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URBAN HEAT ISLAND PHENOMENON IN PENANG ISLAND, MALAYSIA

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Abstract: -

Urban heat island is a serious phenomenon affecting human discomfort, health problem and increased pollution. A lot of initiative was taken to decrease its impact. However, as urban area is developed tremendously, this scenario is still a serious issue. This study attempted to identify occurring of urban heat island in Penang Island, MBPP area by using a method of temperature field observation. All the data obtained were analysed to get the temperature contour image by using ArcGIS 10.1 software through SPLINE techniques and CLIP. The results showed that showed the existence of the urban heat island at the MBPP area occurred between 7 a.m to 10 p.m. This phenomenon occured in congested area and during peak hour. The study concluded that heat island has increased yearly due to various factors such as increased of population and motor vehicles because of development, industrialization and urbanization.

Keywords: *urban heat island, land surface temperature, causes of urban heat islands.*

INTRODUCTION

Development in Malaysia is growing rapidly nowadays and forging ahead to become a develop nation in the international arena. Many residential, industrial and business center were built due to increasing density population from year to year. Consequently, this scenario gave a big impact to the environment and climate as it involves the use of space and acres of land, process of deforestation and vegetation, reclamation also resulted in the existence of urban heat island phenomenon. Urban heat island is the most popular research discussed for the past decades. Heat island is an analogy climate and form as temperature island in urban and sub-urban areas (Gartland, 2008). The island has a disparity in terms of climate and geomorphology involving the parameters of temperature, precipitation and air quality (Sham Sani, 1989). Urban heat island also gave a negative impact to humans. The examples of negative effects are rising temperature in urban area, high temperature at night, diseases to the human because of temperature such as cold and flu, increase of energy consumption, increased use of air condition and at the same time caused an increase of CFC gases production and influence of green house.

Previous research on the urban heat island was conducted using various techniques in countries around the world. The most popular technique is by using hygrometer, an instrument to measure the temperatures. Due to the passage of time, hygrometers have been created for manual and digital use. In addition, an instrument named Campbell (R21) Micrologger, also has been used by previous researchers to record the temperatures (Jauregui, 1997). Other former researchers have done this type of research by combining the data from the meteorological department within their study area. This technique intended to investigate the existence of the urban heat island.

In addition to measure and record temperature, other sophisticated techniques using remote sensing and geographical information system (GIS) has been created. Remote sensing and GIS techniques were used to obtain a thermal image that displays the temperature condition in research area and at the same time, showed the existence of urban heat island. This technique is excellent in explaining the characteristics of the land surface temperature in a chosen area.

RESEARCH AREA

Penang Island also known as 'Pearl of the Orient' is a small country located in the north of Peninsular Malaysia within latitudes 5°12'N to 5°30'N and longitudes 100°09'E to 100°26'E. The state is compact with development, population and urbanisation and is suitable for the study of the influence of urban heat island. In this study, the research of urban heat islands only covers in Penang Island that is in district of MBPP (City Council of Penang Island) (Penang State Government, 2013). The coverage area is shown in Figure 1. The area of Penang Island is approximately 103,105.65 hectares of land consisting of two parts of district administration namely Seberang Perai Municipal Council (MPSP) and City Council of Penang Island (MBPP). MBPP have local administrative area of approximately 302.53 square kilometers and has a variety of multi-ethnic population of about 722,300 (Penang Structure Plan, 2020). This area has also been active in the development process and the population increased rapidly due to natural growth, internal and external migration. In addition, MBPP focused its development on various aspects such as education, housing, business, service and growth centers of lights and heavy industry and as a catalyst for urban development in the present and future. Thus, the population density also increased from year to year. Table 1 shows the rate of population increase in Penang and Malaysia from 2005 to 2010.

Table 1: Rate of population increase in Penang and Malaysia from 2005 to 2010.

Year	2005	2006	2007	2008	2009	2010
Pulau Pinang	80.6	80.7	80.8	80.8	80.9	80.9
Malaysia	62.7	62.9	63.0	63.2	63.3	63.4

Source: Department of Statistic, Malaysia (2010).

