© 2016 IJSRSET | Volume 2 | Issue 4 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

Perspectives on Heat Index and Climate Change on Thermal Comfort and Human Health

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ABSTRACT

The overdependence on fossil fuels has resulted in significant socio-economic and environmental challenges such as global warming and climate change. The associated greenhouse gas (GHG) and pollutant emissions have raised global temperatures by 2°C above pre-industrial levels worsening climate change. Similarly, lack of adaptive mitigative strategies could possibly result in disastrous effects on human health, safety, and the environment. However, this will require studies on the effects of rising temperatures, heat indexes and its effects on human health, safety and thermal comfort against the backdrop of rising global temperatures. Therefore, this paper seeks to examine and highlight the role of heat index on the thermal comfort health and safety of building occupants. It also presents perspectives on the potential health related disorders such as heat strokes, cramps, rashes arising from rising global temperatures, global warming and climate change. The findings showed setting up Low Carbon Materials (LCM), Renewable Energy Technologies (RET) and Sustainable Design Practises (SDP) could potential aid climate mitigation. In addition, the outlined strategies will improve, preserve and protect human health, safety and the thermal comfort of building occupants against the adverse effects of rising global temperatures and climate change.

Keywords: Heat Index, Thermal Comfort, Human health, Shady Conditions, Environment.

I. INTRODUCTION

Climate change is one of the greatest threats to the existence of humanity today [1]. The continued use of fossil fuels with its associated greenhouse gas (GHG) and pollutant emissions will raise global temperatures by 2°C [2-4]. Further estimates suggest climate change could raise global average temperatures to 1.5°C by the year 2040, 2°C by 2060 and 4°C or higher above pre-industrial levels by the year 2100 [5]. However, the consensus is that lack of adaptive mitigative strategies will result in disastrous effects on human health, safety, and the environment [6]. In addition, projections suggest climate change will significantly impact on socio-economic growth and sustainable development [7, 8]. Consequently, the United Nations Climate Change Conference (COP21 or 2015 Paris Agreement) pledged to limit global warming by reducing the rate of anthropogenic GHG emissions. Furthermore, signatory nations agreed to binding targets, plans and efforts dedicated to reducing climate change by 2050. According to the charter, developed nations pledged to yearly invest USD$100 billion towards mitigation strategies. However, analysts consider the amount insignificant compared with the projected scale of devastation posed by climate change. Empirical evidence points out the global cost of climate change will account for 2 – 10% of GDP by the year 2100. As a result, climate change could severely impact on the global development agenda by impacting on hunger, poverty, and mass migration [9]. Besides, scientists predict the effects of climate change will be significant in developing nations where climate change accounts for 3 - 5% of GDP [5, 7, 10, 11]. The effect of climate change on human health, safety and the environment has been examined extensively [12-15]. The authors agree climate change will severely influence global public health because of inconsistent global temperatures and extreme weather. Thus, the projected heatwaves and cold spells will result in severe droughts, desertification, deforestation, floods, and rising sea levels [16, 17]. In effect, climate change related illnesses such as heat strokes, respiratory and cardiovascular diseases are estimated to rise geometrically increasing pressure on already overstretched health care around the globe. The global rise in surrounding temperatures also presents other significant challenges. Climate change will potential increase energy needs for cooling and heating buildings, which currently accounts for 30-40 % of the energy consumption. However, the pervasive energy poverty in developing countries suggests that alternative measures are needed to reduce the potential effects of global warming and climate change. This will require studies on heat indexes due to rising temperatures and its effects on the thermal comfort of building occupants. In addition, the role of heat indexes and thermal comfort on the health of building occupants also needs comprehensive evaluation. Therefore, the main objective of this paper is to examine the role of heat index on the thermal comfort and health of building occupants. It will also provide perspectives on the potential health related maladies arising from soaring global temperatures, global warming and climate change. Last, the paper will offer potential low cost strategies and carbon technologies to help mitigate the effects of climate change in developing countries.

