Middle-East Journal of Scientific Research 11 (11): 1602-1613, 2012
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2012.11.11.1590

Mitigation of the Urban Heat Island of the City of Kuala Lumpur, Malaysia

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Abstract: The study focuses on five strategies to mitigate the urban heat island of the city of Kuala Lumpur, Malaysia. The study discusses and summarized the UHI studies on the city since the first study done 1972 by Sham S. It is concluded that, heat island intensity is ranging from 4° C-6° C influencing air pollution dispersion and energy demand for cooling in city of Kuala Lumpur. The study discusses the causes and effects of the UHI. Six factors contribute to the cause of the urban heat island; Urban Fabric, Nature of the City Structure, Artificial Heat Production, Evapotranspiration, Unique Property of the Urban Environment and Urbanization and Human Activities. On the other hand, five noticeable effects of the urban heat island are discussed; Human Thermal Comfort, Human Health, Economics, Pollution and Meteorological and Climatologically Effects. Previous studies show that, most of these causes and effects are applicable on the City of Kuala Lumpur. Therefore, the study necessitates five strategies should be functioned by political leaders, policy makers, urban planners and engineers to mitigate the UHI of the city. The main strategy for lessening the intensity of the UHI of the city is Land Management and Plant Cover. While, raising the awareness strategy is vital. That is because of its effect on the rest of strategies. Land, Building, Roof and Traffic strategies will not be acquired without good levels of awareness and understanding to the effects of the outdoor living environment on indoor environment and to what extent it might put human comfort and health into risk.

Key words: Urban Heat Island · Mitigation · Strategies · City of Kuala Lumpur · Malaysia

INTRODUCTION

Malaysia is experiencing similar climate of hot humid temperature throughout the year. The typical Kuala Lumpur climate has the characteristics of very small variation in monthly temperature, highest temperature of the hottest month (February/March) is 32-33 °C and the coolest month is December with 31 °C. The lowest temperature is 23-24°C [1]. Malaysia has 14 metropolitan regions with a population of 75,000 persons. Kuala Lumpur (KL) city is the capital city of Malaysia with a population of 1504300 persons, recognized as the greatest metropolitan area within the country [2]. Large urbanized regions have been shown to physically alter their climates in the form of elevated temperatures relative to rural areas at their periphery. Urbanization that took place in 30 urban centers in Malaysia including Kuala Lumpur to some extent plays a quite significant role in changing the urban air temperature pattern. Brian [3] compared the elevation of temperature caused by global warming phenomenon and that which is caused by the urban heat island (UHI). He contends that the global warming forecasts predict a rise in temperature of 3.5 to 6°F over the next century, while large urbanized regions are measured to be 6 to 8 °F warmer than surrounding rural regions. Increasing at a rate of 0.25 to 2 °F per decade, the heat island effect within urban cores of rapidly growing metropolitan regions may double within 50 years. In light of the roughly 2.9 billion new residents projected to arrive in urban regions between 1990 and 2025, there is a pressing need to ascertain the implications of urban warming for metropolitan regions and to identify potential strategies to counteract regional climate change. While Sham [4] added that, the effect of metropolitan regions is not only confined to horizontal temperatures but also to those in the vertical direction with far-reaching consequences, studies have shown that the thermal influence of a large city commonly extends up to 200-300 m and even to 500 m and more. Deterioration of the environment is always related to development and human activities. The impact of human activities is increasing. Man through his activities produces a significant amount of heat. Man has

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become a primary source of heat production from transportation systems, industrial plants and heating ventilation and air conditioning systems that is installed for cooling the buildings to lower the internal temperature to suit human thermal comfort inside the buildings. Studies show that the urbanization and human activity are major factors in increasing the intensity of the UHI and contribute significantly as one of the causes of the urban heat islands [5]. Heat Island is one of the many areas of deterioration of the environment due to development and human activities.

The research discusses strategies that will contribute to the mitigation of the urban heat island of city of Kuala Lumpur the capital of Malaysia.

Urban Heat Island Studies in City of Kuala Lumpur: The urban heat island of city of Kuala Lumpur was first studied by Sham S. early 70s. He did his studies in 1972, 1973, 1976, 1977, 1980, 1984, 1986, 1987 1989 and 1990/1991. He [6] used temperature traverse technique to study the urban micro-climate in Kuala Lumpur and he found that temperatures were normally higher in the central district than in the rural areas around the city and the intensity of heat island was normally greatest during calm and clear sky at nights as compared to the intensity of heat island during the day. Later Sham [7] proved that the maximum heat island intensity for Kuala Lumpur-Petaling Jaya twin cities was between 6° and 7°C. Shaharuddin [8] studied some effects of urban parks on air temperature variations in Kuala Lumpur. He used the technique of temperature traverse across the study area during clear and cloudy skies. He found that the maximum UHI intensities of from 3° to 5°C were mostly established under partly cloudy skies and clear conditions. On the other hand, the lowest UHI intensity of about 1°C was mostly associated with rain condition prior to data collections. Sham [4] concluded from the previous studies carried out over 20 years period, the mean annual temperature difference between the city of Kuala Lumpur and Subang Airport was approximately 1.0-2.0°C but under calm and relatively clear sky nights, the temperature differential could go up to 6-7°C.