Penang island have hilly terrain and the highest point is Western Hill which is located at 830 m above sea level. The terrain is mostly comprised of coastal plains, hills, and mountains. Geographical landform of Penang Island showed the coastal plains are narrow and, in the northeast, it formed a triangular promontory where the capital city of Penang, George Town is located. In addition, George Town had been listed as George Town World Heritage by UNESCO in 2014 indicating George Town as one of the historic cities of the straits of Malacca and have a unique architectural and cultural townscape in Southeast Asia. Figure 2 showed maps of ten sampling station in this study. The coordinates showed in detail the geographical position of sampling stations in this research. The instrument that record the geographical position is Global Positioning System (GPS). The sampling was conducted on the 5th October 2013, Saturday from 7 a.m to 10 p.m.

Figure1: Location of MBPP area in Malaysia.

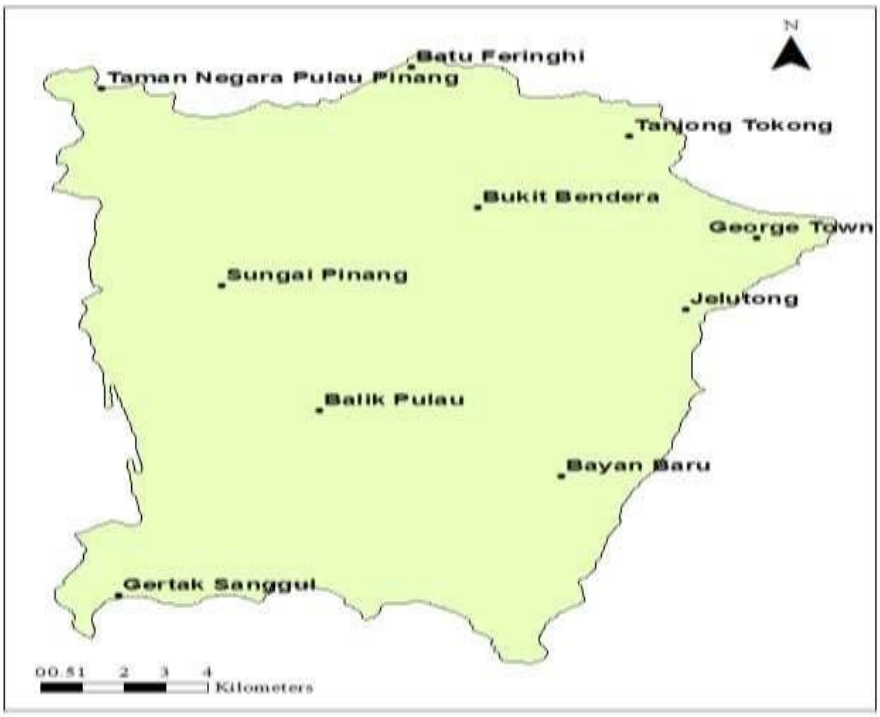

Figure 2: Ten sampling station at MBPP area.

MATERIALS AND METHODS

The method of this study was performed using temperature field observation. It aimed to examine the existence of urban heat island in 2013. The method was taken at ten sampling station and details of the place is discussed in Table 2. The sampling involved the measurement of ambient temperature, relative humidity and monitoring wind and weather condition at the sampling area. The ambient temperature and relative humidity were record using a digital hygrometer. In addition, the coordinates of the sampling stations were also recorded to show in detail the geographical position of sampling stations in this research. The measurement of ambient temperature, relative humidity and monitoring wind and weather condition at the sampling area was conducted at ten sampling area with the help of a group assistants. This is to make sure all the measurement were take at the same time during the day and night. The assistants consist of Geography students and they were divide into ten group to take the measurement at ten sampling area. All the information were recorded in the Template Record Size Elements Weather in each sampling station.

Subsequently, the temperature data obtained was processed and analyzed to design the temperature contour image in the MBPP area. Temperature contour image was design by using ArcGIS 10.1 software through SPLINE techniques and CLIP. The results of the temperature contour image were presented and involved an extensive discussion on the existence of urban heat island in the study area. The temperature contour images that were obtained is shown in the results section (Figure 3-6). The results of the temperature contour image were divided into average four hours, where the hours were divided into groups of 7 a.m to 10 a.m, 11 a.m to 2 p.m, 3 to 6 p.m and 7 p.m to 10 p.m. A detailed explanation of divided time into average four hours is described in Table 2.

Table 2: Detailed explanation of divided time into average four hours.

