Geospatial Analysis and Modeling of Melioidosis Prevention and Control in Si Sa Ket Province, Thailand

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Abstract
Melioidosis is a communicable disease caused by the gram-negative bacterium of Burkholderia pseudomallei. There were founded in soil, water and mammals. In 2017, Thailand was highest a prevalence of Melioidosis at Northeast area. The aimed of this study were to determine the factors affecting the prevalence of Melioidosis. According to sample, there was 265 patients, who has diagnosed by IHA/IFA in 2018-2019. The results showed that the majority of the samples 67.17% were male, 31.32% were agriculture, and 41.89% had underlying disease. The factors associated with the prevalence of disease in the area were: Sex (p-value 0.019, 95%CI = 1.108 - 3.132), household environment (p-value 0.025, 95%CI = 0.163 - 0.885), patient exposure [p-value= 0.001, 95%CI = 0.186 – 0.644), smoking (p-value <0.001, 95%CI = 1.468 – 2.914), underlying disease (p-value<0.001, 95%CI = 1.48 – 4.047), season (p-value 0.016, 95%CI = 1.112 – 2.763), perceived susceptibility (p-value<0.001, 95%CI = 0.207 - 0.726) and perceived severity (p-value 0.005, 95%CI = 0.416 – 0.854). Finally, establishing people aware of the risk of disease combined with these surveillances should be carried out using a geographic map that monitors risk areas, so that can prevent and control melioidosis appropriately for people at risk area.

Keywords: *Burkholderia pseudomallei*, Melioidosis, Geography, Geospatial Analysis

1. Introduction

Melioidosis is a contagious disease caused by the gram-negative bacterium of *Burkholderia pseudomallei*, there was founded in soil, water and mammals. It is highly prevalent in Southeast Asia and Northern Australia. There was transmitted through percutaneous inoculation, inhalation or ingestion [1] and [2]. Most patients present ill with lung infections, joint infections, skin infections, hepatitis and septicemia [3] [4] and [5]. In the sometime, patients who infected with *Burkholderia pseudomallei* more than 50% have a high chance of death. In addition, this infection can survive in acidic conditions at 24°C - 32°C, on the water surface was survive in 60-90 cm deep under the soil surface [6] and [7]. For the risk factors for melioidosis include: agricultural, chronic diseases especially diabetics, alcohol consumption, and smoking [7] [8] [9] [10] [11] and [12]. Whereas, there was estimated that there will be an additional 165,000 cases per year and 89,000 deaths in worldwide [13]. There was also no vaccine available to prevent them [14] and [15]. According to the report from the Department of Disease Control in Thailand, the morbidity rate had l to increase. In 2017, Thailand was highest morbidity rate in 13.32 /100,000 population. (The morbidity rate was 5.21 /100,000 population; mortality rate was 0.18 /100,000 population). Most infections were founded in the male 67.9% within the age between 45-54 years old, there were Thai 98.8%, with agriculture 52.6% of occupation, and low health literacy 32.6%. During the rainy season, the province has a high incidence in the Northeast, Thailand. There were the first 5 provinces with the highest morbidity rates include; Mukdahan, Si Sa Ket, Yasothon, Amnat Charoen and Ubon Ratchathani province.

For *Burkholderia pseudomallei* detection, the environment in high prevalence areas has been found in both soil and water from fields or farms, wells and swamps [16] and [17]. The melioidosis IHA is a diagnostic test for melioidosis by detecting antibodies to *B. pseudomallei* in the patient's serum.

It binds to the antigen of *B. pseudomallei* coated on the red blood cells, causing the red blood cell agglutination reaction. *B. pseudomallei* antibody detection in patient serum using the IFA method is the detection of IgG and IgM antibodies in patient serum against *B. pseudomallei* coated on slides and their reaction is monitored by fluorescent staining. The *B. pseudomallei* spores glow green when viewed under a fluorescence microscope [16].

The GIS makes it possible to know the risk point or high-risk area and which will be useful for using the information for protection and disease surveillance with geographical coordinates. Therefore, in areas with epidemic or high prevalence, disease prevention should be prevented by wearing protective equipment, minimizing exposure to contaminated environments and encouraging people to knowledge of self-protection [8] and [18]. Especially those with wounds should avoid direct contact with soil [10]. The principles used in disease prevention and control was establish the measures when an epidemic occurs by government policies. However, from a review of the outbreak in Si Sa Ket province, it was founded that some areas still had a high incidence and prevalence while, another area can be protected and controlled. Therefore, we would like to know the factors affecting the prevalence in the area and should develop preventive measures to control this disease.

