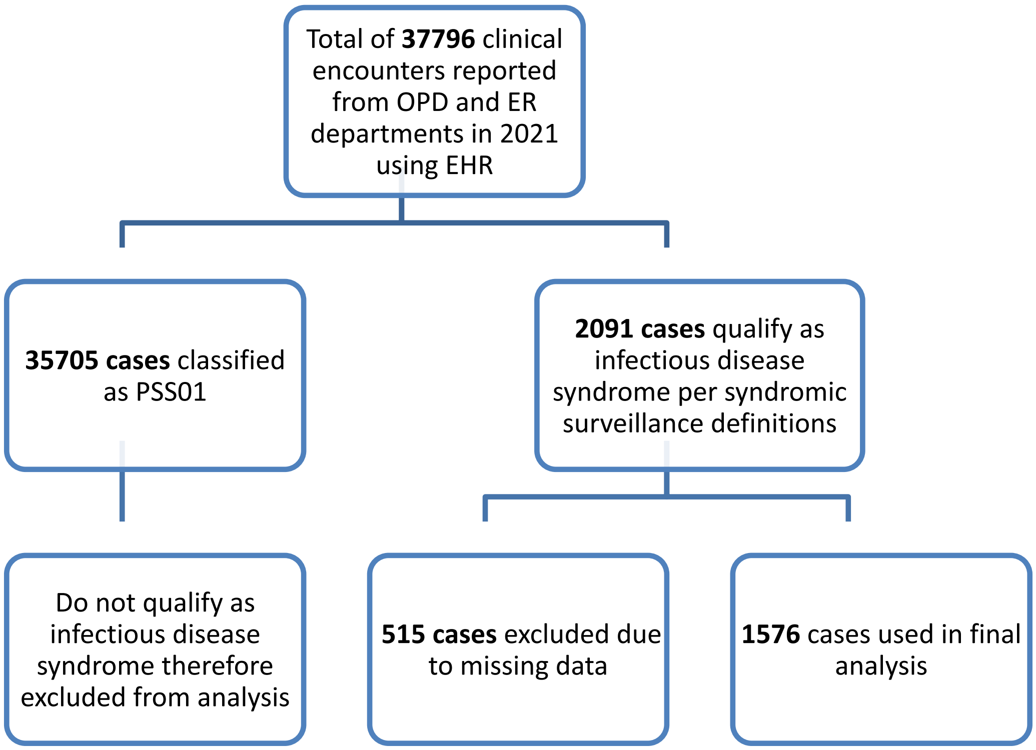
A total of 30583 clinical encounters were reported in OPD and ER departments in 2020 using the EHR. Encounters classified as PSS01 (27863 cases) were excluded because these cases did not fit the syndromic surveillance definitions (Figure 1). Another 587 cases were excluded due to missing data. Finally, for the 2020 dataset, 2403 syndromes (2403/30583; 7.9%) were analysed. The most frequent syndrome reported was ILI (1305/2403; 54.3%), followed by diarrhoea (1037/2403; 43.2%), probable dengue (24/2403; 1%), acute fever and rash (18/2403; 0.7%), prolonged fever (17/2403; 0.7%) and SARI (2/2403; 0.08%).

Figure SEQ Figure * ARABIC 1. Selection of cases for analysis 2020 dataset.



A total of 37796 clinical encounters were reported in OPD and ER departments in 2021 using the EHR. From this total, 35705 cases did not fit the syndromic surveillance definitions (PSS01) and were excluded (Figure 2). Another 515 cases were excluded due to missing data. Finally, for the 2021 dataset, 1576 syndromes (1576/37796; 4.2%) were analysed. The most frequent syndrome was diarrhoea (911/1576; 57.8%) followed by ILI (538/1576; 34.1%), probable dengue (65/1576; 4.1%), prolonged fever (28/1576; 1.8%), acute fever and rash (24/1576; 1.5%) and SARI (10/1576; 0.6%).

Figure SEQ Figure * ARABIC 2. Selection of cases for analysis 2021 dataset.



4.3 Syndrome frequency and distribution by age

For the 2020 dataset, the median age was seven years, mode was one year and interquartile range of 35 years. For the 2021 dataset, the median age was 15 years, mode was one year and interquartile range of 43 years.

Age frequencies were categorised into 10-year age groups to evaluate syndrome frequency and distribution within the specified age groups. Influenza-like-illness and diarrhoea were the most common syndromes in the 0 to 10 years in 2020 and 2021. Influenza-like illness and diarrhoea were the most frequent syndromes reported in all age groups in 2020 (Figure 3) and 2021 (Figure 4). The proportion of ILI cases in this age group was more than twice the number of diarrhoea cases in 2020 but almost equal in 2021. With increasing age, a decreasing trend in ILI and diarrhoea frequency was observed. The declining trend of diarrhoea with age ceased in the 31 to 40 age group and then rose with advancing age. This phenomenon was observed in 2020 and 2021.

Figure 3. Frequency distribution of syndrome by age groups, 2020.

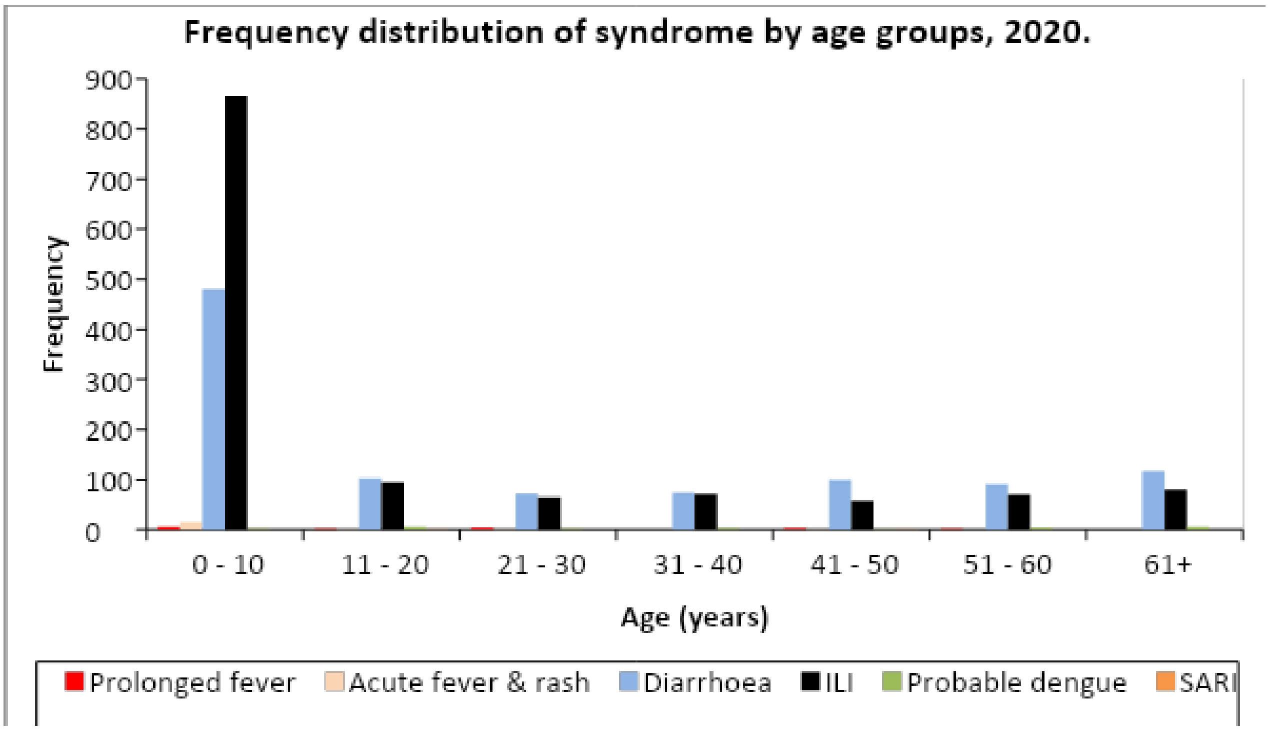
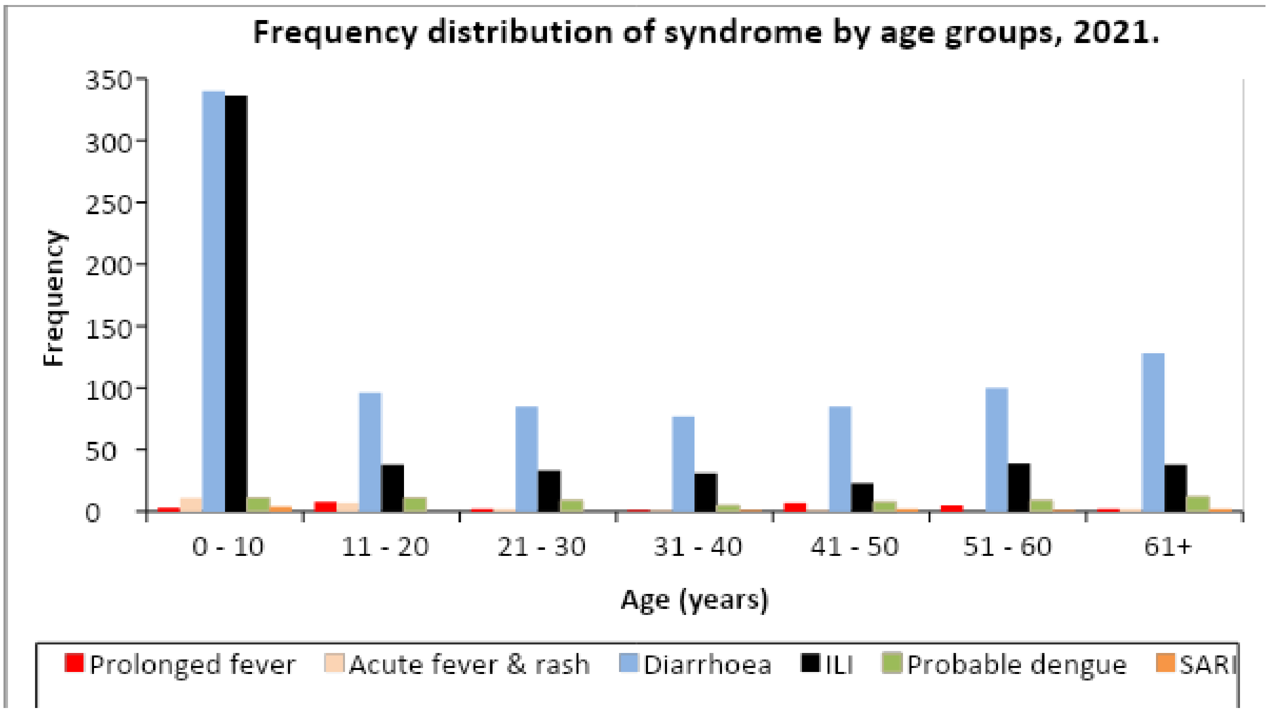


Figure 4. Frequency distribution of syndrome by age groups, 2021.