Average Time	*Explanation*
7 a.m to 10 a.m	Temperature observation done at this time to study the relative humidity, wind movement and weather conditions after sunrise. In addition, this time is the beginning day to the public to start and perform daily activities as well as commercial and industrial sector etc.
11 a.m to 2 p.m	Temperature observation done at this time to study the relative humidity, wind movement and weather conditions after the sun emits light to the maximum extent. This time normally show a very high temperature. The condition currently is normally busy due to the public with their daily activities outside from the home.
3 p.m to 6 p.m	Temperature observation done at this time to study the relative humidity, wind movement and weather conditions after the sun lessens the emission light. Normally, at this time was after lunch and public will continues their duties as well as synthetic influence of heat seen at this time. In addition, this time can also indicate a strong influence of the sea breeze.
7 p.m to 10 p.m	Temperature observation done at this time to study the relative humidity, wind movement and weather conditions after sunset. Currently, the sun no longer influences the heat setting.Therefore, urban heat island phenomenon that exists is clearly visible through the influence of synthetic heat.

FINDINGS

The results of the temperature measured were included in this research to ensure this study is complete with previous and latest data and to observe the pattern of temperature contour with existence of urban heat island in recent years. Ten sampling stations are George Town, Jelutong, Bayan Baru, Balik Pulau, Gertak Sanggul, Sungai Pinang, Tanjong Tokong, Batu Feringghi, Penang Hill and Penang National Park (Figure 2). The results of the temperature contour images obtained is shown in four groups of 7 a.m to 10 a.m, 11 a.m to 2 p.m, 3 p.m to 6 p.m and 7 p.m to 10 p.m. The image of the temperature contours shown in Figure 3, 4, 5 and 6 according to different time each. Results showed that from 7 a.m to 10 a.m (Figure 3) the highest temperature was record in Batu Feringghi 31.15 ° C while the lowest temperature was record in the Bukit Bendera, 27.7 ° C. The average relative humidity from 7 a.m to 10 a.m is between 51.5 to 78.1% at the whole sampling area. Furthermore, it was raining at several sampling area such as Gertak Sanggul, Bukit Bendera and Jelutong. While, George Town, Bayan Baru, Balik Pulau, Sungai Pinang, Tanjong Tokong and Penang National Park were cloudy. In addition, the results in Figure 3 show that the urban heat island has existed at the Batu Ferringhi and Tanjong Tokong area. The highest temperature obtained was 31.15 ° C. The highest temperature obtained at Batu Ferringhi and Tanjong Tokong was in the morning. It is classified as a reasonable as the situation of land use in the area is dense with development and the sampling of temperature data were done at the congested area. Besides, the observations also show that the wind conditions at the area is weak and moderate rate from 7 a.m to 10 a.m.

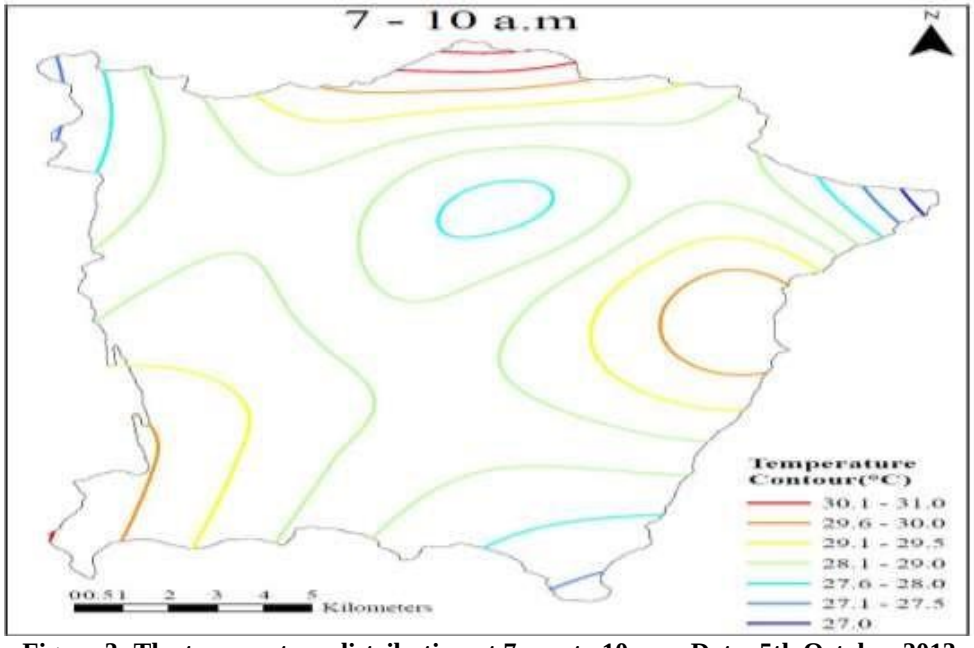

Figure 3: The temperature distribution at 7 a.m to 10 a.m. Date: 5th October 2013