2. Materials and Methods

2.1 Study Design

This study was a retrospective descriptive study. There was a study of both human and environmental factors with the following study patterns.

2.1.1 Melioidosis outbreak study

This is a study of the outbreak and factors affecting the prevalence of melioidosis and study of pathogens detection in the environment from soil and water that the patient was exposed. In 2019, the prevalence of melioidosis patients burden in Thailand, shown in Figure 1. As the Si Sa Ket Province as increasing of cases and there was missed the report in previously. In addition, during the past 5 years, there was a distribution of patients throughout the province, 22 districts, as shown in Figure 2. The prevalence of melioidosis in 2019 were 1,834 cases in 22 districts.

A retrospective study was conducted in Si Sa Ket, located in the Northeastern of Thailand. Si Sa Ket province was divided by 22 districts, 206 subdistricts, 2,675 villages, and 393,356 households. The population of province over aged 18 years was 1,003,696 people. Sample size was simple random sampling. The criteria for eligible respondents was that they were; over aged 18 years, diagnosed melioidosis in 2019, only persons with at least 20 years of residence in the area, who were involved with occupations or activities that required them to be exposed to wet soil, mud, local natural water for a long time and were living closely to reservoir animals host (Farmer, Fisherman, Livestock, Gardener). Si Sa Ket province was selected based on its prevalence of melioidosis (Figure 2). The study location within the province were selected by simple random sampling. There were 265 patients in Si Sa Ket province who were diagnosed by IHA/IFA method in 2019. They were divided into 2 groups: study group, 132 samples were from high prevalence areas, while the control groups were 133 samples, there were from low prevalence areas.

2.1.2 Environmental study related to Burkholderia pseudomallei outbreak

For the prevalence of *Burkholderia pseudomallei* in soil and water, the study was randomized to interview 27 patients from areas with high prevalence; Prang ku, Srirattana, Nonkoon, Kantrarom and Khu Khun. All soil and water samples were culture. In 2019, there were 104 environmental were collected (including 40 from soil, and 64 from water). Out of 64 samples from water were collected for 6 days, there were collected from the pond (N = 30), rice paddy field (N = 13), drinking water tank (N = 3), rain barrel (N = 9), pump well jar (N = 19). On the other hand, the soil sampling was collected from 30 cm deep hole dug by clean spade and 100 grams of soil transported to a clean plastic bag. The bag was sealed and stored away from direct sunlight at an ambient temperature until transported to the laboratory within 2 days. The utensils were washed by rinsing them with bottled water to remove visible dust, cleaned with 70% ethanol and air-dried between each sample collection. For water sampling, sterile bottles were submerged approximately 10 cm below the water surface to collect 50 ml of water. The collected samples were stored at an ambient temperature transported to the laboratory within 2 days. While, the rice rhizosphere was carefully excised from the plant and stored in a sterile plastic container and stored at an ambient temperature and transported to the laboratory within 2 days the same as before [16] [17] and [19].

2.2 Statistic Analysis

Statistical analysis was used the packaged computer software by the percentage and frequency to describe the general information and melioidosis cases. The relationship of each factor was used the Pearson χ^2 test or Fisher's exact tests.