4.4 Syndrome frequency and distribution by gender

There were 1154 males (1154/2403; 48%) and 1249 females (1249/2403; 52%) in the 2020 dataset. There were 774 (774/1576; 49%) males and 802 (802/1576; 51%) females in the 2021 dataset. Diarrhoea and ILI were the most frequent syndromes in both males and females in 2020 (Figure 5) and 2021 (Figure 6).

Diarrhoea accounted for 19.8% (477/2403) of male cases and 23.3% (560/2403) in females in 2020. Influenza-like illness accounted for 26.8% (644/2403) of male patients and 27.5% (661/2403) of females in 2020.

Diarrhoea accounted for 28.9% (456/1576) of male cases and 28.8% (455/1576) of females in 2021. Influenza-like illness accounted for 15.9% (252/1576) of male patients and 18.1% (286/1576) of females in 2021.

Figure 5. Frequency distribution of syndrome by gender, 2020.

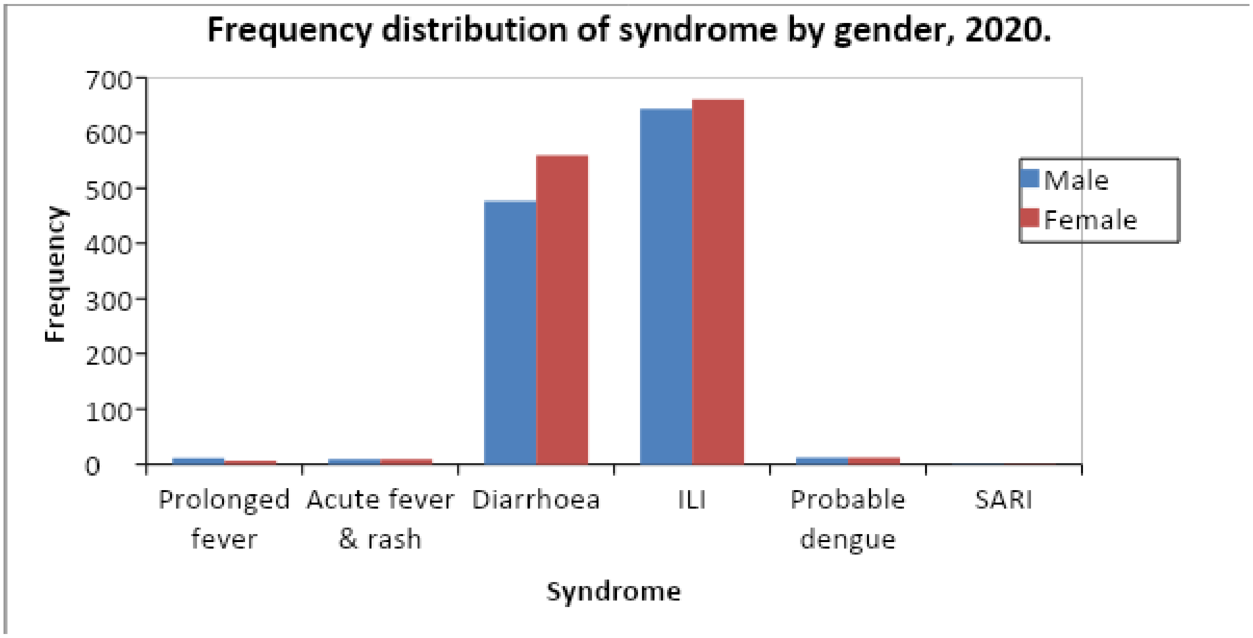
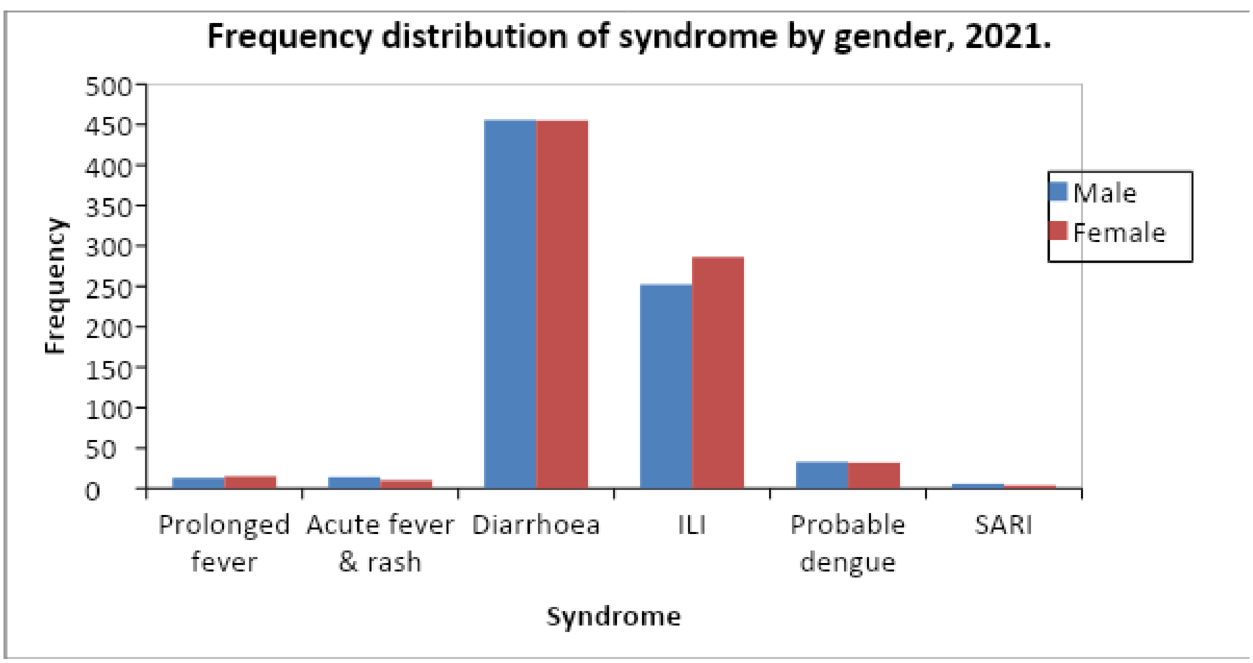


Figure 6. Frequency distribution of syndrome by gender, 2021.



4.5 Syndrome frequency and distribution by municipality

Diarrhoea and ILI constituted more than 90% of the syndromes reported from the municipalities. The cases came from the four large municipalities of Pohnpei (Nett, Sokehs, Kitti, Kolonia and Madolenihmw). This phenomenon was observed in 2020 (Figure 7) and 2021 (Figure 8).

In 2020, 26% (636/2403) of all syndromes reported were from Nett. Kitti (412/2403; 17%), Sokehs (460/2403; 17%) and Kolonia (375/2403; 16%) had equal distribution. Uh had 11% (257/2403) of the syndromes. Less than one percent was from the other municipalities.

In 2021, 23% (369/1576) of all syndromes reported were from Nett. Kitt (296/1576; 19%), Kolonia (246/1576; 16%) and Sokehs (238/1576; 15%) had equal distribution. Uh had 12% (182/1576) of the syndromes. Less than one percent was from the other municipalities.

Figure 7. Frequency distribution of syndrome by municipality, 2020.

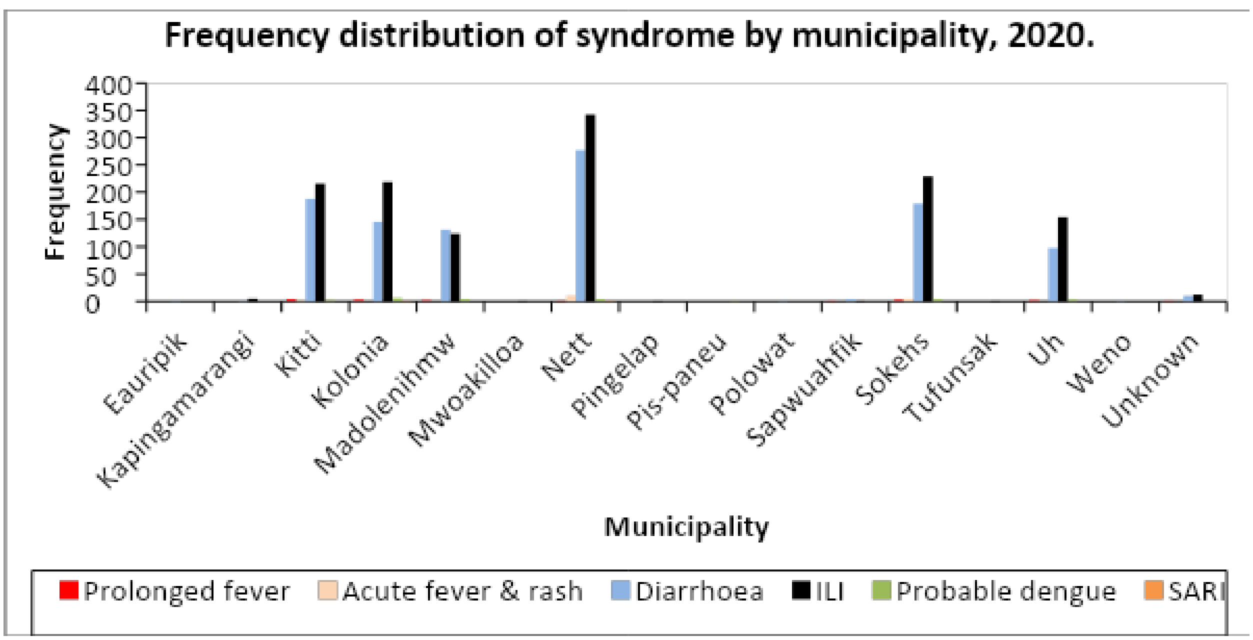
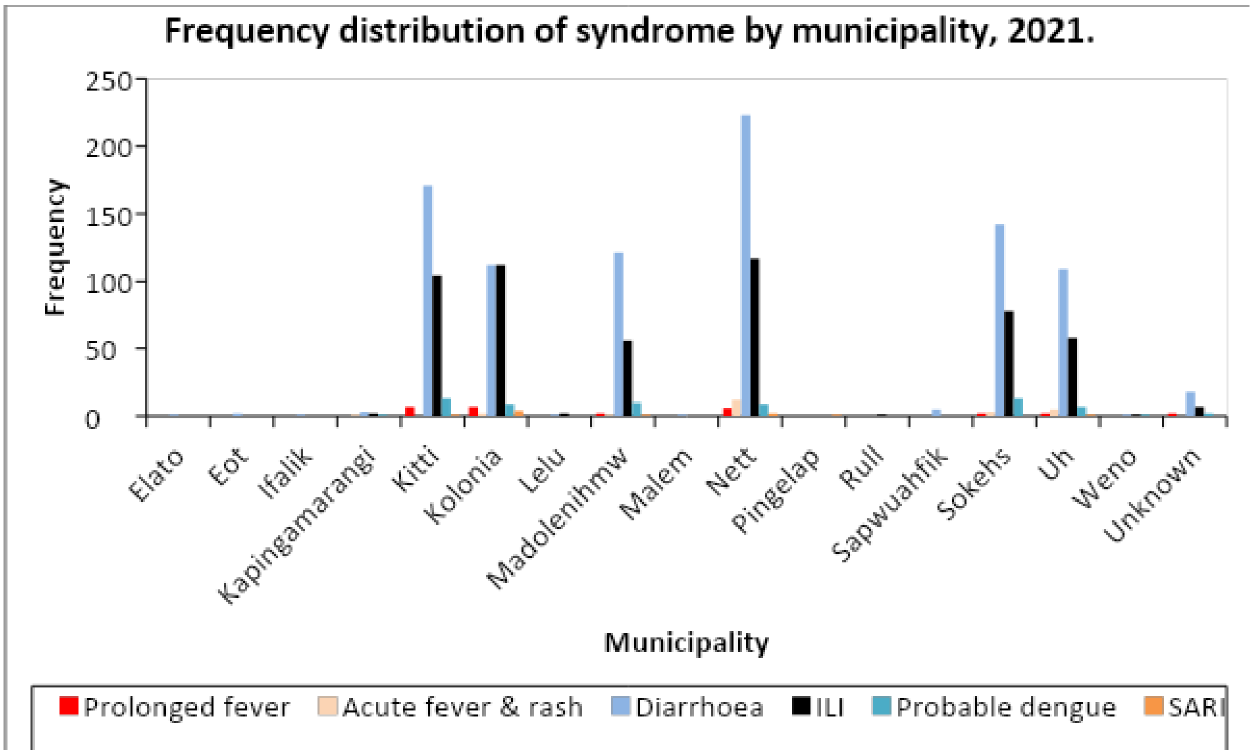