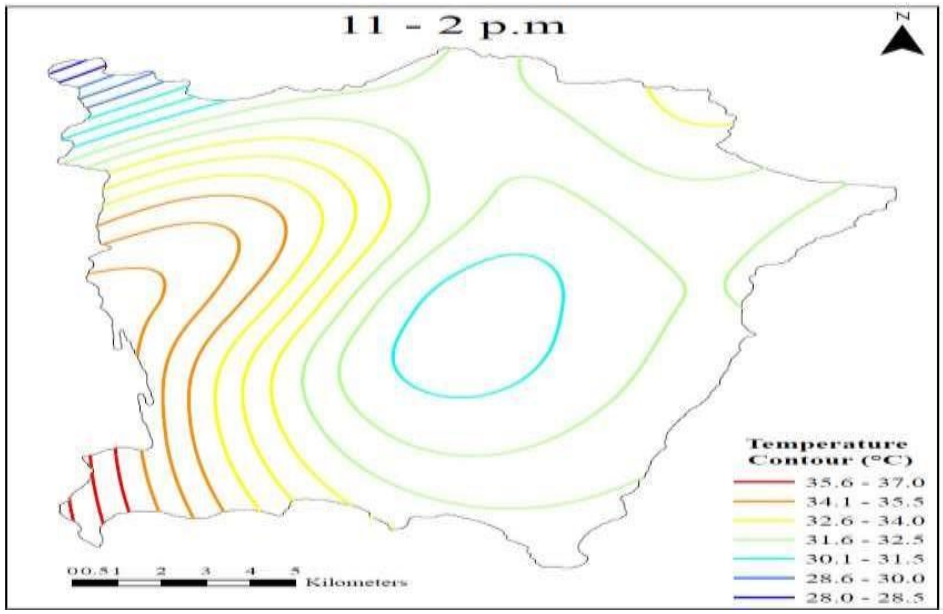

Figure 4: The temperature distribution at 11 a.m to 2 p.m. Date: 5th October 2013

Temperature contour patterns obtained between the hours of 11 a.m to 2 p.m (Figure 4) showed a different pattern between times from 7 a.m to 10 a.m. The highest temperature was recorded in Gertak Sanggul, 36.13 ° C while the minimum temperature was record at the Penang National Park, which is 29.05 ° C. The average relative humidity was recorded between 57.08 to 76.25%. Moreover, only Gertak Sanggul station was hot from 11 a.m to 2 p.m while the weather at the nine-sampling station were rainy and cloudy. The observation results also show that wind conditions from 11 a.m to 2 p.m at Gertak Sanggul was weak in the afternoon. While in other areas, the wind conditions were found in moderate and strong condition due to the cloudy weather and rain at the area. Figure 4 show urban heat island have occurred at that time in the MBPP Southwest area. Gertak Sanggul recorded the highest temperature up to 36.13 ° C due to warm weather and afternoon factor.

Figure 5 shows the temperature contour patterns obtained at 3 p.m to 6 p.m. The highest temperature recorded in Sungai Pinang was 31.73 ° C while the minimum temperature recorded at Bukit Bendera was 25.8 ° C. The average relative humidity currently was between 60.75 to 85.68%. Weather conditions obtained at 3 p.m to 6 p.m showed rainy day in Sungai Pinang, Gertak Sanggul and Penang National Park while cloudy day at other area in this time. However, the temperature contour patterns derived from Figure 5 shows that the urban heat island still exist, particularly in areas with the highest temperature within 3 p.m to 6 p.m in Sungai Pinang. Sungai Pinang is a rural area and small town but full of the residential capacity. The results of observation also showed wind conditions in Sungai Pinang was weak and moderate due to rainy day. While in other area, wind conditions showed weak, moderate in several area and strong conditions in other area due to rainy and cloudy day.