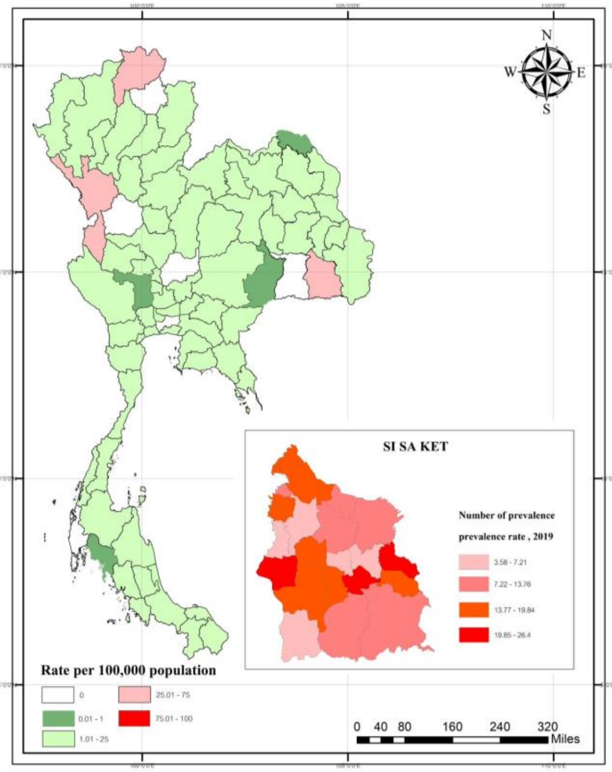

Figure 1: Melioidosis burden in Thailand

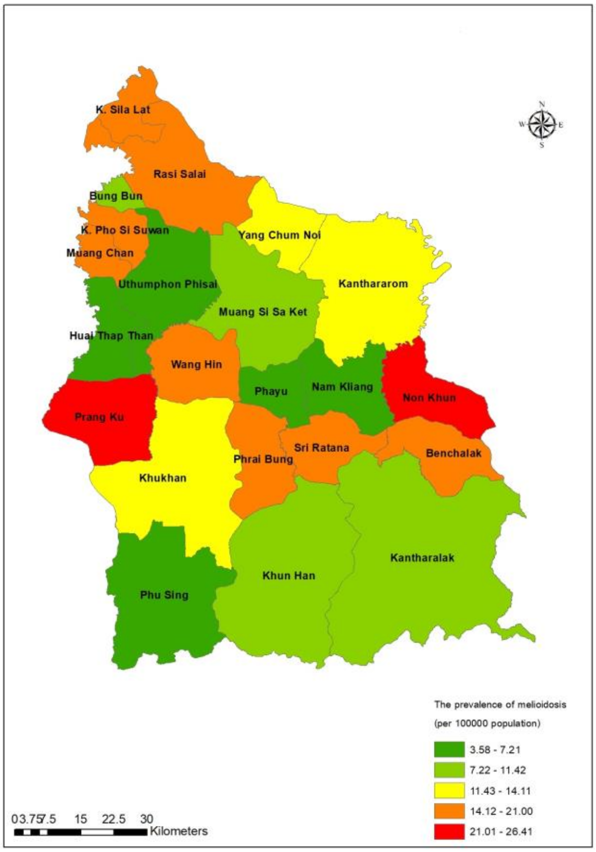

Figure 2: The prevalence of melioidosis in 2019 in Si Sa Ket province, Thailand

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3. Results

From the study of the outbreak in Si Sa Ket was collected. The data from 2015-2019 (B.E. 2558-2562), there was tended to be in the same direction during the outbreak. Moreover, the data was shown that the morbidity rate increasing during the rainy season on May - October. There also found that in 2016 was the highest morbidity rate. As shown in Figure 3. The 265 patients in Si Sa Ket province with confirmed melioidosis found that majority of the cases were in male 67.17% with agriculture-related activities 31.32% with underlying disease 41.89%. The factors affecting the prevalence of melioidosis in Si Sa Ket province include; Sex (p-value 0.019, 95%CI = 1.108 - 3.132), household environment (p-value 0.025, 95%CI = 0.163 - 0.885), patient exposure (p-value= 0.001, 95%CI = 0.186 – 0.644), smoking (p-value <0.001, 95%CI = 1.468 – 2.914), underlying disease (p-value<0.001, 95%CI = 1.48 – 4.047), season (p-value 0.016, 95%CI = 1.112 – 2.763), perceived susceptibility (p-value<0.001, 95%CI = 0.207 - 0.726) and perceived severity (p-value 0.005, 95%CI = 0.416 – 0.854) as show in Table 1. An environmental factor, there was finding out the *B. pseudomallei* by culture**.** That the distribution of *B. pseudomallei* and pursue the potential sources of infection in 104 samples. The 40 soil and 64 water samples were collected at two different times from two environmental sites: (i) the surrounding the patient's household (ii) the suspected exposure sites (the pond, rice paddy field, and community-dug well). The patients lived in high prevalence areas such as Prangku, Noonkhun, Srirattana, Kanthararom and Khukhan. There were mention the distance between the patient's household, the pond and rice paddy field were approximately 0.3 kilometers, and the distance between the patient's household and the community-dug well was 5 kilometers. *B. pseudomallei* isolates were detected from 15/104 (14.42%) environmental samples, there are include sample from soil 7/40 (17.5%) that were distributed around the suspected exposure sites, in other hand, water sample was detected 8/64 (12.50%) that collected from a pond in rice fields. A total of 15 patients, representing 55.56% of 27 sample. A monitoring for area at risk can be demonstrated (red color is the spreading radius) as shown in Figure 4. From the collection of environmental data to detect *B. pseudomallei*, it was found that Kanthararom district had the highest detection rate of *B. pseudomallei.* Moreover, an infection was found in some district high because the settle near Ubon Ratchathani Province, which is the source of the outbreak. Then people from different areas come to fish and mushrooms, which is more abundant than other areas. Followed by Prang Ku, Sri Rattana, Non Khun and Khukhan respectively, that show in Figure 5.