Figure 8. Frequency distribution of syndrome by municipality, 2021.



4.6 Weekly syndrome trend

The weekly trend of the syndromes in 2020 (Figure 9) was not the same in 2021 (Figure 10).

The number of ILI cases at the beginning of 2020 was very high (week 1-15), peaked at 120 cases per week by week 11, and steeply declined by week 15. There were five more spikes (weeks 20, 24, 29, 33 and 47) in the number of ILI cases per week for the rest of 2020, but these did not rise above 30 cases per week. There were two periods during which there were zero ILI cases. The first period was weeks 15 to19, lasting five weeks, and the second was weeks 35 to 46, which lasted 12 weeks.

There was a steady rise in diarrhoea cases per week in 2020, which started in week one and peaked at week 11, reaching 60 cases per week. After week 11, a steady decline in diarrhoea cases can be observed that plateaus around week 15. The diarrhoea trend was stable at around

20 cases per week, even though a small spike reached 30 cases per week at week 17. The other syndromes' trends remained under five weekly cases throughout 2020.

Six peaks in the ILI trend for 2021 can be observed. The first three peaks at the beginning of 2021 were close together (weeks 20, 8-9 and 12-15). After that, the successive three peaks (weeks 24, 35 and 50) were separated by eight to 10 weeks with very few ILI cases. The highest number of ILI cases reported per week was in week 51 (90 cases per week).

The diarrhoea trend in 2021 was steady throughout the year (10-30 cases per week), apart from a spike in weeks 37 and 38, where 56 cases were reported.

Although there was an increase in the total number of probable dengue cases in 2021 (65 cases) compared to 2020 (24 cases), the weekly trend remained under 10 cases per week throughout both years. A similar phenomenon was observed in the SARI trend, where 10 cases were reported in 2021 compared to only two instances in 2020, and the weekly trend remained below five cases per week.

Figure 9. Weekly syndrome trend, 2020.

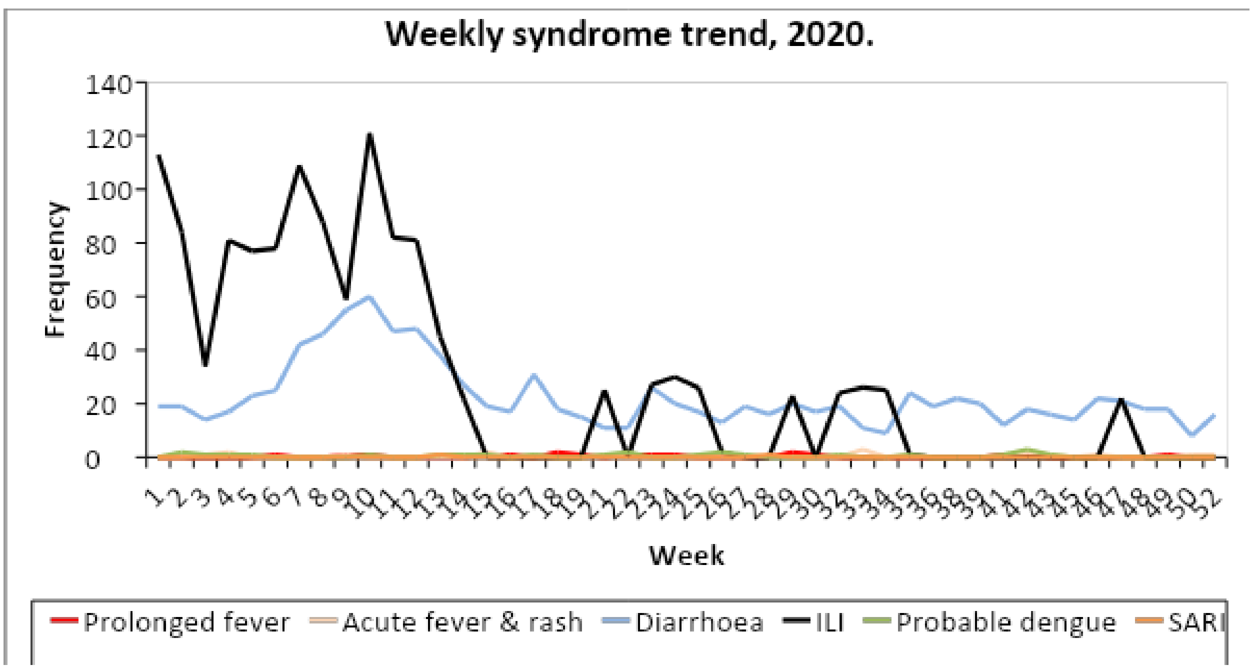
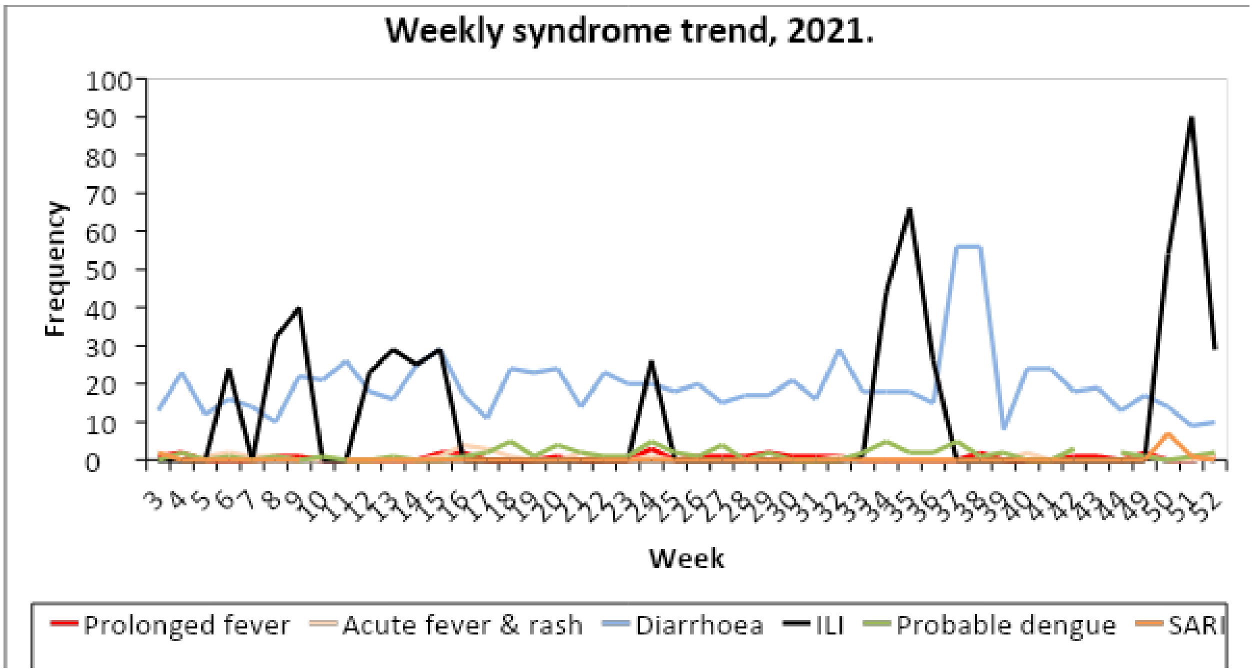


Figure 10. Weekly syndrome trend, 2021.



4.7 Monthly syndrome trend

The monthly syndrome trends for 2020 (Figure 11) and 2021 (Figure 12) represent the cumulative weekly data for each month.

The monthly ILI trend for 2020 shows a significant spike at the beginning of the year, then a steep decline to less than 50 cases per month by April. There are three smaller spikes observed in June, August and November. These increases in ILI cases were less than 50 cases a month. There were two periods where few ILI cases were reported in 2020. The two periods were April and May and September and October 2020.

The 2020 diarrhoea trend shows a steady rise from January to March, reaching a peak of about 200 cases a month. This observed trend plateaued in May and remained the same until year's end. The diarrhoea trend shows a steady decline in the latter part of the year.