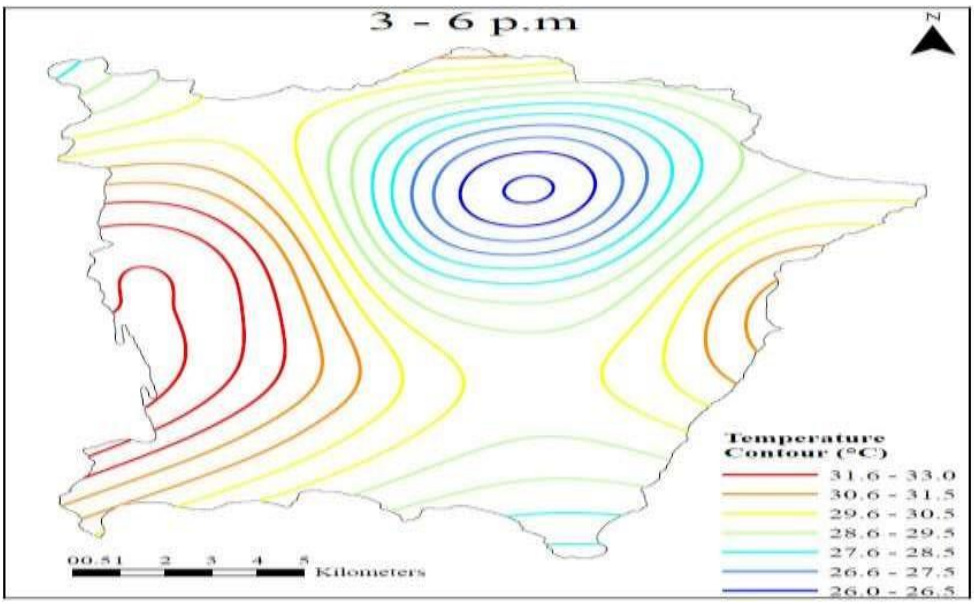

Figure 5: The temperature distribution at 3 a.m to 6 p.m. Date: 5th October 2013

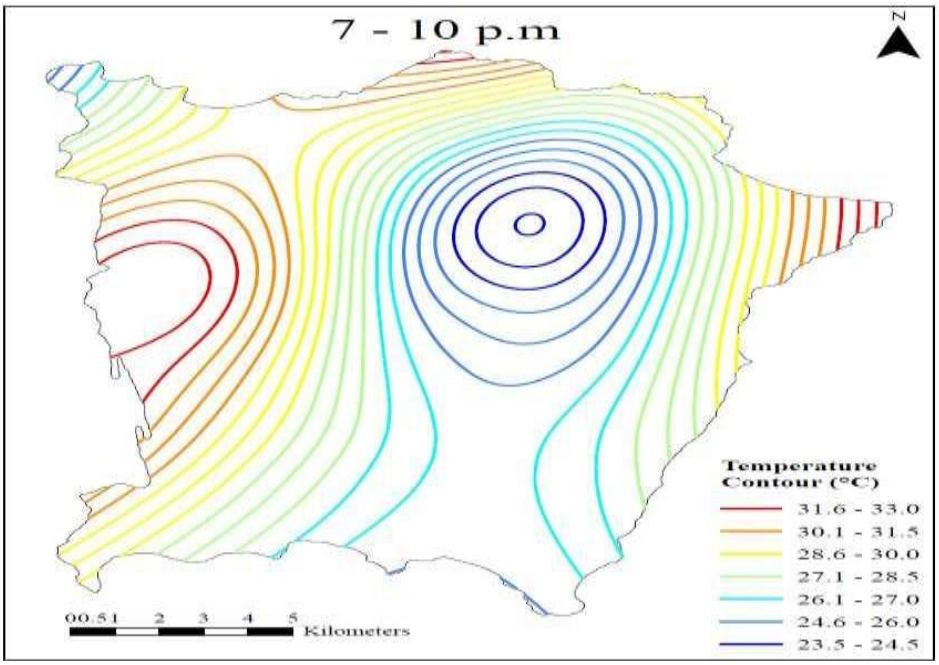

Figure 6: The temperature distribution at 7 p.m to 10 p.m. Date: 5th October 2013

Meanwhile, the results of temperature observations from 7 p.m to 10 p.m (Figure 6) showed highest temperature recorded at Batu Feringghi (31.58 °C) and Sungai Pinang (31.55 °C). The lowest temperature recorded in the Bukit Bendera (23.88 °C) and average relative humidity obtained at this time is between of 60.30% to 93.08%. Weather conditions in all places is cloudy and rainy. However, Batu Ferringhi and Sungai Pinang recorded the highest temperature despite the cloudy and rainy day at this place.