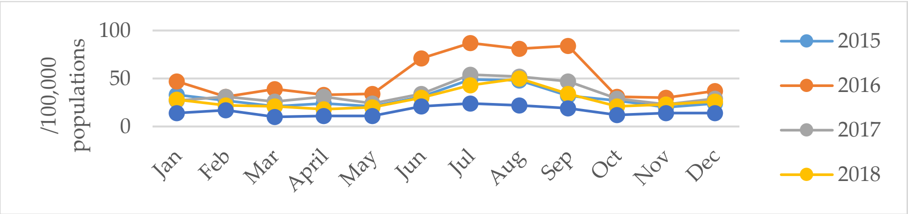


Figure 3: Morbidity rate of melioidosis in Si Sa Ket province during 2015-2019

Table 1: Risk factors for prevalence of melioidosis patients, Si Sa Ket province

Risk Factor	OR	95% CI	P-value
Age	1.364	0.962 – 1.932	0.081
Sex	1.863	1.108 - 3.132	0.019
Occupation	0.885	0.741 - 1.057	0.176
Muddy Soil water Outdoor	0.762	0.628 – 0.925	0.006*
Home character	0.997	0.783 – 1.27	0.981
Household environment	0.38	0.163 - 0.885	0.025
patient exposure	0.346	0.186 – 0.644	0.001*
Ever-smoker	2.068	1.468 – 2.914	0.001**
alcohol consumption	0.740	0.508 – 1.075	0.114
Live in risk area >20 years	0.96	0.747 – 1.233	0.748
Underlying disease	2.447	1.48 – 4.047	0.001**
Season	1.753	1.112 – 2.763	0.016*
Perceived knowledge	0.851	0.606 – 1.194	0.351
Perceived susceptibility	0.472	0.207 - 0.726	0.001**
Perceived severity	0.596	0.416 – 0.854	0.005*
Perceived benefits	0.821	0.557 – 1.209	0.318

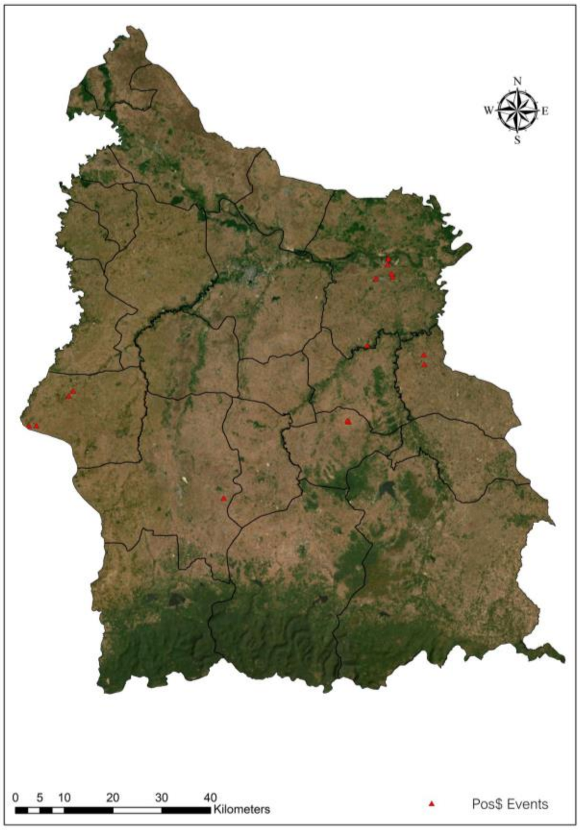


Figure 4: The map classifies geography to point out the patient with *B. pseudomallei*