Siti Zakiah [9] anticipated to provide a basis for understanding and create awareness on the importance of comfortable outdoor living environment for comfortable human life and living with serious attention on issues of urban heat and the effective use of natural elements such as plants and water as heat ameliorator for Kuala Lumpur city. Her results showed that the temperature and humidity readings taken at vegetated and densely built-up areas in the city, showed a difference of an increase of 5°C to 8°C temperature and a reduction of 10% to 14% humidity. She mentioned that, general public displayed a lack of understanding and awareness on the impact of heat to their outdoor comfort while professionals gave priority to requirements and guidelines in their own professional area rather than looking at the urban environment in total during the designing and implementation stage.

Elsayed [2] measured the intensity of the nocturnal UHI of the city of Kuala Lumpur. She used traverses survey method similar to that used by Sham in 1985 at similar timing. She compared the intensity and the location of UHI of the city. She found that, the location of the nucleus of the UHI is shifted from Chow Kit area to Puduraya area. Furthermore, she found an increase in the intensity of the UHI equivalent to 1.5°C.

Shaharuddin and Hashim [10] investigated the application of remote sensing thermal infra red band for detecting land surface temperature and the effect of soil moisture content on urban heat island occurrences. The study believed that the high moisture content due to antecedent precipitation in 1999 image has a removal effect on the urban heat island intensity.

In a recent study [11] based on Moderate Resolution Imaging Spectroradiometer-Earth Observing System (MODIS) data of Kuala Lumpur Metropolitan City from 2008-2009, land surface temperature (LST) was retrieved and used to get the pattern of the UHI of the city. The preliminary result showed that the mean highest LST occurred in South West Monsoon period during daytime, while area with high urban imperviousness coverage is the most notable UHI gradient. Surface urban heat islands are typically present day and night, but tend to be strongest during the day especially in the Northeast monsoon. The existence of urban Cold Island in some season can be associated with the occurrences of urban green patch within the metropolitan area.

The latest study done [12] observed the problems of Kuala Lumpur shophouses using conceptual framework to understand the correlation among increasing the intensity of UHI, the production of anthropogenic heat and energy consumption. The study literately investigated the impact of Urban Heat Island on energy consumption and determined factors can directly affect energy use in shophouses with focus on anthropogenic heat factor. It suggested three important strategies to minimize the impact of UHI on energy consumption. Although the strategies focus on promoting natural ventilation of shophouses, using appropriate materials on

external surfaces and providing appropriate greenery, the study did not explain how far the intensity of the UHI was during the study period.

Generally, Observations carried out in the Klang Valley and Kuala Lumpur, indicated that commercial centers are usually several degrees warmer than the surrounding countryside. On the average, the mean annual temperature difference between the city and the airport was approximately 1.0-2.0° C but under calm and relatively clear sky nights, the urban-rural temperature differential could go up to 6-7° C.

Cause and Effect of the Uhi

Cause of the UHI: There are many factors combine to warm cities generally and city of Kuala Lumpur specifically. There are at least six causes and factors, being unique to cities in general and metropolis especially, that control the urban climate and hence the urban heat island formation. Malaysia has 14 metropolitan regions. Kuala Lumpur city is the capital city of Malaysia and the greatest metropolitan area within the country [13]. The six factors that contribute to the cause of the urban heat island are discussed as follows:

Urban Fabric: The vegetation, crops and soil of the countryside are replaced in the urban environment by bricks, concrete, steel, asphalt and glass. Thus compared to the rural area, the city is generally a drier, denser, less pervious and more rigid surface. Thus, the thermal properties for the two surface areas are significantly different. Particularly, it is usual to assume the urban fabric to possess a much higher conductive capacity and hence a greater ability to absorb and store daytime solar radiation, resulting in a time lag in the diurnal temperature and a subsequent release of the stored heat during the night time. Primary constituents of urban construction, such as asphalt cement and roofing tile, have a much greater heat capacity than the forest vegetation and other natural features that have been increasingly displace within metropolitan regions such as the city of Kuala Lumpur. As a result, urban structures absorb a large quantity of thermal energy during the daylight hours and slowly re-emit this stored heat during the late afternoon and night.