The contour patterns result from 7 p.m to 10 p.m showed the existence of the urban heat island in the procurement of the highest temperature of Batu Feringghi, Sungai Pinang and including George Town even on a rainy day. The probability of urban heat island existence currently is due to public focus and high density at this area. Batu Feringghi and Sungai Pinang also was a tourism place that provided an entertainment and variety of foods. George Town was an urban area and busy until night. Moreover, the observation of the presence of wind showed that the wind conditions in the area are weak and moderate. However, at other areas such as Bukit Bendera and Gertak Sanggul showed wind are strong and moderate from 7 p.m to 10 p.m.

Generally, weather conditions on the day of temperature observations (5th October 2013, Saturday) is rainy and cloudy. As a result, sampling stations was encountered cloudy and rainy day eventhough at different times. According to Meteorological Department (2013), Malaysia has experienced a period of monsoon in October 2013 that led to rain and thunderstorms in the early morning and late afternoon on the West Coast states of Peninsular Malaysia including Penang. Penang also received rain up to 60% above normal. The Bayan Lepas Meteorological Station has also recorded the highest rainfall of 495.2 mm in October. Rainfall throughout the country in October 2013 is shown in Figure 7.

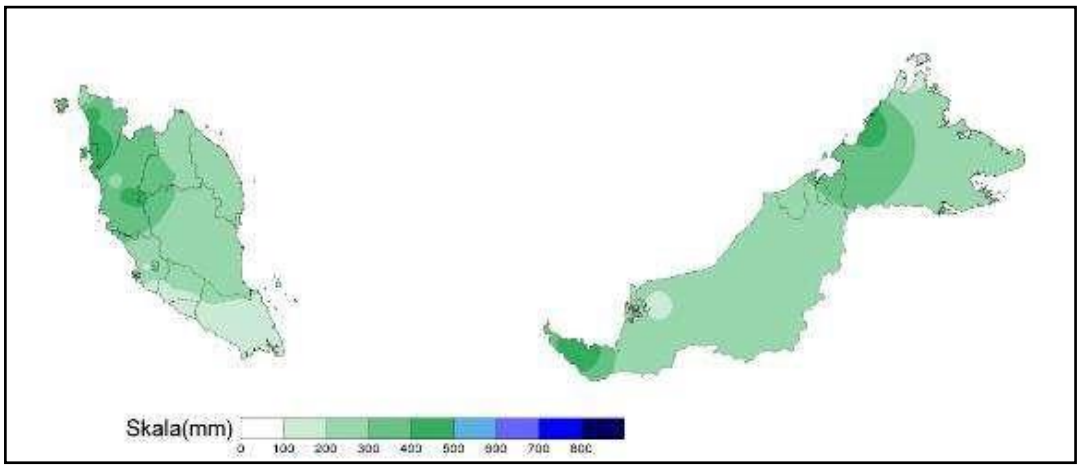

Figure 7: Rainfall chart in Malaysia (October 2013).

Source: Department of Meteorology, Malaysia (2013).

Even though results of temperature observations and monitoring on wind and weather shows cloudy and rainy condition in all areas, the urban heat island still exists in certain areas. The comparison was made at four contour images, and the results showed urban heat island increased during the night. The pattern of temperature contours shown in Figure 3, 4, 5 and 6. In addition, Batu Ferringhi and Tanjong Tokong faced the highest temperature at 7 a.m to 10 a.m. Batu Feringghi is Penang's famous tourist area because it has a beautiful beach and attracted many tourists from abroad. The area was gazetted as a coastal city and one of the main settlement centers by the Penang State Government. Therefore, this area was compacted with construction of hotels, restaurants and residence. While Tanjong Tokong was a focal point in various business activities and entertainment services for the public. Straits Quay, Plaza Island, Gurney Plaza and Gurney Paragon were built here and become an attraction to tourist. Therefore, these factors strengthen the existence of the urban heat island in both areas.

Urban heat island is also show at 11 a.m to 2 p.m in the Teluk Kumbar, Gertak Sanggul and Balik Pulau, which covers MBPP southwest district. Even though these three areas are categorized as suburban areas, they became one of most favourite settlement area by Penang citizens due to its adjacent to the industrial area and city as well as factor of rental and purchase price of houses in the area are still affordable for most residents of Penang. The main factor causing high temperatures in these areas between 11 a.m to 2 p.m was due to the residents in this area goes out for daily activities as well as development of residential buildings became more active.