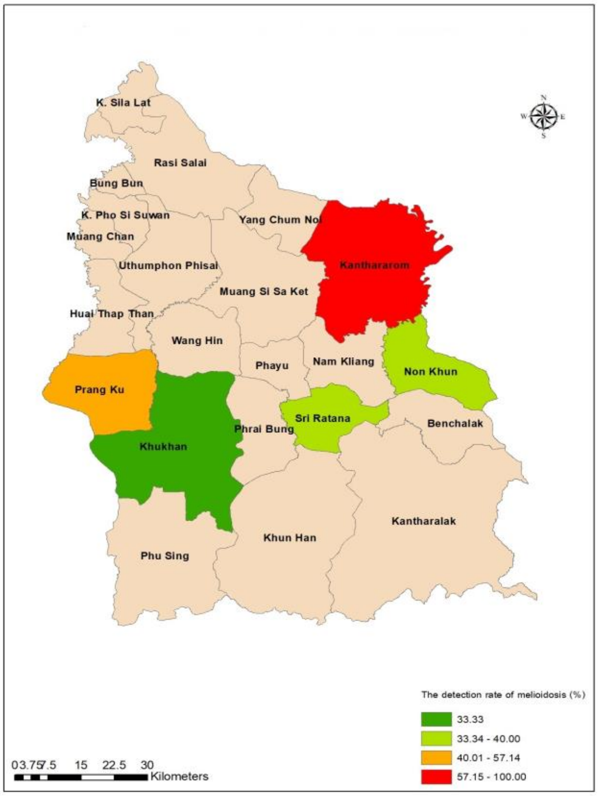


Figure 5: The detection rate of *B. pseudomallei* detection in Si Sa Ket, Thailand

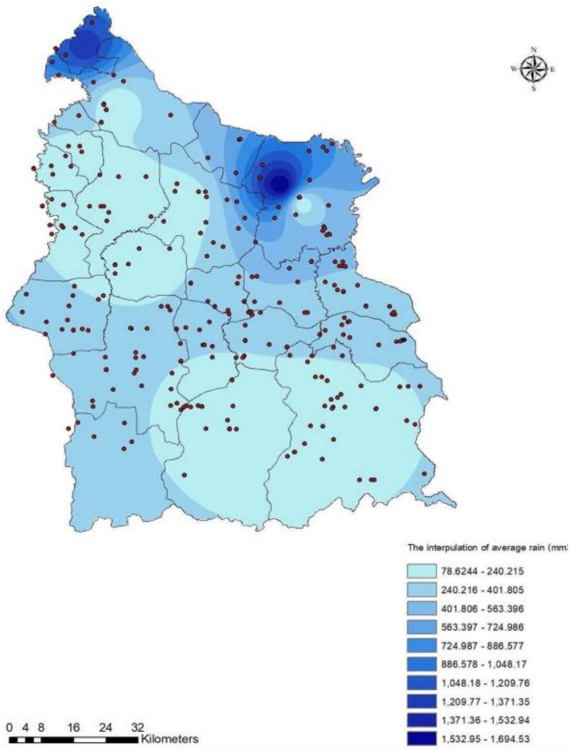
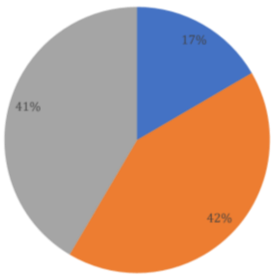
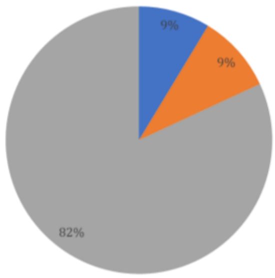


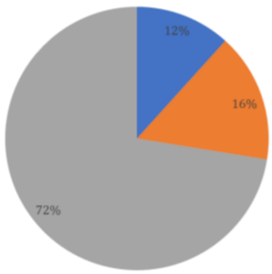
Figure 6: The distribution of melioidosis with the interpolation of average rain



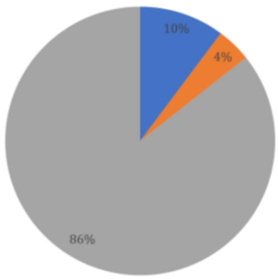
(a) Knowledge of disease prevention and control



(b) Risk opportunities for disease prevention and control



(c) Awareness of violence



(d) Awareness of benefits

Low Moderate high

Figure 7: The awareness of patient about melioidosis in Si Sa Ket province, Thailand 2019

The awareness of patient about melioidosis in Si Sa Ket preovince was found to be the knowledge about prevention and control of the disease, there had a moderate level of awareness, 41.89%, regarding risk opportunities in disease prevention and control. Most of them had a high level of awareness, 81.89%, in terms of awareness of violence in disease prevention and control. Most of them had a high level of awareness, 72.45%, and awareness of the benefits of disease prevention and control. Most of them had a high level of awareness, 85.66 percent as show in Figure 7.