Streutker [14] discussed the thermal properties of materials used to build urban structures and cover urban land surfaces, describing its substantial variation from materials found naturally in rural areas. He recognized that, the specific heat capacity of moist soil is approximately 50% greater than that of asphalt and concrete. Moreover, the radiative properties also differ, such as the very low albedo of asphalt relative to that of natural surfaces. The thermal admittance of the surface material is one of the most important thermal properties in causing the urban heat island. The thermal admittance plays a role in determining the amount of thermal flux throughout a substance of a given temperature profile. Generally, temperature variation depends inversely on the thermal admittance. While urban materials have low thermal admittance, moist soils and vegetation have higher thermal admittance. As cities grow, buildings and paved surfaces replace the natural landscape. Hard inert surfaces absorb heat, causing their temperature to rise steadily with increasing exposure. Dark colored surfaces like roofs, roads and parking lots absorb the greatest amount of heat. Large masses of tarmac, concrete and steel buildings absorb and store large amounts of heat, which in turn is radiated into the surroundings. Elsayed [15] mentioned that, as the city of Kuala Lumpur grows, two important effects take place: the amount of trees is reduced and there is an increase in ambient temperature.

Nature of the City Structure: The effective surface area of a city is much larger than that of a rural countryside of equivalent size. Due to the canyon-like topography of urban areas, especially the urban cores, one might expect the city to possess a greater ability to exchange heat by radiative and turbulent transfer. Shortwave radiation is more efficiently absorbed in the urban areas than in rural areas. The canyon topography leads to an increase in the active absorbing surface and allows for multiple reflections of solar radiation, resulting in the shortwave radiation being more easily absorbed than in rural areas. In reality, however, the configuration of buildings tends to trap radiation within the city and even reduces the turbulent transport at street level due to stagnation between the roughness elements. This subsequently leads to strong heating of the lowest layers of the atmosphere directly above the ground. Streutker [14] contended that, multiple geometries allow for better absorption of sunlight during periods of high solar zenith angle. The canyon effect lowers the overall albedo of the entire urban area independent of the individual albedos of the surface materials. Moreover, the canyon geometry also decreases sky view. Thus, the efficiency with which the urban area can radiate long wave radiation into the atmosphere and out into space is decreased. The multiple surfaces of canyon permit for the reabsorption of long wave radiation, inhibiting the loss of heat through radiative cooling.

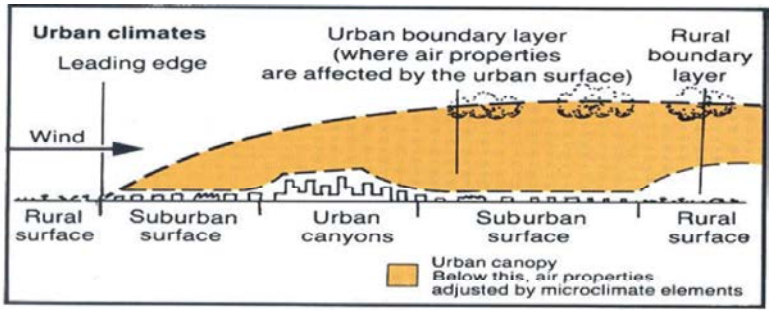

Fig. 1: Impact of an Urban Area on the Surrounding Climate
Source: Tamagno B. *et al*. [16]

Urban areas occupied by multi stories buildings, tall buildings and skyscrapers have had a huge visual impact on the world's large cities. These multi-storied buildings found in cities centers dominate the skyline and have a dramatic effect on the microclimates of the cities. Large cities have a considerable impact on the climate of their immediate surrounding areas [16] (Figure 1). Some of these effects are the creation of heat sources and the dramatic changes in airflow and wind speed.

Artificial Heat Production: The amount of artificial heat produced to cool down homes and offices, to operate industrial plants and to propel automobiles is one of the recognized factors that share in the increase of temperatures in urban areas. Oke [17] reported average sensible heat releases from the steel works in Hamilton, Ontario as 0.53-0.80 cal. cm? ^{2} min? ^{1}.Which in turn helps in increasing the amount of heat available for cooling in urban areas. In tropical modern cities like Kuala Lumpur [18], in order to produce the cooling effect by air-conditioning buildings, a considerable amount of hot air must be pumped out to the atmosphere.

Evapotranspiration: The displacement of vegetation and soils further enhances heat retention by limiting the effectiveness of a natural cooling mechanism known as evapotranspiration [18]. The largely reduced evapotranspiration caused by the rapid run-off of precipitation into drains and by the limited amount of vegetation in urban areas is a contributing factor affecting the urban heat island. Urban areas typically replace natural surfaces with artificial ones; there is a marked lack of vegetation in the urban environment. The city with its acres of concrete has a high thermal conductivity and heat capacity. Heat flows easily into the concrete during the day and is stored. At night, as the surface cools, there is a flow of heat upward to balance the surface heat loss. Thus the city, with high thermal admittance, stores more heat during the day and releases more at night. On the other hand, trees and natural vegetation use the sun's energy for photosynthesis to produce food. They make use of sun light instead of heating up compare to other surfaces within city. They also absorb water from their roots and transpire through their leaves, this evaporation process through which heat is absorbed from surrounding surfaces. Tropical forests are always cool even at the hottest time of day.

