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ASSESSMENT OF THE ASSOCIATION BETWEEN RAINFALL AND CLIMATE-SENSITIVE INFECTIONS USING SYNDROMIC SURVEILLANCE SYSTEMS: A LITERATURE REVIEW WITH IMPLICATIONS FOR SYNDROMIC SURVEILLANCE IN PACIFIC ISLAND COUNTRIES

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ABSTRACT:
Although Pacific Island countries are vulnerable to the effects of climate change, studies evaluating climate change's influence on infectious disease trends within the region are scanty. A rapid literature review was conducted to assess available published information on the association between infectious disease syndromes and rainfall. This paper discusses the review findings that have important implications for syndromic surveillance of climate-sensitive infections in Pacific Island countries. Google Scholar and PubMed were used to find literature assessing the association between infectious disease syndromes and rainfall. The purpose of the rapid review was to provide background information for a study aimed at determining whether the trends of infections are associated with rainfall in Pohnpei. The results showed influenza-like illnesses may be positively correlated with rainfall, but the trends are also determined by seasonal presence of respiratory viruses. Diarrhoeal diseases are influenced by both heavy rainfall and drought. Febrile illnesses are associated with rainfall through the effect of rainfall on disease vectors. Weather factors may influence COVID-19 transmission, but current literature is inconclusive. Association between infectious disease trends and rainfall is multifactorial and geography-specific. Conclusions from studies in one geographical region cannot be applied globally, and further research is needed in the Pacific to examine this phenomenon locally.

Keywords: climate change, climate-sensitive infections, syndromic surveillance, mosquito-borne infections, Pacific island countries.

INTRODUCTION:

Recently, considerable literature has grown around climate-sensitive infections, specifically the association with weather variables. For example, diarrhoea and febrile illnesses are linked to heavy rain or drought [1]. At the same time, influenza-like illnesses (ILI) are associated with cold temperatures [2,3]. Surprisingly, similar studies evaluating the association between infectious disease syndromes and weather within the Pacific region are scanty, even though this region is vulnerable to the effects of climate change.

Leptospirosis, diarrhoea, and respiratory illnesses are potential climate-sensitive infections in the Federated States of Micronesia (FSM) [4]. McIver et al. [4] suggested that these infections may be linked to the rainfall pattern, similar to studies elsewhere [5-7]. Furthermore, McIver et al. [4] identified knowledge gaps in the data for these climate-sensitive infections across the four states of FSM. The authors suggested that gaps in their data could be due to unreliable health information systems or human skills capacity constraints. Hence, the authors concluded that the amount of data available for their assessment was inadequate, and no further analysis could be done. They recommended increased research on the epidemiology of climate-sensitive infectious diseases in FSM to provide accurate data on the association between climate-sensitive infections and rainfall patterns [4].

The Pohnpei State Hospital implemented an electronic health record (EHR) system in 2019. The improvement in the hospital's health information system was an initiative of the national FSM government. This literature review guided a research project to assess the association between rainfall and infectious disease syndromes using data generated by the electronic health information system at the Pohnpei State Hospital.

The following questions directed this literature review:

(1) What is the association between rainfall and diarrheal illnesses?

(2) What is the association between rainfall and influenza-like illnesses (ILI), including coronavirus disease 2019 (COVID-19)?

(3) What is the association between rainfall and febrile illnesses?

(4) What is the association between rainfall and leptospirosis? This review focused on studies conducted in the Asia Pacific Region, with particular attention to studies done in the FSM and other small Pacific Island countries. Relevant studies done outside the Asia Pacific Region but with direct implications for Pacific Island countries were also included.

METHODOLOGY:

Google Scholar and PubMed were searched for relevant literature. The keywords used were syndromic surveillance, infectious disease outbreak, Pacific, disease surveillance, infectious disease surveillance, climate change and syndromic surveillance trend.

Boolean operators AND, OR were used as conjunctions to combine the keywords in varying combinations and arrangements to maximise search output [8]. This strategy was repeated with all keywords until all valid combinations were exhausted. Exhaustion of keyword combinations and arrangements was reached when Google Scholar or PubMed search results contained the same articles as previous searches.

The abstracts of all papers were screened using pre-defined inclusion and exclusion criteria. All search results from PubMed were included for initial screening, but only the first ten results from Google Scholar were scanned for relevant articles. All literature was managed using Zotero software.

Article inclusion criteria were defined as (1) peer-reviewed open access quantitative and qualitative literature, (2) government or non-government reports, (3) consensus statements, (4) conference proceedings and (5) studies conducted in the Asia-Pacific region.

Exclusion criteria were (1) studies conducted outside the Asia-Pacific region except studies that has direct link to the Pacific region, (2) non-English publications, (3) opinions except editorials and (4) personal web pages. Duplicate articles were deleted.