Evaluation of the 2021 monthly trends showed a steep increase in ILI cases during January and February. After February, there was a slowly declining trend to May. From June to December, three more peaks (June, August and December) in ILI cases were noted, each spike higher than the preceding one. The peak in June reached a maximum of 20 cases per month, and the August spike reached 100 cases per month. A sudden increase in ILI cases was observed from October to December 2021. This last peak was higher than the other increases in ILI cases throughout 2021.

A steady rise in diarrhoea syndromes from January to August 2021 can be seen, followed by a low spike in May, reaching 108 cases. Between June and August, diarrhoea cases are stable. In September, there was a second spike in diarrhoea cases, peaking at 135 cases, then a steady decline to 50 cases by December.

Between April and October of 2021, there was a slight increase in the number of probable dengue cases. This trend was not observed in 2020. A small peak in acute fever and rash syndromes was reported in April. This trend showed a gradual decline over May and June. This trend was not observed in 2020. An increase in SARI syndromes was reported between October and December of 2021, a phenomenon not observed in 2020.

Figure 11. Monthly syndrome trend, 2020.

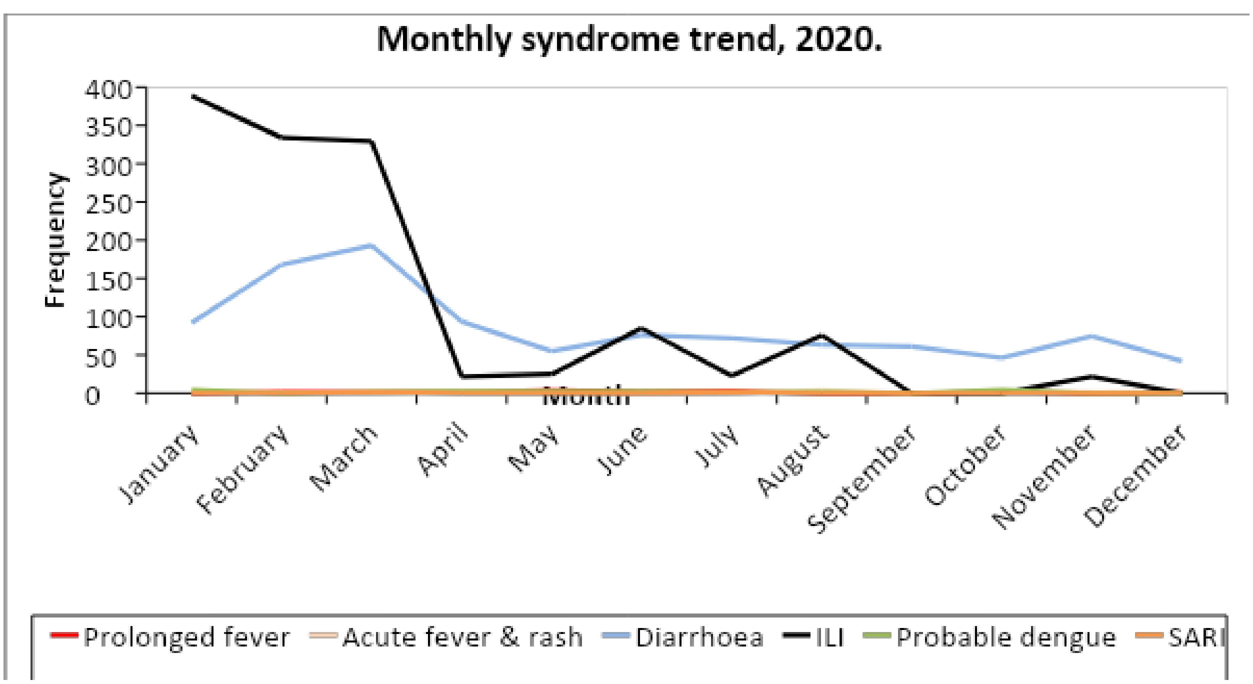
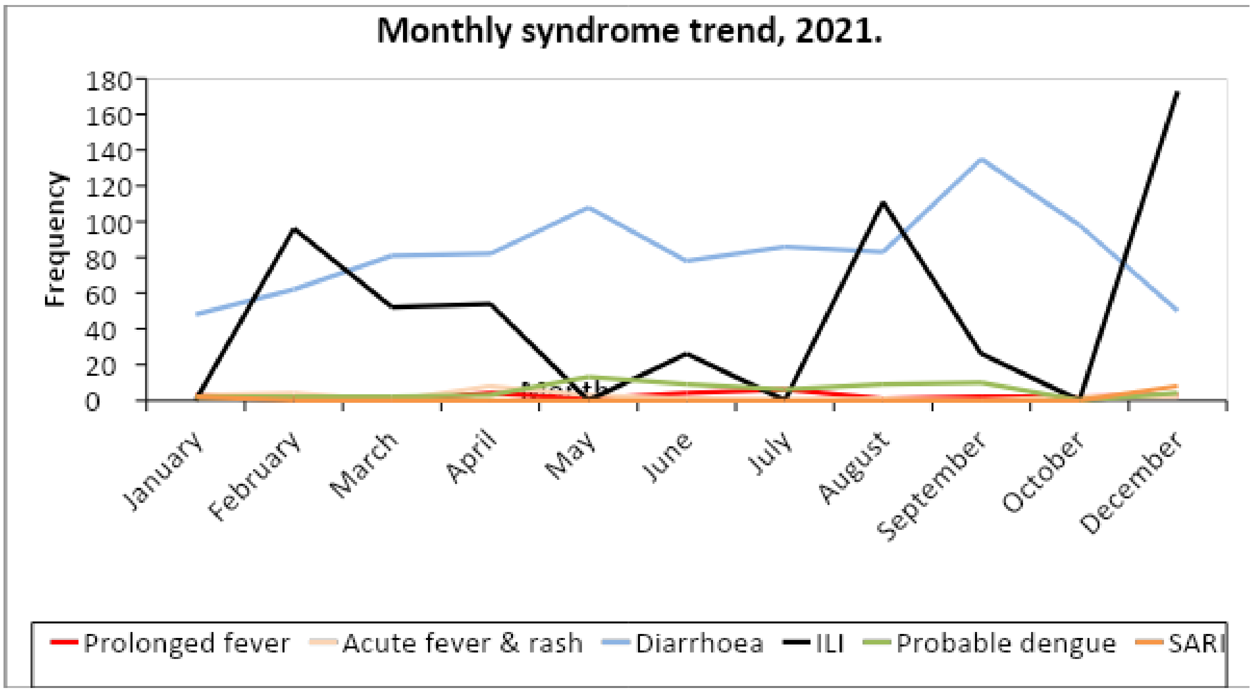


Figure 12. Monthly syndrome trend, 2021.



4.8 Association between rainfall and syndrome

The total rainfall for Pohnpei in 2020 was 4915.7 mm, with a weekly mean of 91.2±70.3 mm and a monthly mean of 349.5±168.9 mm. The total rain in 2021 was 5103.8 mm, with a weekly mean of 110.9±76.3 mm and a monthly mean of 463.9±210.5 mm.

The connection between rainfall and syndromes was investigated using simple linear regression analysis (Table 1, Table 2, Table 3 and Table 4). Statistical significance was set at $p<0.05$. Graphs showing trends (Figure 13, Figure 14, Figure 15 and Figure 16) were also visually assessed for general correlation between syndromes and rainfall.

Linear regression analysis showed ILI was negatively associated with ILIs in 2020. However, the correlation coefficient was only 0.19. Interestingly, the negative relationship was obtained with regression analysis of the weekly data but not when the analysis was repeated with the aggregated monthly data. The other syndromes had no significant association with rainfall.

Rainfall had a statistically significant association with prolonged fever in 2021. However, the correlation coefficient was only 0.1. The association was noted when regression analysis was applied to the weekly data but not when the analysis was repeated with the aggregated monthly data. The other syndromes had no significant association with rainfall.

Visual assessment of syndrome frequency with rainfall volume suggests ILI may be negatively associated with rainfall in 2020 (Figure 13 and Figure 14) but not in 2021 (Figure 15 and Figure 16).

Figure 13. Weekly trend of syndrome and rainfall, 2020.

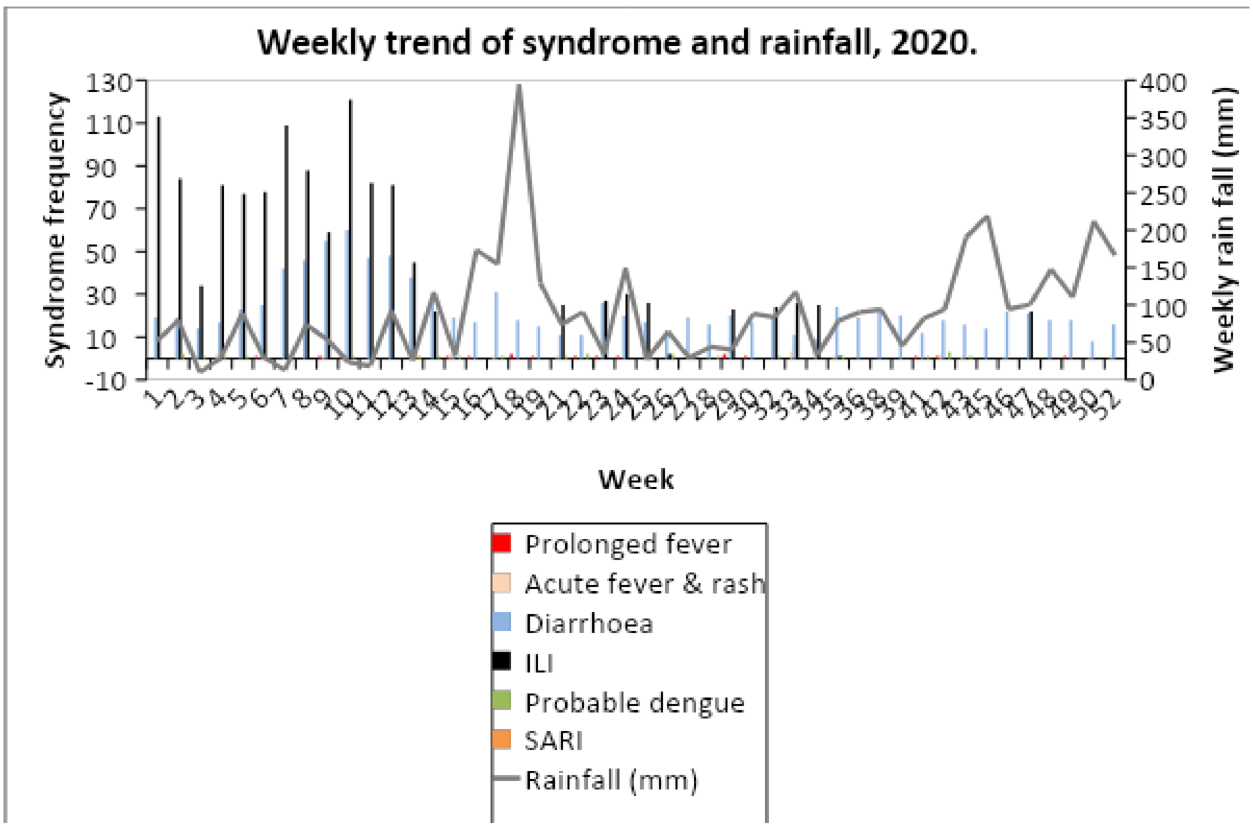


Figure 14. Monthly trend of syndrome and rainfall, 2020.