The Unique Property of the Urban Environment: The unique property of the urban environment is its envelope of air pollution. The atmosphere of urban areas typically has higher pollution levels than that of surrounding rural areas [14]. The anthropogenic heat sources and aerosols from pollutants is one of many factors contribute to the formation of the urban heat island [11]. Climatically, air pollution plays its most effective role in modifying the component fluxes of the radiation balance [18]. The most affected areas by this unpleasant magnitude of heat are the metropolis and city center, which describes the urban heat island phenomenon.

Urbanization and Human Activities: Atmospheric modifications through urbanization have been noted. Climatically, one obvious consequence of urbanization is the creation of the heat island [18]. Most people would argue that changes in the location and concentration of commercial activities, especially in large cities, have produced the greatest visual impact on the built environment [16]. In cities, man has altered the roughness of the earth's surface. He changes small features, such as trees, bushes, houses, the spaces between them…etc. The city, in most situations, has rough features and surfaces compared to the open countryside. Increase surface roughness affects the wind structure and causes a major modification in the vertical wind profile so that wind speed near the surface is reduced (Figure 2).

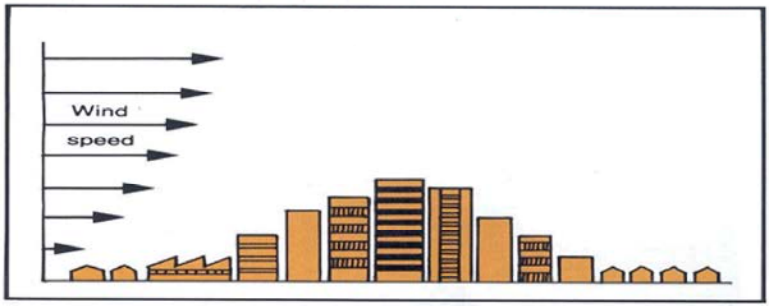

Fig. 2: Elevation and Wind Speed
Source: Tamagno [16]

These urban areas have an increased surface roughness, which slow down the surface winds. This inhibits sensible heat loss from the urban surface through atmospheric convection [14]. The structural features of cities, because they interfere with laminar flow, increase the number of local eddies and thus increase the turbulence. The decrease of wind speed over cities is poorly documented. From available records, suggest that wind speed in cities is about 25% less than in rural areas [18]. Man, through his urban constructions, has affected the exchange of energy and moisture within the system by altering the physical qualities and materials of the earth's surface. Furthermore, he has become a primary source of heat production within the system of the city. These changes ranging from the heat release of fossil fuel combustion to that of the human metabolism have been documented. A typical automobile operating in a city burns about three gallons of fuel per hour, while a man produces heat at a rate of between 100 and 300 watts depending on his activities, a person produces about 100 watts at rest and about 200-300 watts while working. Some heavy work done by man may produces even more. The net contributions of combustion, heating and metabolism together with the impact of changes in the physical surfaces can produce an impressive adjustment of the earth's heat budget in urban areas.

There are other factors related to human activity that contribute to the formation of the urban heat island like the anthropogenic heat sources. These anthropogenic heat sources are coming indirectly from transportation systems hot air exhaust, industrial manufacturing processes and, HVAC systems for commercial and residential buildings [2]. Moreover, the absence of vegetation and greenery that were replaced by homes, offices and buildings.

Effects of Urban Heat Island

Human Thermal Comfort: In many developing countries, towns are expanding and an increasing proportion of the land is being taken up for urban land use, replacing fields, farms, forests and open spaces resulting in a distinctive unpleasant climatic conditions, which are experienced by the majority of urban inhabitants in the world today [8]. His study described how development and changes of urban land use in Kuala Lumpur-Petaling Jaya over time are related to the modification of ambient temperature, the relative humidity and wind speed and hence, the human comfort. He found that the annual effective temperature had increased by about 1.0°C from 23.1°C in the 1970s to 24.1°C in the 1980s, while Elsayed [2] found an increase in the intensity of the UHI of the city of 1.5 °C. The increased thermal load in warm and hot environment, in a tropical city like Kuala Lumpur, will only increase the feelings of discomfort. The excess warmth within the urban layer causes an increase in human heat stress leading to greater cooling demands and a concomitant increase in energy utilization. Of course, the outdoor air temperatures play a significant role in influencing the indoor environment. Unless the outside temperature is suitable, human could not experience nice indoor environment and feel thermal comfort.