Furthermore, Sungai Pinang recorded highest temperature and shows the existence of the urban heat island between 3 p.m to 6 p.m. Sungai Pinang, located in the southwest area of Penang is a village and rural area. This place is a community area filled with residents and neighborhoods. The probability that this area had a high temperature at this time is due to the production of heat from the ground because of heavy rains earlier. Besides, other probability of high temperature occur here because of residents in Sungai Pinang were going out doing their activities soon after the heavy rain.

The factors that led to the existence of the urban heat island in Batu Ferringhi and George Town at 7 p.m to 10 p.m even on a rainy day are due to these areas were town and public areas. Besides, sampling was conducted on a Saturday; therefore, 7 p.m to 10 p.m was a leisure time for the citizen of Penang and foreign tourists. In addition, the next day was Sunday, the weekend for the working community, so they grab a chance to have many activities currently.

In conclusion, the results of the sampling data of temperature, humidity and observations of weather conditions and wind in ten selected areas from 7 a.m to 10
p.m on the date of the 5 October 2013 show the existence of the urban heat island in MBPP. It shown from temperature contours using software ArcGIS 10.1. Various factors led to the existence of the urban heat island in this area. Besides population growth and current patterns of land use, other factors that affect the existence of the urban heat island were increasing number of motor vehicles, industrial areas such as factories and pollution. Therefore, the Penang State Council (MBPP) must push efforts to address the problem of rising temperatures because it invites various negative effects.

DISSCUSSION

In general, this paper shows the temperature of the surrounding land acquired by using temperature measurements in the MBPP area to associate the existence of the urban heat island. Results obtained from the method of temperature observations at ten sampling stations MBPP area from 7 a.m to 10 p.m on Saturdays, dated 5th October 2013 also showed the existence of the urban heat island in the study area. In addition, results obtained from the temperature contour image indicates that the heat island had existed during the period of 7 a.m to 10 a.m, 11 a.m to 2 p.m, 3 to 6 p.m and 7 p.m to 10 p.m. Similar results obtained by Sin Hui Teng (2003 & 2004) who studied the existence of the urban heat island at Penang by observations of temperature using a sling psychrometer in the field. In the results, it was found that the highest temperatures in major cities and the urban heat island exist in the morning, afternoon and evening (Sin Hui Teng, 2005).

The results of this research also show that the urban heat island exists in the area that became the focus of the public such as in urban and housing areas. This clearly shows that the environment temperature inordinately high in areas filled with human and development. The result of this research was also supported by Ilham (2012), which found the urban heat island in Kuala Lumpur through observation methods of temperatures at 12 sampling stations. From the studies, it was detected the presence of heat islands in major cities and also the focus areas of human development at Puduraya, Bukit Bintang, Chow Kit and KLCC area. It was explained that factors of existence of the urban heat island in the region is related to land use and human activities.

Results obtained from the temperature observations in the field and temperature contours image also explains that the urban heat island is increasing at night. This situation is clearly shown by the temperature contours image in Figure 3, 4, 5 and 6 as the contour obtained compacted at the time from 3 p.m to 6 p.m and from 7 p.m to 10 p.m. Furthermore, the heat island detected only in one or two areas during the day, but at night, the heat island has been detected around the island in three areas. It showed abnormal high temperature was detected at night. The result also supported by Fujibe (2011) who studied urban heating and correlated with the existence of urban heat island in the major cities of Japan using temperature data from the Japan Meteorological Department. The results showed that the ambient temperature is high in busy cities, particularly Tokyo and increased at night.

The existence of the urban heat island in MBPP areas depends on variety of factors. Beside the factor of increasing in population and the current land use patterns that have been discussed. Other factors such as increasing number of motor vehicles will also affect the existence of this phenomenon. This is because the presence of a motor vehicle can increase the temperature with production of carbon monoxide from vehicle emissions and fuel used in vehicle engine (Sham Sani, 1987). Growth of urban and housing development also was a cause of rise of using of motor vehicles at the MBPP area. This is evident showed in the data obtained from the Ministry of Transport in Figure 8. The number of motor vehicles in Penang is increasing every year and this contributed to an increase in heat setting.