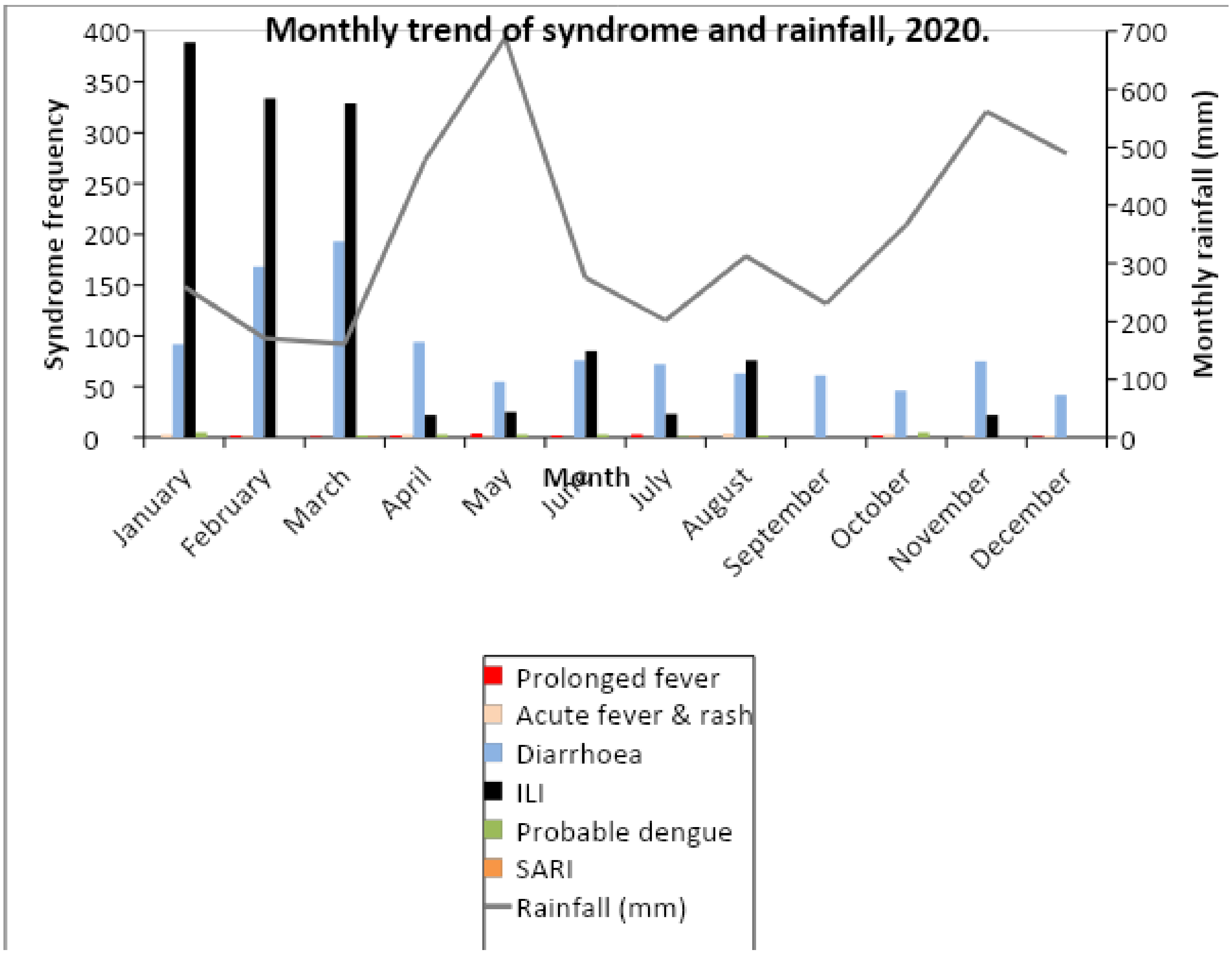


Figure 15. Weekly trend of syndrome and rainfall, 2021.

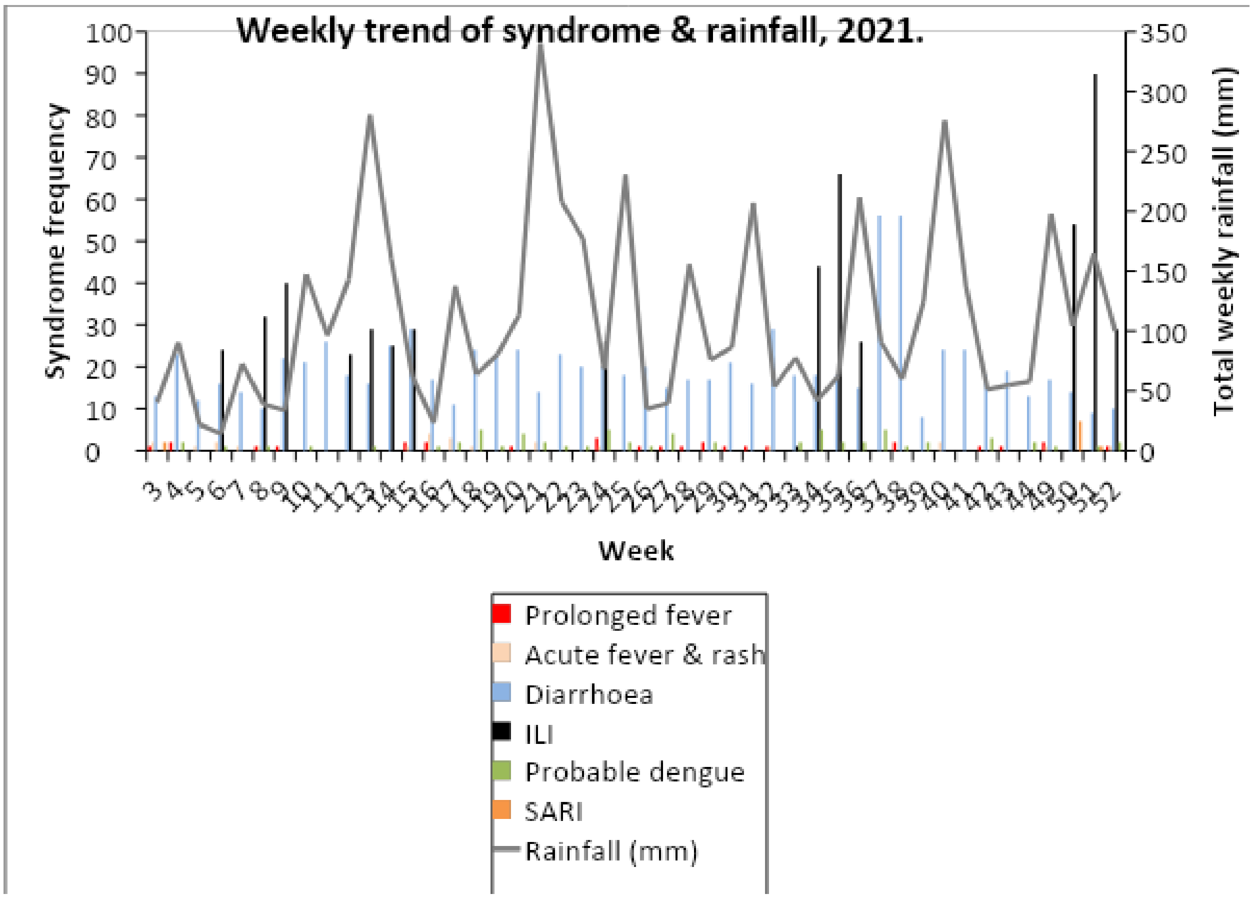


Figure 16. Monthly trend of syndrome and rainfall, 2021.