Human Health: The implications of urban warming for human health within affected regions can be substantial. Environmental temperatures affect human well being and, in extreme circumstances, affect human health. The effect of the city upon out-door temperatures may often warrant serious considerations. High environmental temperatures are deleterious to health and comfort and prolonged exposure can be instrumental to the incidence of stroke, heart diseases and pulmonary disorders. Streutker [14] described a devastating heat, wave that killed over 500 people in Chicago in 1995. With the vast urban population, urban heat waves pose a major threat to a huge number of people across the United States and around the world. On average over 1000 people die each year in the United States due to extreme heat, more than from any other type of weather-related event by nearly an

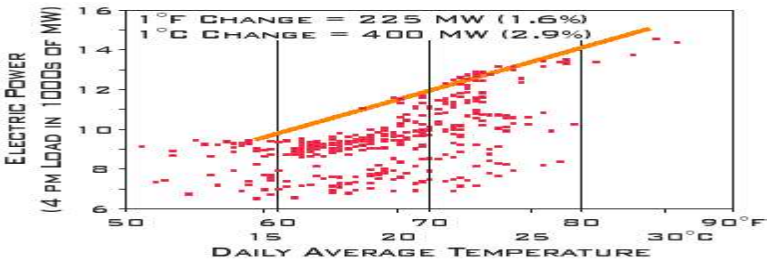

Fig. 3: Heat Island and Energy Cost
Source: Heat Island Group, http://eetd.lbl.gov/EA/Buildings/Projects

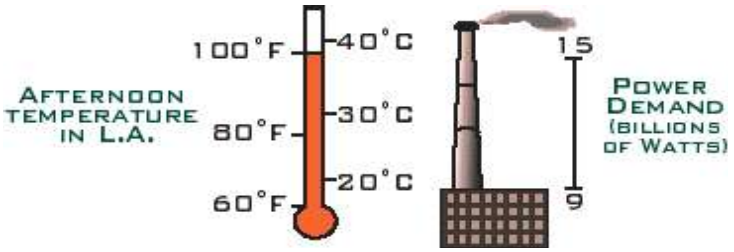

Fig. 4: High Temperature and Energy
Source: Heat Island Group, http://eetd.lbl.gov/EA/Buildings/Projects

order of magnitude. Heat-related deaths most often occur during periods of prolonged high temperatures, heat waves. Heat waves and the resulting mortalities can be exacerbated within cities by the increased temperature due to the urban heat island. Even though temperatures are highest during the day, the extreme night time temperatures resulting from the urban heat island are thought to have a more deleterious effect on mortality. This occurs because inhabitants of urban areas experience heat stress both day and night. The total mortality rate during a heat wave increases exponentially with maximum daily air temperature. Stronger heat islands are therefore quite likely to increase mortality rates. While the increase in pollution levels leads to more incidences of respiratory illnesses, another impact of the urban heat island on public health.

Economics: The effect of the urban heat island in some cities has been estimated to cost millions of dollars annually. Mostly due to the greater need to cool buildings, Houston alone could save $82M annually (as well as reduce carbon emission by 59 kilotons) with the implementation of techniques used to reduce the urban heat island, such as urban reforestation and the use of high albedo roofing materials [14]. Higher temperatures in urban heat islands bring with them increased energy use, mostly due to a greater demand for air conditioning. As power plants burn more fossil fuels, they increase both the pollution level and energy costs. On warm afternoons in Los Angeles, the demand for electric power rises nearly 2% for every degree Fahrenheit the daily maximum temperature raises. It is estimated that about 1-1.5 Giga-watts of power are used to compensate the impact of the heat island. This increased power costs the Los Angeles ratepayers about $100,000 per hour, about $100 million per year (Figure 3 and 4). In urban areas especially in Kuala Lumpur and the Klang Valley conurbation [10] heat island intensity in the order of 4°C-6°C influencing air pollution dispersion and energy demand for cooling. The effect of UHI obviously has far-reaching implications. It has not only affects human thermal comfort, health and energy utilization for air conditioning; it also affects Malaysians' national economy.

Pollution: Higher ambient temperatures increase air conditioning energy use. Thus, power plants burn more fossil fuels. This directly raises pollution levels. Urban heat islands are smoggier. Smog is created by photochemical reactions of pollutants in the air. These reactions are more likely to occur and intensify at higher temperatures. Figure 5 and 6 show the situation in Los Angeles City where, for every degree Fahrenheit the temperature rises above 70°F, the incidence of smog increases by 3%. The higher is the temperature, the higher is the formation and concentration of smog.