4. Discussion

Addition factors affecting the prevalence of melioidosis in Si Sa Ket Province, the researcher was studied both the patient interviews and the environment determinant from the soil and water in the area of the house, farm, rice field and various water sources that the patient came into expose with. There was an analysis of risk areas and coordinates of risk area for use in surveillance. Which will result in the development of prevention and control of melioidosis, especially changes in personal behavior in self-defense and reduce the severity of melioidosis. The results of the study of personal factors revealed that Sex (p-value 0.019, 95%CI = 1.108 - 3.132), patient exposure (p-value= 0.001, 95%CI = 0.186 – 0.644), had an effect on the prevalence of melioidosis in the area. Because the patient can infect the soil and water, or soil and water can infect people by eating or inhaling it into the body. The pathogens found in high-risk areas can predict the incidence or prevalence of melioidosis at the local level. Which was consistent with the several study of risk factors for the disease, mainly due to individual characteristics [8] [20] and [21] especially diabetics were at higher risk of infection than normal people [12] and [22]. There were others factors; perceived susceptibility (p-value<0.001, 95%CI = 0.207 - 0.726) and perceived severity (p-value 0.005, 95%CI = 0.416 – 0.854). Which both perceived susceptibility and perceived severity were factors affecting the personal behavior change.

As for the environmental factors, such as household environment (p-value 0.025, 95%CI = 0.163 - 0.885), a house that entirely protected against dust was more resistant to germs than a basement house. This depends on climatic factors such as wind speed or storm that can carry pathogens contaminating airborne particulate matter to the house [23] [24] and [25]. While the raining season factor (p-value 0.016, 95%CI = 1.112 – 2.763), was factor affecting the prevalence of melioidosis because the farmers were rice cultivation with water as a barrier to prevent the spread and the chance of infection [8] [25] and [27]. When analyzed by back ward multivariable logistic regression founded that smoking (p-value <0.001, 95%CI = 1.468 – 2.914) and underlying disease (p-value<0.001, 95%CI = 1.48 – 4.047) was the factors affecting the prevalence of diseases. Therefore, prevention and control were developed that surveillance should be exercised in people with chronic and frequent smokers and active case finding, especially during the rainy season. That is, the distribution of cases affected the prevalence and in areas with moderate mean rainfall was linkage the prevalence of patients than in areas with low and high mean rainfall. Addition to the mean rainfall was used the annually record by Inverse distance weight technique (Figure 6).

The study of environmental factors was the finding out the pathogens in soil and water from areas that the interviews patient exposure in the five districts with the highest prevalence, where the infection was found from both soil and water environments for confirmed the outbreak of melioidosis in the area. [9] [18] [28] [29] [30] and [31]. In addition, making a map that can show the risk area will raise awareness among people in the area and the coordinates of the infection to be monitored within a radius of 5-10 kilometers [17]. In current, soil and water trading can be carried or carried the germ to another site. The difference in rainfall is part of the increase in the disease. While, there are also variables related to disease control operations in the area. While, the coordinates from people behavior modification will help reduce the morbidity in the area.

In conclusion, the melioidosis in Si Sa Ket province was linkage to the environmental determinant. The prevalence of disease was 129.93 moderate level of awareness. Which is beneficial for the development the model of melioidosis preventive and control. Especially people who are at risk groups such as people with chronic diseases, smokers and patient exposure that living in high prevalence areas or high rate of *B. pseudomallei* detection in area. The most suitable protection was to wear protective equipment at work. Moreover, in the rainy season should more surveillance measures for melioidosis, in the same time the active case screening was an initial risk assessment. In addition, the map showing the risk area and encouraging people to be aware the risk of disease. While, the rapid response network should be reported and on-site urgently. The strength of this study was a novel study in this area and there was study in population at risk and the environment together. In other hand, a limitation was the GIS programs should be used by local staff to more precisely locate patients and risk areas.

Ethical Consideration

A review of human research ethics from Mahasarakham University. Finally, individual informed consent was obtained in each participation who met the inclusion criteria. (Approval code no149/2019 and date of approval 21 August 2019)

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