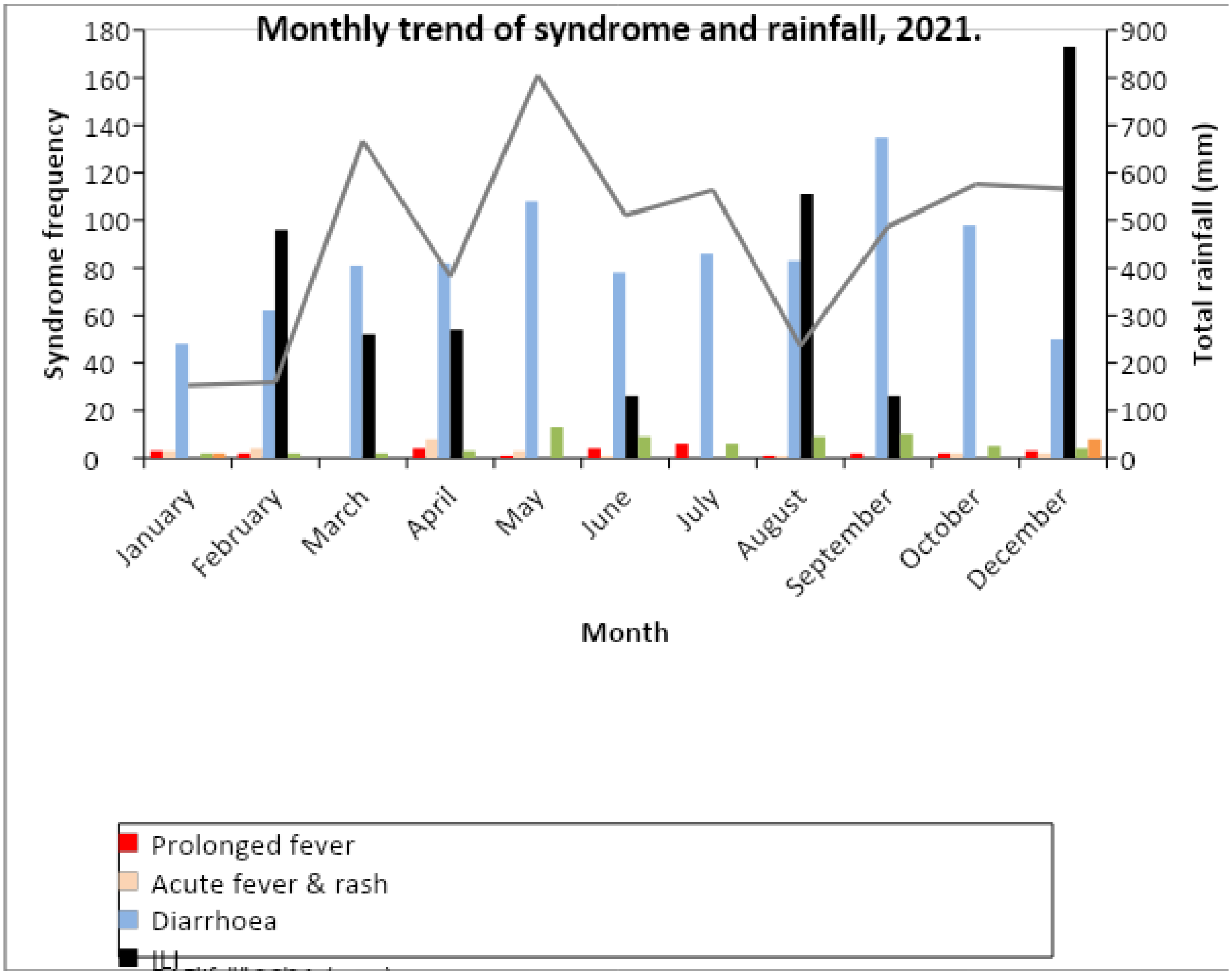


Table 1. Summary of linear regression analysis for weekly syndrome frequency and rainfall, 2020. (* = statistically significant, p<0.05).

	Prolonged fever	Acute fever & rash	Diarrhoea	ILI	Probable dengue	SARI
Correlation coefficient (r^2)	0.05	0.0	0.08	0.19	0.03	0.03
p value	0.1291	0.8666	0.0513	0.0028*	0.2567	0.2552

Table 2. Summary of linear regression analysis for monthly syndrome frequency and rainfall, 2020. (* = statistically significant, p<0.05).

	Prolonged fever	Acute fever & rash	Diarrhoea	ILI	Probable dengue	SARI
Correlation coefficient (r^2)	0.07	0.06	0.29	0.31	0.0	0.22
p value	0.4052	0.437	0.0693	0.0624	0.8494	0.128

Table 3. Summary of linear regression analysis for weekly syndrome frequency and rainfall, 2021. (* = statistically significant, p<0.05).

	Prolonged fever	Acute fever & rash	Diarrhoea	ILI	Probable dengue	SARI
Correlation coefficient (r^2)	0.1	0.0	0.01	0.0	0.02	0.0
p value	0.031*	0.7652	0.5147	0.7885	0.3892	0.8085

Table 4. Summary of linear regression analysis for monthly syndrome frequency and rainfall, 2021.

(* = statistically significant, p<0.05).

	Prolonged fever	Acute fever & rash	Diarrhoea	ILI	Probable dengue	SARI
Correlation coefficient (r^2)	0.01	0.1	0.22	0.06	0.19	0.0
p value	0.7432	0.3527	0.1416	0.4706	0.1766	0.9101

4.9 Summary of the chapter

Diarrhoea and ILI were the most frequent syndromes reported in all age groups. The highest frequency was reported in the age group 0 to 10 years. More than 90% of the syndromes were from the four large municipalities on the main island of Pohnpei.

There were more diarrhoea cases compared to ILI in 2020, whereas in 2021, it was the opposite. However, the proportion of male and female patients was almost equal in both years.

More than 90% of the syndromes came from the four large municipalities of Pohnpei.

The frequency of diarrhoea appears to be constant throughout the year, whereas ILI seems to be seasonal. However, there appears to be no predictable pattern when examining the ILI trends for 2020 and 2021.

Linear regression analysis suggests a negative relationship between ILI and rainfall. This phenomenon was observed when the 2020 data were analysed as a weekly summary but not when the regression analysis was repeated using the monthly summary. In addition, the correlation coefficient was about 0.2.

Prolonged fever was significantly associated with rainfall but with a correlation coefficient of only 0.1. The relationship was observed when the 2021 dataset was analysed as a weekly summary. The monthly summary data analysis showed no significant association with rainfall. The other syndromes had no relationship with rainfall.

SARI cases increased from two in 2020 to 10 cases in 2021, reflecting a frequency increase of 500%.

Chapter 5 Discussion of research findings

5.1 Introduction to the chapter

The literature on the effects of climate change on infectious disease trends is increasing (Rao & Nagendra, 2020; Semenza et al., 2012). Syndromic surveillance systems can use climate-sensitive infectious disease syndromes as early indicators of changes in infection trends due to climate change. Unfortunately, little research exists into this phenomenon in Pacific Island countries and territories (PICTs), including Papua New Guinea (PNG). McIver et al. (2015) proposed in their review of infectious disease syndromes in the FSM that febrile illness, ILIs and diarrhoea were potential climate-sensitive infections. However, the authors highlighted the need for accurate data because the data used in their analysis were incomplete, and some data were missing. The digitisation of the syndromic surveillance system in Pohnpei in 2019 presented an excellent opportunity to assess infectious disease trends in Pohnpei using the syndromic surveillance datasets for 2020 and 2021.

This study assessed the trends of six infectious disease syndromes using electronic syndromic surveillance at the Pohnpei State Hospital. In addition, this study also evaluated the relation between the six syndromes and rainfall. The remainder of this chapter will discuss the results and highlight some limitations of this research. It is hoped that the results of this study will provide accurate data on the trends of potential climate-sensitive infectious disease syndromes in Pohnpei and contribute to the development of evidence-based public health policies.

5.2 Discussion

Evaluation of the 2020 and 2021 syndromic surveillance datasets revealed diarrhoea and ILI as Pohnpei's most frequent infectious disease syndromes. All syndromes were equally distributed among males and females. The syndrome distribution by municipality reflected the population distribution of the main island of Pohnpei, where more than 90% of the population is constituted from the four municipalities of Pohnpei Island. Diarrhoea and ILI accounted for more than 90% of the occurrences in children under 10 years of age. Assessment of the syndrome trends showed that the frequency of diarrhoea was steady, with a frequency of 10 to

20 cases a week and 40 to 100 cases a month. On the other hand, the frequency of ILI appears to be seasonal, with regular spikes in 2020 and 2021. Although linear regression suggests the frequency of ILI may be negatively associated with rainfall, there was no significant association between the other five infectious disease syndromes and rainfall.

Diarrhoea and ILI accounted for over 90% of all syndromes in 2020 and 2021. Furthermore, these two syndromes were most frequently reported in the 0 to 10 years age group. The proportion of ILI cases in 2020 was twice that of diarrhoea cases, whereas, in 2021, the proportion was almost equal. Rotavirus is a common cause of seasonal diarrhoea in children under five (Nath et al., 1992)**.** Similar factors may explain the high frequency of diarrhoea in children observed in this study. Respiratory viruses such as respiratory syncytial virus, adenovirus and influenza virus have been reported in up to 42% of children under 10 years in one study (Saadi et al., 2021). The current study's design did not allow a review of laboratory test results in children with ILI symptoms. Therefore, respiratory viruses possibly circulate among children in Pohnpei and may account for the seasonal spikes in ILI syndromes. Follow-up studies backed by laboratory investigation would need to be done to examine this hypothesis.

The annual diarrhoea trend was stable between 10 to 30 cases a week in 2020 and 2021. However, one surge of diarrhoea occurred in week 10 of 2020 and another in weeks 37 and 38 of 2021. Although the highest frequency of diarrhoea was in children under 10 years, it was also relatively common in all the other age groups. No stool samples were obtained from patients during the spike in 2020, but in 2021 laboratory tests done on stool samples from paediatric patients returned positive for Escherichia coli (E. coli) and norovirus (personal communication, paediatrician). Norovirus and E.coli are common causes of a seasonal or sporadic increase in diarrhoeal illnesses (Gong et al., 2018). Another common cause of seasonal outbreaks of diarrhoea in children is rotavirus (Levy et al., 2008). These pathogens may have contributed to the increased frequency of diarrhoea, but other factors, such as poor water and sanitation practices, may also explain the steady cases of diarrhoea throughout the year (Andrade et al., 2009; Prasetyo et al., 2015)**.** Many of Pohnpei's population do not have access to clean water (personal communication, UNICEF). Most households use pit latrines or rivers to discharge human waste and tailings from piggeries (personal communication, UNICEF). These unsanitary practices most likely contribute to the steady trend of diarrhoea observed throughout this study. The regular cases of diarrhoeal illness, interspersed with sporadic increases that may be caused by E. coli, norovirus or other pathogens, pose a significant public health risk for Pohnpei. Pohnpei experienced a cholera outbreak in 2000 (Kirk et al., 2005) and the potential for another outbreak presently exists.

The ILI trend for 2020 and 2021 appear to be seasonal. The results showed five to six spikes in ILI cases throughout the years of study. The data trend showed one big spike followed by four to five smaller spikes. The influenza virus is seasonal, and analysis of the trend allows vaccination planning (Likitkererat, 2013). A similar seasonal ILI phenomenon could be happening in Pohnpei. Furthermore, epidemiological studies backed by laboratory studies to correlate with the trend could provide accurate data. Although studies in countries with clear definable wet and dry seasons indicate a positive relationship between ILI and rainfall (Soebiyanto et al., 2014; Watson et al., 2006), results from this study showed no significant relationship between ILI syndrome and rainfall. Pohnpei has steady rain with minimal annual variation in rainfall since 1953 (Pohnpei State Government, 2015) and therefore does not have a clearly defined wet and dry season. The regular ILI spikes observed in the results could be due to seasonal circulation of respiratory viruses, inadequate influenza vaccination coverage or shifts in viral serotypes in the population. Detailed follow-up research will need to identify possible factors contributing to the annual spikes in ILI in Pohnpei.