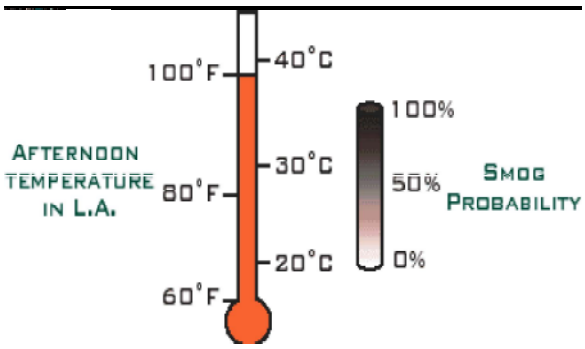

Fig. 5: Temperature and Smog Levels

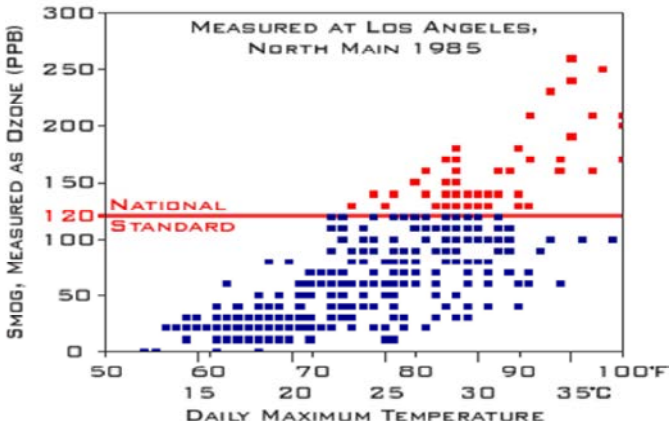

Fig. 6: Temperature Rise and Smog
Source: Heat Island Group, http://eetd.lbl.gov/EA/Buildings/Projects

The increase in temperature in urban areas could accelerate certain atmospheric chemistry cycles leading to an increase in ground-level ozone [14]. Higher air temperatures can also cause an increase in the emissions of biogenic hydrocarbons as well as higher evaporation rates of synthetic volatile organic compounds (VOCs), both of which are linked to the production of tropospheric ozone.

Haze is an additional kind of pollution related to the UHI effects. While pollution sources are an imported contributory factor to the occurrence of the haze, meteorological factors play an equally decisive role in determining the extent and magnitude of the haze [4]. The imported meteorological factors that contribute to the occurrence of the haze are: the synoptic, rainfall intensity, upper air conditions and the surface atmospheric conditions. The surface atmospheric conditions include surface wind, relative humidity, sunshine hours, radiation and temperature. These surface atmospheric conditions are directly related to the intensity of the UHI. Therefore the haze and the intensity of the UHI are connected through these atmospheric conditions. Thus, the occurrence of urban heat islands helps in the formation of severe haze episodes.

The haze phenomenon whose occurrence was first realized in the early 1960's has now become almost a regular feature of Malaysian environment particularly during the dry months of February-March and June-August [4]. The effects of the haze reached their zenith in 1997 when the sky remained dull with pollution from August until November of that year. The 1997 haze reached new levels of intensity and duration, causing much inconvenience and disruption to the Malaysian economy. The haze aggravated respiratory diseases, forced a decline in crop and fishing yields and caused disruption to transport services, manufacturing output and the tourism industry. Air Pollution Index (API) readings reached 500 for the first time and a state of emergency were declared for a ten day period in Sarawak. The API monitors air quality by measuring fine particles and, carbon monoxide, sulphur dioxide, nitrogen dioxide and ozone, which are hazardous to health. The API can be used to ascertain the effects of air quality on health. Continuous hazy conditions affect health, especially high-risk groups such as children, senior citizens and people who smoke, work outdoors or sufferers of asthma, bronchitis, pneumonia, chronic lung diseases, cardio-vascular problems, or allergies.

Table 1: Aggregate Value of 1997 Haze Damage

Type of Damage	RM Million	US$ Million	Percentage
Adjusted cost of illness	21.02	8.41	2.62
Productivity loss during the state of emergency	393.51	157.40	49.07
Decline in tourist arrivals	318.55	127.42	39.72
Flight cancellations	0.45	0.18	0.06
Decline in fish landings	40.58	16.23	5.00
Cost of fire-fighting	25.00	10.00	3.12
Cloud seeding	2.08	0.83	0.26
Expenditure on masks	0.71	0.28	0.09
Total damage cost	801.90	321.00	100.00

Source: David Glover and Timothy Jessup [20].

Table 1 shows the estimated value of the haze damage to Malaysia from August to October 1997 is RM802 million.

The best known aspect of urban atmosphere indubitably is the high concentration of air pollution and , its attendant increase of ambient air temperature [8]. Pollution is one of the recognized effects of UHI and it bears negative reflection on human health, comfort and economy. The higher the intensity of UHI, the higher the levels of pollution, consequently the higher the resultant cost.

Meteorological and Climatologically Effects: The climatologically changes result from urban heat island effects on the cities are shown in the form of increase in the air turbulence and a reduction in the relative humidity. Moreover; the chemical composition of the air changes; receipts and losses of radiation are both reduced; temperatures are raised and rainfall in some cases increases. Buildings and structures in the urban area further complicate the airflow pattern in the city and hence air pollution dispersion [19]. The urban heat island effect can also be studied as a small-scale version of global warming. The urban heat island magnitude is typically on the order of a few degrees Celsius [13], similar to the amount of global warming predicted to occur over the next century. Urban heat islands can thus be used to study how warming affects such things as vegetation growth, atmospheric dynamics and chemistry and energy exchange between the land and atmosphere [14]. The urban heat island effect is believed to play a role in altering other meteorological phenomena in and around urban areas including the development of clouds and fog, the frequency of lightning strikes, the development of thunderstorm and changes in precipitation rates.