Data were extracted using the following themes: (1) rain events and ILI, including COVID-19, (2) rain events and febrile illnesses, (3) rain events and diarrhoea and (4) rain events and leptospirosis. A separate theme for rain events and leptospirosis was used for data extraction because it is the most severe vector-borne infection associated with rain in Pohnpei. Other vector-borne febrile illnesses such as malaria, dengue and other viral mosquito-transmitted infections are not endemic in Pohnpei.

RESULTS:

The initial search identified 94 articles. The abstracts were then reviewed using the inclusion and exclusion criteria. Finally, 43 articles were selected for in-depth reading and data extraction.

Extracted data were summarised under the following headings: (1) Definition of syndromic surveillance, (2) Syndromic surveillance in Pacific Island countries, (3) Association between rainfall and diarrhoeal illnesses, (4) Association between rainfall and febrile illnesses, (5) Association between rainfall and influenza-like-illnesses, and (6) Association between weather and COVID-19.

Definition of syndromic surveillance:

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 [9]. 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 [9]. 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 [9].

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 definitions or syndrome definitions. For example, a study by Guasticchi et al. [10] showed 90% sensitivity for coma but only 22% for hemorrhagic diarrhoea. In the same study, the positive predictive value of syndromes ranged between 99.3% and 20% [10]. The sensitivity of syndromic surveillance to detect waterborne outbreaks is also highly variable and depends on multiple environmental and other health factors [11]. Therefore, syndromic surveillance systems have the potential to detect a lot of 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 surveillance have shown that having a syndromic surveillance system that detects a lot of false positives can be an advantage in a pandemic [12]. Ongoing reviews of syndrome definitions, regular refresher training for physicians who report syndromes and review of syndromic trends can improve the accuracy of syndromic surveillance systems.

Syndromic surveillance in Pacific Island countries:

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 [13]. 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 overseas laboratory testing of samples, resulting in delayed responses to possible outbreaks [14]. In 2010, a simplified surveillance system based on syndrome definitions that use clinical signs and symptoms, termed the Pacific Syndromic Surveillance System (PSSS) was proposed and successfully trialed in three Pacific Island countries and later implemented in 21 Pacific Island countries [13,14].

Twenty-one countries in the Pacific region presently use the PSSS, including the FSM. 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. Improving the syndromic surveillance system in Pohnpei is aimed at overcoming challenges such as late data input, incomplete reporting, slow response to outbreak investigation and poor-quality data [14].

Association between rainfall and diarrhoeal illnesses:

Studies assessing the association between rainfall and diarrhoea have shown mixed results. A review by Ghazani et al. [1] 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 rainfalls were linked to increased diarrhoea cases. This trend was not surprising since heavy flooding and drought can lead to diarrhoeal outbreaks. For example, extreme drought led to outbreaks of diarrheal illnesses and eye infections in the Marshall Islands in 2013 [15]. Other studies assessing seasonal diarrhoea suggest that rain events may influence the seasonal presence of rotavirus, directly influencing the seasonal trend in diarrhoea cases (16–18). Diarrhoea is not associated with rain events in areas where rotavirus is not seasonal [6].

Rainfall as a single factor may not be linked to diarrhoea but requires the added multiplying effect of other weather factors, such as temperature or humidity [16,18]. 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 [16] and thereby affecting the trend of diarrhoea cases. The results of the aforementioned studies indicate water and sanitation as common themes. Indeed, regardless of weather changes, Njuguna et al. [19] suggest water and sanitation practices as the critical risk factors for diarrhoeal outbreaks.

Association between rainfall and febrile illnesses:

Increased rainfall can also affect the habitat of vectors and influence the trend of infectious diseases [4]. Assessing the correlation between the trend of febrile illnesses and rainfall can provide the evidence needed to plan for outbreaks that may arise because of changes in local weather patterns. Common febrile infections associated with rain events include dengue, leptospirosis and enteric fever [20-22]. Rainfall variation can also influence hepatitis E virus infection [23]. It is unknown if the volume of rainfall affects the trends of dengue, leptospirosis or other febrile illnesses.

Most studies show a positive correlation between dengue, leptospirosis and rainfall, with a lag time of two to three weeks [24-28]. Furthermore, these trends appear to have seasonal variations following the rainy or monsoon seasons [29,30]. On the other hand, some studies do not show a correlation between dengue fever or leptospirosis with rainfall [31,32]. The differences could be due to reasonable vector control or good ecological management of vectors in these countries. Environmental factors such as soil conditions could also contribute to leptospirosis [33].

Leptospirosis is a frequent cause of febrile illness in the FSM and is commonly associated with dogs, pigs and rats [34,35]. 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 leptospirosis has a seasonal trend and peaked one month after heavy rainfall [28]. However, similar correlation studies have not been done in the FSM or other Pacific island countries.