In addition, beside increased the number of motor vehicles, major roads in the MBPP area always crowded with vehicles too. Especially streets in town such as George Town, Tanjong Tokong, Batu Feringghi and Bayan Baru. City streets and the road connecting settlements to the town and industrial areas are also congested. This congestion becomes high at peak hour, in example in the morning hours, 6 a.m to 10 a.m and afternoon at 4 p.m to 7 p.m. This is due to this time; the residents of Penang are travelling to the workplace and going home from the workplace. Furthermore, Penang became one of the largest industrial areas, which provide many jobs for citizens and non-citizens of Penang. Consequently, these factors strengthen the presence of urban heat island in the MBPP area.

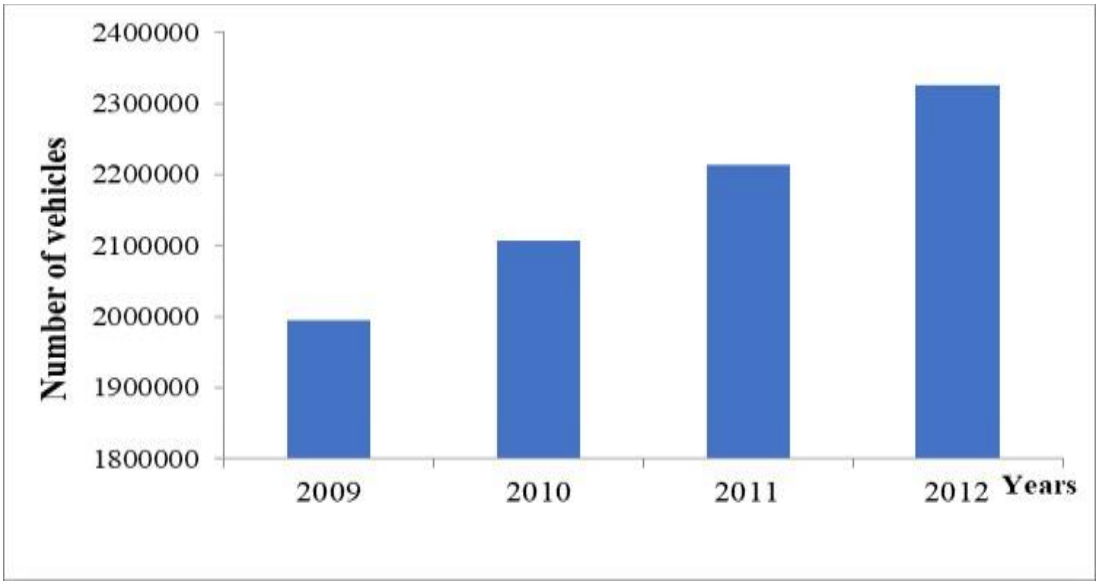

Figure 8: Increased of motor vehicles in Penang.

Source: Edited data from Ministry of Transport, Malaysia (2013).

Next, another factor that led to the existence of heat islands in the MBPP area is air pollution. This is due to the various activities carried out in this area has increased the rate of the Air Pollution Index (API). In example, motor vehicles and industrial activities such as factories are growing rapidly every year. Among the gases that are released by this activity causes air pollution and rising temperatures are carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone (O3) and suspended particles less than 10 microns (PM10) and used lead (Shaharuddin Ahmad, 2006). All the gases and suspended particles were monitored by the Department of Environment in Penang to make sure it is not exceeding to the the danger level. In addition, in 2013, Penang has experienced severe haze caused by forest fires in Sumatra, Indonesia and Penang is geographically close to these areas. IPU Index readings on the haze was more than 300 and showing the danger situations (Meteorology Department, 2013).

Thus, research on the existence of the urban heat island in the area MBPP give a useful knowledge. Although the study of the existence of the urban heat island made by Sin Hui Teng (2005) and Lim Guat Eng (1980) in previous years, but research in recent years, 2009 and 2013 also provide results on the urban heat island phenomenon that exists in Penang (Chen et al. 2009;Cui et al. 2013). This research applies latest methods such as remote sensing data and digital hygrometer instrument for measuring temperature. The pattern and heat island temperature characteristics showed an increase from year to year due to factors such as municipal activities, increase in population, the number of motor vehicles and pollution.

CONCLUSION

Thus, conclusions drawn from the results and discussion in this paper is that the observations of temperature at ten sampling stations in the area MBPP indicate the existence of the urban heat island in the study area. Various reasons that influence this phenomenon has been discussed. Thus, this research has addressed the research objective in this paper, which is investigation of the temperature, and the heat island has increased over recent decades due to various factors involved.

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