RESULTS AND DISCUSSION

The Malaysian Environmental Quality Report mentions that almost all aspects of the environment have been affected by development activities ranging from deforestation to erosion, hazardous and toxic wastes to water and air pollution and creation of heat islands [21]. This is not surprising as the basis for Malaysia's growth and development has been its relatively rich natural resource. In the early years after independence, environmental problems were considered less important rather, development priorities were regarded foremost. In many of the early development projects, little or no consideration was given to environmental aspects. Although there were some 20 environment-related pieces of legislation available by the end of the 1960s, these were not originally designed specifically to address environmental problems but rather to merely promote sound house-keeping practices in specific sectors in line with government policies at that time [4]. While, developed countries like Canada, Australia, USA and Japan are already issuing comprehensive guidelines to all their big cities to encounter the effects of UHI, even though the phenomena are only a problem in summer. In the hot Tropical cities as Kuala Lumpur, such excess heat could be unbearable especially in the afternoon time. The urban heat island studies done on the city discussed previously show that most of the causes and effects of the UHI is typical and applicable in the city. The study is discussing and recommending five strategies that might be used by Political Leaders, Policy Makers, Urban Planners and Engineers to mitigate the UHI of the city below:

Land Management and Plant Cover:

- Large green areas definitely have positive effect on the temperature of the city. Areas with fewer plants always have higher temperature. On the other hand, the Central Business District area has the highest temperature due to high density and high rise development. Previous studies [4,5,18,22,23] proved that green areas moderate urban temperatures where green areas in city of Kuala Lumpur are relatively low in temperature than non-green areas. Therefore, tree planting programs should be reinforced in the city of KL and incentives and subsidies should be part of the long term planning for the city. Therefore, a well-planned tree-planting program is the main strategy to ameliorate this unbearable excess heat. The use of sufficient and properly spaced parks would also help to ameliorate conditions there. Within the city of KL, many open areas are covered with blocks of marble, granite or tiles. Although these are better than black tarmac, these areas still absorb a lot of heat in direct sunlight and release the heat at late afternoons,

evenings and early nights. Such open areas should be turned into green areas or even very small parks. The creation of as many cities parks as possible will improve the situation and help significantly in reducing the intensity of the UHI of the city.

- The continuous massive tree-planting programs should encourage vertical landscape or rooftop gardens.
- Moreover, tree planting programs should be reintroduced for all housing estates. Incentives and subsidies should be part of the long term planning.
- Furthermore, trees should be planted to shade the hot tarmac of inner city roads like Jalan Tuanku Abdul Rahman, Chow Kit…etc; or low level bushes planted along the covered drains in such areas. Roads and highways, which take up an ever-increasing proportion of the urban area, should also be creatively designed to include green shade, at the very least along the medians. The large masses of concrete in new flyovers continuously being built all over the city, which can capture and store large quantities of solar heat, should also take into consideration plant cover, like overhanging creepers which can shield or block absorption of the heat and reduce the air temperature significantly.
- Car parks areas should comply with a minimum of 50% shade requirement. Previous studies [4,5,18,22,23] show that shade trees contribute significantly to temperature reduction, hence reduction on the intensity of the UHI. Therefore, car parks should comply with a minimum of 50% shade requirement by plantation of trees or/and at least low level bushes.
- Reduce summer solar radiation by managing the land covered by critical surfaces, for example, pedestrian walks, waiting areas and busy streets. Reduce the abundance of concrete and asphalt and increase the amount of vegetation and open water. This will increase higher volumetric heat capacities and greater rates of latent heat influx, thereby lowering air temperatures.

Roof Cover and New Materials:

- Roof tiles for buildings should be manufactured and used to comply with high albedo, reflectivity, values. This means that the tiles reflect most of the sunlight instead of absorbing it and should have light color; dark tiles have the characteristic of heat absorbing. Urban Planner and engineers should recommend and use new materials such as Pre-Painted Steel Roofing that shown in the 12th Malaysia Architecture, Interior Design and Building Exhibition)ARCHIDEX 2011).
- Many commercial buildings, almost all [24] are having flat roofs in Malaysia either to accommodate air-conditioning equipment or water tanks, or for another purposes. Such buildings should green their roofs and planted them with shrubs or low level bushes. This means cultivating greenery on the flat roof surfaces to absorb the heat. This will not only help the city to counter UHI but building owners will also benefit in terms of savings in air-conditioning power consumption.