Evaluation of 2019 data from the Pacific Syndromic Surveillance System showed that influenza B/Victoria caused unseasonal ILI outbreaks in four US-affiliated Pacific Island countries: Commonwealth of Northern Marianas, the FSM, Guam and the Republic of the Marshall Islands (O'Connor et al., 2021). In that study, 83% of cases that had laboratory testing were positive for influenza B/Victoria and included two positive specimens from the FSM (O'Connor et al., 2021). Pohnpei experienced the ILI spike in weeks 1 to 20 of 2019 and contributed to 67% of all ILI cases reported from the FSM (O'Connor et al., 2021). The present study showed one big ILI spike in weeks 1 to 15 of 2020, whereas, in 2021, there were two ILI spikes, the first spike in weeks 33 to 37 and the second spike in weeks 49 to 51. A review of 2020 weekly syndromic reports produced by the Pohnpei EpiNet team did not indicate whether samples were tested for respiratory viruses, so the possible causes of the ILI surges in 2020 could not be determined. However, in 2021, laboratory testing of 21 nasopharyngeal swab specimens in week 36 tested positive for rhinovirus/enterovirus (Pohnpei EpiNet Team, 2021a). In week 51, 14 nasopharyngeal specimens tested positive for Coronavirus NL63 (Pohnpei EpiNet Team, 2021b). All samples tested negative for influenza B and COVID-19. The positive results during the period of high ILI cases in 2021 indicate rhinovirus/enterovirus and Coronavirus NL63 were circulating in Pohnpei. These viruses could have been the possible causes of the increase in ILI cases in 2021.

Rhinovirus/enterovirus and Coronavirus NL63 occur predominantly in infants and children under ten years (Asner et al., 2014; Killerby et al., 2018; van der Hoek et al., 2005). In the current study, the frequency of ILI cases was highest in the age group 0 to 10 years, which fit the profile of the viruses detected. All specimens tested in 2021 were negative for influenza B/Victoria. One possible reason is that influenza B/Victoria was thought to enter the Micronesian region in 2019 via passengers entering Guam or Northern Marianas from East Asia, where this virus is predominant (O'Connor et al., 2021). The FSM was in complete lockdown in 2020 and 2021 due to the COVID-19 pandemic (Itaki et al., 2020) and may have prevented the Influenza B/Victoria virus from entering the FSM. It is possible that many respiratory viruses that cause ILI symptoms are circulating in the FSM, and cause a periodic increase in ILI cases, perhaps facilitated by low influenza vaccination among the vulnerable segments of the population. Further research backed by laboratory testing will need to be done to provide additional information about respiratory viruses circulating within the Micronesian region.

Many infections can cause prolonged fever. Prolonged fever, as used in the syndromic surveillance system in the FSM, is defined as a fever lasting more than three days. In this study, prolonged fever was associated with rainfall. But the phenomenon was observed with the analysis of the weekly summary data but not with the monthly summary data. A similar result was obtained with regression analysis exploring the association between ILI and rainfall. In this instance, the 2020 weekly summary data analysis showed a statistically significant association between ILI and rain but no relationship with repeat analysis of the same dataset summarised as monthly data. The difference could be most likely due to the effect of sample size on statistical testing. To increase the sample numbers, regression analysis of the monthly data (constituted by pooling weekly cases) did not confirm the results obtained with the weekly data analysis, which had smaller sample numbers. The sample size is one of the factors that can affect statistical significance testing (Norton & Strube, 2001). However, it could be a genuine relationship. Dengue, leptospirosis and lymphatic filariasis are endemic in the FSM (McIver et al., 2015), and these infections commonly cause fever that can last more than three days. A follow-up study that investigates the causes of prolonged fever in the FSM using laboratory testing will confirm the exact etiologies.

The WHO recommended using SARI to observe influenza outbreaks in 2015 (Buda et al., 2017)**.** Following the COVID-19 pandemic, some European countries adapted SARI for COVID-19 surveillance and found that SARI syndrome reports from hospital emergency departments correlated well with population data (Klavs et al., 2021; Tolksdorf et al., 2022)**.** Severe acute respiratory illness encompasses serious cases of respiratory diseases that require hospitalisation and is a sensitive indicator for COVID-19. However, SARI may capture only severe COVID-19 patients presenting at the hospital and excludes mild to moderate cases that do not present at hospitals. The FSM government added SARI syndrome to the syndromic surveillance system in Pohnpei in 2019. In 2020 there were two SARI reports in Pohnpei compared to 10 in 2021, reflecting a reporting increase of 500%. All cases in 2020 and 2021 tested negative for COVID-19. A review of the clinical encounter of the SARI cases showed these patients were admitted to the hospital due to exacerbation of pre-existing chronic lung diseases. This increase most likely represents greater awareness of SARI syndromic reporting among doctors leading to improved reporting. The FSM is one of few countries that remain COVID-19 free. As the country prepares to open its borders in August 2022, it can be stated that the electronic syndromic surveillance system in Pohnpei will be vital for ongoing surveillance, response and control of COVID-19 in Pohnpei.

Many infectious diseases tend to be seasonal, coinciding with the rainy season. In areas where toilet practices are poor, rain can lead to flooding with surface runoff containing faecal matter that contaminates drinking water sources and causes diarrhoea outbreaks. Conversely, extreme drought can also lead to diarrhoea when people consume contaminated water because their usual water sources dry up. Mosquitoes transmit many viral and parasitic infections, which can cause outbreaks of febrile illnesses two to three weeks after a rainy season when mosquito populations are high in number. Respiratory diseases, including the common cold and other influenza-like infections, tend to be more common in the colder parts of the year because the common respiratory viruses like RSV and adenoviruses favour colder temperatures. Analysing trends of surveillance data in association with rainfall can indicate the periods of the year when these infections associated with rain are expected so that resources can be allocated to accommodate the increases. Such data can also inform public awareness and be used in preventive messages. Surveillance data can also help construct statistical models to predict changes in trends so that resources can be allocated to manage a surge in hospital encounters.

5.2 Study limitations

This study has several limitations. Firstly, researchers encounter missing data when studies use secondary data. The 2020 and 2021 datasets had missing data. The number of encounters excluded due to missing data was about equal in both datasets. Although missing data may have affected the regression analysis findings, it can be stated that the quantity of missing data would not have significantly influenced the overall trends observed in the results.

Secondly, the electronic syndromic surveillance system does not give a unique identification number for each consultation visit or syndrome recorded. Every patient presenting at the Pohnpei State Hospital has a unique hospital registration number used every time a person visits the hospital for a test or consultation. Consequently, the system cannot differentiate whether a syndrome is an initial consultation or a revisit for the same clinical complaint, resulting in possible duplication of syndromic records. Such duplicates may have resulted in an increased number of cases and may have contributed to false elevation in syndrome thresholds.

Thirdly, this study used syndromic surveillance data from the state hospital only. Data captured by private health facilities, CHCs and dispensaries were excluded from the syndromic surveillance data. Therefore, the results in the present study represent syndrome reports from the hospital only. However, because patients with severe illnesses tend to come to the main hospital, it is assumed that the results are a good representation of the general infectious disease trends in Pohnpei.

Finally, the potential for misdiagnosis and misclassification of syndromes exists despite physicians receiving syndromic surveillance data entry training. Syndrome misclassification by physicians is also a potential source of error. These errors are usually picked up by the public health data analyst, who is required to contact the physician via phone and verify the classification or correct the mistake.

5.3 Summary of the chapter

This research showed that diarrhoea and ILI are common syndromes in Pohnpei. These two syndromes account for 90% of all infectious disease syndromes reported using the syndromic surveillance system in Pohnpei in 2020 and 2021. Diarrhoea and ILI are the most common syndromes in all age groups, but the highest frequency is observed in the age group 0 to 10 years. Whereas the diarrhoea trend was steady throughout the years of the study, ILI had five to six spikes in 2020 and 2021. Linear regression analyses suggest a weak negative relationship between ILI and rainfall. The regression analysis also suggests prolonged fever to be weakly associated with rainfall. The results of this study can be used as the foundation for further epidemiological studies supported by laboratory investigation to identify factors contributing to the trends observed in this study.

Chapter 6 Conclusions and Recommendations

6.1 Conclusions

An analysis of the 2020 and 2021 syndromic surveillance datasets shows that diarrhoea and ILI were the most frequent syndromes in all age groups and accounted for more than 90% of the infectious disease syndromes reported. However, the highest frequency of the syndromes in 2020 and 2021 was reported in children aged 0 to 10 years.

The diarrhoea trend throughout the years of the study showed a steady and stable frequency of cases. However, the ILI trend showed a seasonal pattern with five to six spikes in 2020 and 2021.

Although the results suggest a negative relationship between ILI and rain, this phenomenon was only observed with the 2020 dataset.

Regression analysis suggests prolonged fever may be associated with rainfall. This relationship was only observed with the 2021 dataset.

The other syndromes do not show any association with the volume of rainfall in Pohnpei.

6.2 Recommendations

Several recommendations can be made following this study. Firstly, health promotional programmes must include awareness and education messages to reduce the frequency of diarrhoea and ILI syndromes in the hospital. Secondly, a more detailed study of the syndromes supported by laboratory testing will provide more detailed information to confirm the results of this study. Thirdly, the electronic syndromic surveillance system used at the Pohnpei State Hospital needs to be improved to ensure the system detects duplicate syndrome records if a patient presents more than once for the same clinical complaint. This will prevent a false increase in syndromes. Fourthly, additional weather indices such as temperature and humidity may be incorporated into the regression analysis to assess the relationship between infectious disease syndromes and weather variables. And lastly, the relationship between syndromes and rainfall in Pohnpei may not be linear. Therefore, additional possible contributing variables will need to be considered to enable multiple variable analyses to elicit the nature of the relationship between syndromes and weather indices, if there are any.

The significance of the association between ILI and rainfall, and prolonged fever and rainfall, is unknown. A follow-up study using a five-year dataset could be more accurate and confirm the observed relationship between the syndromes and rainfall.