II. METHODS AND MATERIAL

1. Review of Thermal Comfort and Heat Index

Thermal comfort is the desirable or positive state of a person. It describes how cold or warm a person feels about his environment [18]. However, the most widely recognised definition of the term is described by ASHRAE [19], "Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment". The thermal is typically described using six basic parameters; air temperature, radiant temperature, humidity, air velocity, clothing insulation and heat produced by the person. Therefore the four environmental and two personal factors that influence thermal comfort [18]. However studies by Fanger [20] defines three conditions for thermal comfort; heat balance of the body, sweat rate and mean skin temperature within the comfort limits. The assessment of thermal comfort is the basis of many studies on how people feel thermal changes in the environment. The most commonly used methods are the seven-point scale of Bedford [21] Comfort Scale and the ASHRAE [19] Sensation Scale presented in Table 1. However, one of the most useful metrics for describing, designing and assessing thermal comfort in the environments is the heat (thermal) index. Heat index is the temperature (° F) that determines the thermal comfort experienced by occupants in a shady environment. It is the apparent temperature the human body achieves when relative humidity is combined with the ambient temperature. The heat index has notable impact on both human body and thermal comfort. Thus, the heat index describes the sensations felt by people in a hot, cold, warm or cool environment. In principle, the heat index integrates all the potential human responses in thermal environments into a single value.

Table 1: Scales of warmth sensation [18]

Bedford Scale	Value	ASHRAE Scale	Value
Much too warm	7	Hot	7
Too Warm	6	Warm	6
Comfortably Warm	5	Slightly Warm	5
Comfortable	4	Neutral	4
Comfortably Cool	3	Slightly cool	3
Too cool	2	Cool	2
Much too cool	1	Cold	1

Consequently, when the human body senses heat, it begins to perspire producing sweat to begin the homeostatic process of cooling down through evaporation. Conversely, when the atmospheric moisture content (i.e. relative humidity) is high, the rate of perspiration decreases. In other words, the human body feels warmer in humid conditions. The opposite is true when the relative humidity decreases because the rate of perspiration increases accordingly. Consequently, there is a direct relationship linking air temperature, relative humidity, and heat index. The heat index can assess the effect of rising temperature and by extension global warming and climate change on human health. This is corroborated by empirical studies stating the direct link between heat or high temperature and weather related deaths from the year 2004 to 2013 [14, 15, 22].

The studies revealed that 12.9% of cardiovascular admissions were because of heatwave during the study period. With the growing wave of rising temperatures, it is important to identify, examine and highlight the thermal conditions of buildings. This will not only erase the potential risks of heat related diseases due to climate change and global warming but also ensure the thermal comfort of building occupants. In addition, it will support efforts to optimize energy efficiency of future buildings around the globe. The heat index of any environment can be determined from Table 2.

Table 2: Classification of heat or thermal conditions of an environment [23]

Classification	Heat Index (°F)	Heat Index (°C)	Effect on the body
Caution	80 - 90	26.7 – 32.2	Fatigue
Extreme Caution	90-103	32.2 – 39.4	Heat stroke, cramps or exhaustion
Danger	103-124	39.4 - 51.1	Heat cramps and heat exhaustion
Extreme Danger	125 or higher	51.7&above	Heat stroke

The data presented shows that air temperature is a significant environmental factor that influences thermal comfort. As observed in Table 2, temperatures above 80 °F (26.7°C) will not only result in great discomfort but also health related heat illnesses. Above this threshold, individuals will experience heatstroke, fatigue, cramps, and exhaustion with severe health risks. Therefore, it is critical to identify and examine whether a condition of an environment is favourable, caution, extreme caution, danger, or extreme danger. Similarly, heat index is determined from Figure 1 using relative humidity and temperature [23]. In order to determine the heat index using the chart, data on air temperature and relative humidity must be known. For example, at 100 °F (37.8 °C) air temperature and 55% relative humidity, the heat index will be 124 °F (51.1 °C).

Based on Table 1, such an environment is considered dangerous, as individuals will experience severe cramps and exhaustion. Other heat related maladies will be highlighted in section 3.

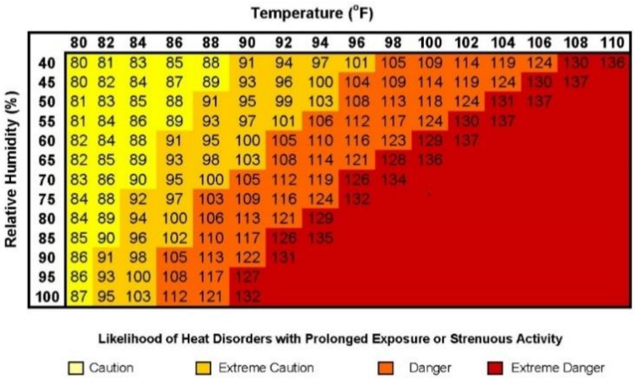

Figure 1: Heat index Chart for Shady Conditions [23].