Buildings

- The implication for the proper urban design of cities in high temperature climates is to plan the buildings so as to weaken the heat island and particularly street temperatures, as much as possible. This may done by the use of sufficient and properly spaced parks and the use of high-albedo, low thermal-capacity, low thermal-conductivity building materials. An aerodynamically rough urban surface would aid turbulent heat diffusion between buildings and a radial street plan, allowing country air to penetrate as deeply as possible into the city centre, would also help to ameliorate conditions there.
- Urban buildings should not be painted in dark colors. Tall buildings should take into consideration that the sides of the buildings are subject to long hours of exposure to sunlight. It would also be advisable to use high albedo tiles for the sides of the buildings.
- Managing the land cover and building design contribute much in increasing airflow at ground level to flush heated and polluted air away from the city.
- Air conditioners, used for buildings make urban heat build-up worse as they continuously emit hot air out into the atmosphere. In developed countries where concerted action is being taken on urban heat island, the main concern is on the large increase in power consumption in urban areas to cool down buildings, with additional air-conditioners or a heavier usage of existing air-conditioners. Whenever the air temperatures are high, the quality of air is deteriorated and that because of the increase in the ozone and pollution levels. Urban heat island will continue to increase power consumption in urban areas in ever-increasing spirals. As urban heat builds

up, people will resort to more air conditioners to mitigate the unpleasant indoor temperature. This in turn builds up more heat and so on. I the city of KL, owners of large buildings especially hotels should recycle this pumped out hot air by installed heat exchangers, which recycle the heat back to the hot water supply or suchlike.

- The reduction of the energy consumption of buildings by combining techniques to improve the thermal quality of the ambient urban environment with the use of up-to-date alternative passive cooling and lighting techniques can partly decrease these kinds of environmental problems.

Traffic Activity

- The use of private cars should be restricted and replaced by public transportation in spotted heat islands within the city, as Elsayed [2] found that, the UHI of the city is directly proportional to the number of cars and inversely proportional to public transport vehicles.
- Moreover, more regulations are needed to control the number and type of registered vehicles in the city of Kuala Lumpur, that increased from 85,000 vehicles in 1984 to more than 2,000,000 vehicles by 2004 [2]. She found that, the intensity of the UHI of the city is directly proportional to the number and type of registered vehicles.
- Air conditioners used for different means of transportations, make urban heat build-up worse as they continuously emit hot air out into the atmosphere. Regulation used for such means should be reinforced and penalties should be applied perfectly.
- Puduraya Neighborhood problem should be tackled seriously. In the city of Kuala Lumpur, the working days are relatively hot compare to non working days, while in the city centre of Kuala Lumpur and specifically at Puduraya station this statement is not true [2]. At Puduraya station, even Sunday is very hot and that because of the location of Puduraya Bus Station. Puduraya is one of the busiest neighborhoods in the city with very high traffic intensity where the main and largest national and international bus station, Puduraya Bus Station, is located Moreover the nucleus of the UHI of the city is shifted from chow Kit area (1985) [25] to Puduraya area (2004) [2] that means the nucleus coincides with the busiest point in the city in terms of traffic activity.

Awareness

- Awareness is in need of a great deal of work. A recent study [1] confirms that the city of Kuala Lumpur lack awareness. The study conducted semi structured expert interviews with planners, architects. The interviews revealed that the consideration of climate in urban development and design is limited in the city. It showed lacks of the exposure to climate responsive design, insufficient guidelines and procedures and use of friendly tools to predict the effect of urban design on the microclimate. She stated that, more than 70 percent of her respondents stated that the urban form of the city was more to do with aesthetics and beautification than the climate responsive design. Consequently, Political leaders, policy makers and the public need to understand and be more aware of the effects of the outdoor living environment on indoor environment and to what extent it affect their comfort and health. Furthermore, they should be aware of the proper use of nature and good planning and their role in mankind comfort and sustaining a good outdoor living environment.

CONCLUSION

Although there are many suggestions and some guidelines for mitigation of the urban heat island, the situation varies from a city to another. The study recommends five strategies need to be applied by political leaders, policy makers or/and urban planners to mitigate the intensity of the UHI of KL. Nevertheless, the main strategy for lessening the intensity of the UHI of the city is well-planned tree-planting program, more studies should be made to assess the effectiveness of small city parks and different types of vegetations as temperature moderators.

Raising the awareness strategy affects the four rest strategies. Land Management and Plant Cover, Roof Cover and New Materials, Buildings and Traffic Activity strategies will not acquired without good levels of understanding to the effects of the outdoor living environment on indoor environment and to what extent it might put human comfort and health into risk. More effort and reinforcement is needed from political leaders, decision maker and urban planners to mitigate the UHI and reduce its effects on the city. New and more pressure is needed from general public on political leaders and policy makers leaving them in no qualm that vital new national and regional measures on urban sustainability is

essential. Mitigation of the UHI of the city through planning and designing necessitates the formulation of a series of strategies and guidelines that ensure the cities to remain lively and attractively developed as projected. The incorporation of climate responsive design strategies can help achieve the city's vision to be sustainable, livable, attractive and thriving city.

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