Predictive models generated from syndromic surveillance data can help predict seasonal trends. Such tools can help manage the impacts of climate change on infectious disease trends. For example, predictive models for leptospirosis in India showed a correlation between monthly rainfall and incidences of leptospirosis [21]. The association was predictable but had a variability of 80% [21]. Their models could not accurately predict July to August of 2011 but accurately predicted the number of leptospirosis cases for August 2013 and August 2014 [21]. 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, which influence leptospirosis transmission and may have affected the accuracy of the statistical models [21]. 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.

Infectious diseases transmitted by mosquitoes are sensitive to rainfall. Dengue and lymphatic filariasis, two mosquito-borne infections, are endemic in FSM, and the frequency of these infections is related to rainfall [4]. Kosrae, a state of the FSM, has experienced periodic dengue outbreaks. 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 [36]. Studies in Africa showed malaria positively correlated with rainfall, where parasite density fluctuated with the volume of rain [37]. 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 [4[. But climate change's potential infectious disease-related health impacts remain under-researched. One way to plan and manage climate-change-related impacts of infectious diseases is to strengthen disease surveillance systems. A robust surveillance system can help monitor infectious disease trends and facilitate timely responses. Routine surveillance data must be regularly evaluated to gather reliable evidence to help plan for climate change-related shifts in disease trends.

Association between rainfall and influenza-like-illnesses:

Influenza-like illnesses and other respiratory illnesses generally have seasonal trends. Within the context of climate change, respiratory illnesses' seasonal trends may change due to changing weather patterns. Influenza-like illnesses have been identified in the FSM as climate-sensitive diseases [4]. Research evidence suggests that ILIs and other respiratory diseases, such as pneumonia, are influenced by temperature and humidity [3,38-40]. Respiratory syncytial virus, a common cause of ILIs, is more active in colder months [7]. A study in PNG assessing pneumonia in children less than five years of age showed that the risk of pneumonia is variable between rainy and drier months of the year [39]. The risk of pneumonia was inconsistent across the different provinces studied [39]. The observation by Kim et al. [39] 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 ILIs and weather parameters indicates the relationship is not linear [41]. Human activities that affect the environment or social activities influenced by weather may determine seasonal trends of respiratory diseases in a community.

Understanding the local variation of mosquito populations with rainfall will enhance the environmental management of mosquito transmitted febrile illness. Mosquito populations tend to go up and down following rain events. Ongoing surveillance of febrile syndromes and integration with weather monitoring systems may detect potential early signals of an outbreak.

Continued efforts to eliminate lymphatic filariasis in FSM are ongoing. However, intense transmission continues in the small outer atoll islands [42]. In addition to mass drug administration to eliminate lymphatic filariasis, controlling mosquito breeding sites is a proven preventive strategy.

Association between weather and COVID-19:

Some research suggests 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 [41]. That study showed variation in the correlation across different cities in Pakistan [41]. Humidity was negatively associated with COVID-19 in all towns except Karachi, where it was positively related [41]. Rainfall was positively associated with COVID-19 in all cities studied except in the cities of Islamabad and Peshawar [41]. However, other studies do not confirm or show similar results, prompting calls for robust research designs to examine the relationship between COVID-19 and weather factors [43]. Well-designed studies are needed to identify the intermediate factors and type of relationship (linear or nonlinear) that weather has with intermediate variables and how the factors interact to influence COVID-19 disease dynamics.

Although the weather may influence COVID-19 transmission, other factors are most likely involved. Among the key issues that need to be considered include data quality, non-environmental factors and COVID-19 distribution in time and space within the context of the epidemic's phase [43].

It is also recommended that COVID-19 predictive models include current understanding of disease transmission dynamics [43].

The relationship between COVID-19 and meteorological factors likely varies between tropical and temperate regions. Socioeconomic and cultural practices may also play a role. Predictive models would need to consider all these factors.

DISCUSSION:

Many infectious diseases are associated with rainfall, either increasing or decreasing soon after rain events. This literature review examined studies evaluating the association between rainfall and diarrhoea, febrile illnesses, ILIs and COVID-19 with a focus in the Asia Pacific Region. Such research is crucial because monitoring climate-sensitive infections may help institute risk mitigation strategies for managing the health impacts of climate change. Climate-sensitive infections are linked to the environment through vectors 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. Additionally, 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 infectious disease syndromes may be associated with rainfall, the relation is complex with the interplay of multiple factors. Some research suggests diarrhoea, ILIs, and febrile illnesses may be positively associated with rain, but other studies do not show this association. 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 rainy seasons or rain events, other local weather variables such as temperature and humidity should also be considered in the analysis. Environmental factors such as soil parameters and geographical terrain may influence infection trends. The present state of research in this area is still poorly understood. It presents opportunities for more research into climate-sensitive infections in the Pacific region, where the effects of climate change may be profound.

CONCLUSION:

Association between rainfall and climate-sensitive infections is multifactorial and geography-specific. Conclusions from studies in one geographical region cannot be applied globally. Further research is needed in Pacific island countries to examine the association between rainfall patterns and potential climate-sensitive infections in order to generate data that is country specific and locally relevant.

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