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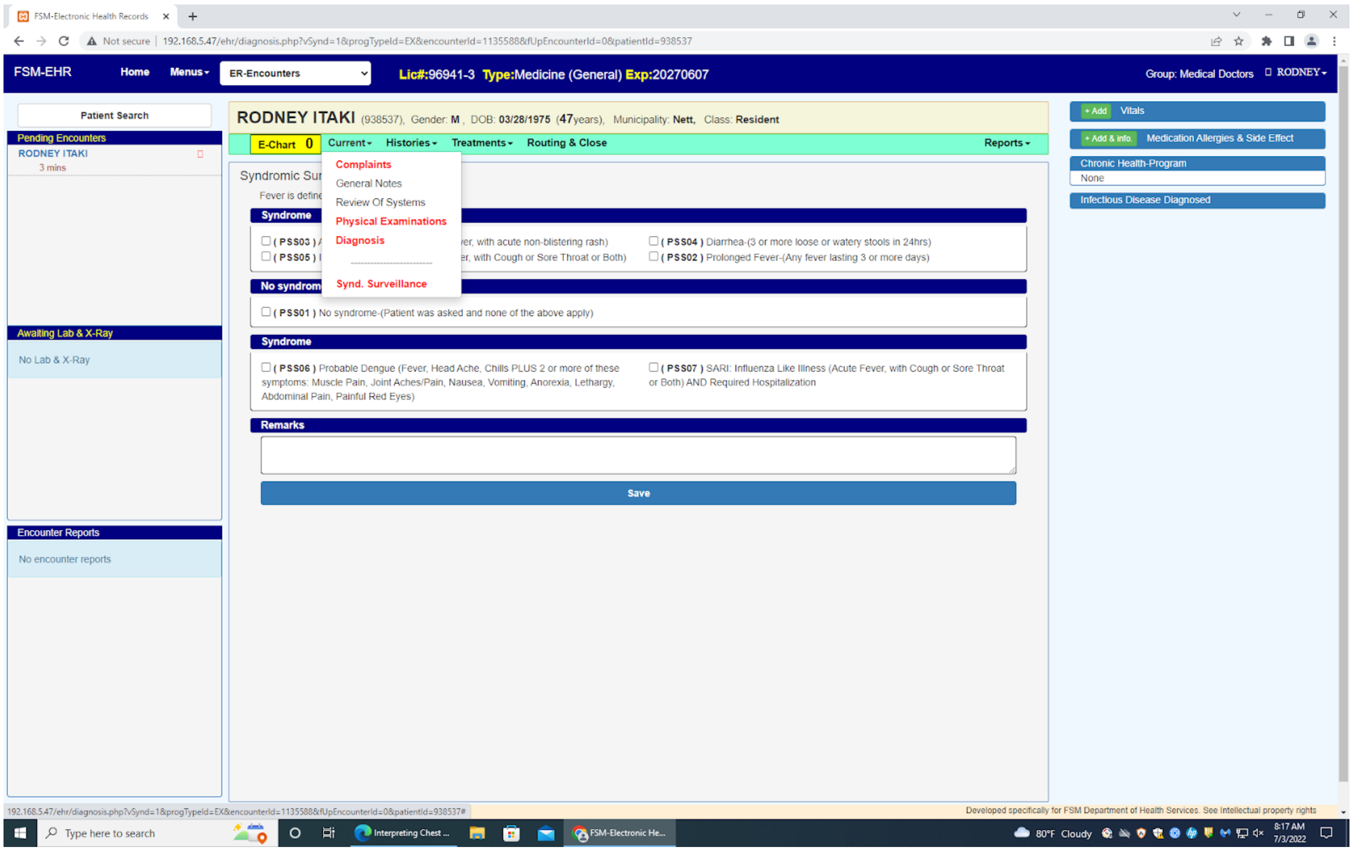
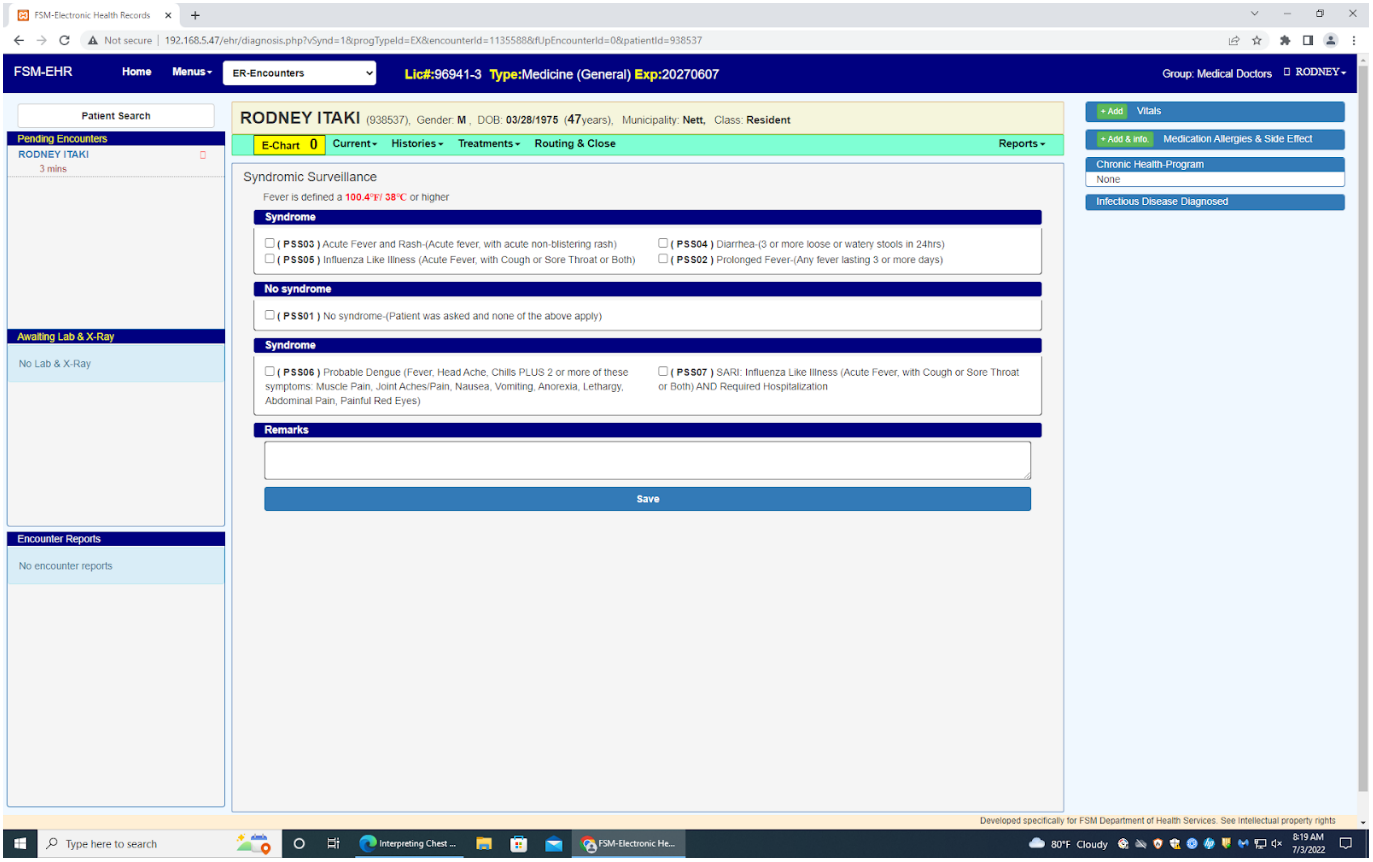
APPENDIXES

Screenshot of clinical encounter data entry page on EHR.



Screenshot of syndromic classification page on EHR.



Sample of automatically generated syndromic surveillance report by the electronic syndromic surveillance system.

Syndromic Surveillance Report

(Pohnpei State Hospital)

Reported at 04/18/2022 04:14 by ritaki from **Pohnpei State Hospital** EHR-server

PSS01 No syndrome-(Patient was asked and none of the above apply)
PSS02 Prolonged Fever-(Any fever lasting 3 or more days)
PSS03 Acute Fever and Rash-(Acute fever, with acute non-blistering rash)
PSS04 Diarrhea-(3 or more loose or watery stools in 24hrs)
PSS05 Influenza Like Illness (Acute Fever, with Cough or Sore Throat or Both)
PSS06 Probable Dengue (Fever, Head Ache, Chills PLUS 2 or more of these symptoms: Muscle Pain, Joint Aches/Pain, Nausea, Vomiting, Anorexia, Lethargy, Abdominal Pain, Painful Red Eyes)
PSS07 SARI: Influenza Like Illness (Acute Fever, with Cough or Sore Throat or Both) AND Required Hospitalization

Syndromic Surveilance Encounter Counts

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	
syndrome	2020/10/26	2020/10/27	2020/10/28	2020/10/29	2020/10/30	2020/10/31	2020/11/01	Total
PSS01	90	61	109	85	65	36	50	496
PSS02	0	0	0	0	0	0	0	0
PSS03	0	0	0	0	0	0	0	0
PSS04	2	4	3	1	5	1	1	17
PSS05	1	0	1	0	2	1	0	5
PSS06	0	0	0	0	0	0	0	0
PSS07	0	0	0	0	0	0	0	0
Total	93	65	113	86	72	38	51	518

Codebook

Variable name	Description/Meaning of variable	Data type/Format	Value
Patient hospital number	Unique patient hospital registration number. Automatically generated by electronic health record system when registering for the first time.	Integer	Six digit numerical description using 0 and positive numbers
Encounter date	Date patient consulted doctor	Integer	Digital description written in the dd/mm/yyyy format

Name	Name of patient consisting of first and last name	Text	Textual description
DOB	Date of birth of patient	Integer	Digital description written in the dd/mm/yyyy format
Age	Approximate age of patient in years	Numerical	Digital description
Gender	Biological sex of patient	Text	Male, Female
Municipalit y	Patient's place of residence as registered in the hospital records	Text	Textual description
Week	Calendar week	Text with integer	Textual description, numbers 1 to 52
Month	Calendar month	Text with integer	Textual description, numbers 1 to 12
Syndrome	Infectious disease classification well defined with a cluster of signs and symptoms that are monitored using the electronic syndromic surveillance	Text	Textual description
PSS01	Patient signs and symptoms do not fit infectious syndrome definition	Integer	Digital description
PSS02	Infectious disease syndrome defined as Prolonged Fever (Any fever lasting 3 or more days)	Integer	Digital description
PSS03	Infectious disease syndrome defined as Acute Fever and Rash (Acute fever, with acute non-blistering rash)	Integer	Digital description
PSS04	Infectious disease syndrome defined as Diarrhoea (3 or more loose or watery stools in 24hrs)	Integer	Digital description

PSS05	Infectious disease syndrome defined as Influenza-like Illness (Acute Fever, with Cough or Sore Throat or Both)	Integer	Digital description
PSS06	Infectious disease syndrome defined as Probable dengue (Fever, Head Ache, Chills PLUS 2 or more of these symptoms: Muscle Pain, Joint Aches/Pain, Nausea, Vomiting, Anorexia, Lethargy, Abdominal Pain, Painful Red Eyes)	Integer	Digital description
PSS07	Severe acute respiratory illness (SARI) defined as Influenza Like Illness (Acute Fever, with Cough or Sore Throat or Both) AND Required Hospitalization	Integer	Digital description
Rainfall	Volume of rainfall recorded by weather station	Numerical, decimal	Digital description