2. Climate Change Related Health Maladies

With soaring global temperatures due to global warming and climate change, health related illnesses are predicted to increase globally. Table 3 presents an overview of some of the possible illnesses [24]. Various studies have investigated the potential health risks of climate change globally [17]. In addition, the heat related maladies already highlighted Table 3 others health risks could potentially arise from physical hazards, poor air quality, and transmission of infectious diseases. Some studies have also examined the deaths due to heatwaves, climate related thermal stress, and their effects on environmental related issues such as floods, landslides among others. Figure 2 presents a summary of the various ways climate change can affect global health [25]. The findings of the study by McMichael et al., [25] reveals the health effects from climate change will arise from changes in the environmental conditions such as variations in temperature, rain, humidity and wind patterns. In effect, these conditions will result in increased thermal stresses (comfort), deaths, illnesses, and spread of diseases. In addition, the ripple effects will result in loss of livelihoods due low crop yields, floods, desertification water and vector borne diseases, declines in fisheries among others [12, 17]. The potential health hazards of variations in climate change are summarised in Table 4.

Table 3: Heat Related Maladies [24].

Illnesses	Description	Risk Age Group	Symptoms	Remedy
Dehydration	Loss of body fluids through perspiration.	All age groups but particularly infants, children, senior citizens above 50.	Headaches, fatigue, dryness of the mouth, decreased urination and coloured urine.	Drink fluids to replenish lost fluids and lower temperature of the body. Eat foods with high-water content.
Heat Rash	Caused by trapped perspiration due to blocked sweat glands under hot conditions.	All age groups particularly infants, and children.	Tiny itchy bumps surrounded by red skin around the body.	Let the skin dry and cool for the rash to clear. Use calamine lotion to quell itching.
Heat Cramps	Muscle pain due to loss of body electrolytes by sweating.	Mostly experiences by athletes.	Painful contractions in the limbs and abdomen.	Seek shelter in shade. Drink plenty of electrolyte rich fluids and satisfactory rest.
Heat Exhaustion	Loss of the body's natural ability to cool itself through sweating.	All age groups but particularly infants, children, senior citizens above 50.	Substantial sweating, pale sweaty skin, fatigue, fainting, irritability, nausea or vomiting, dizziness, headache and rapid pulse.	Seek shelter in shade. Drink plenty of electrolyte rich fluids and adequate rest.
Heat Stroke	Severe condition of the body due to overheating (above 40°C) and prolonged exposure to high temperatures.	All age groups but particularly infants, children, senior citizens above 50.	Hot red skin; heat cramps, heat exhaustion, dehydration, rapid, strong pulse, hallucinations and hyperthermia.	Move victim to shade and apply cold compresses.

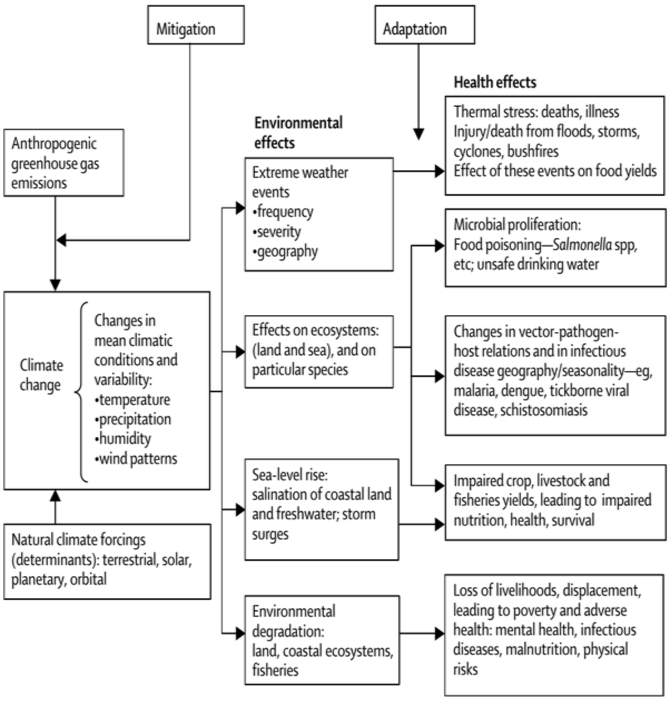

Figure 2: Pathways of climate change effects on global human health [25].

Table 4: Health Effects of Climate Change [25-27].

Hazards	Adverse Effects	Beneficial Effects
Temperature extremes	More daily deaths and disease events due to hotter days.	Reduced disease and deaths during winter in temperate climates.
Floods	More injuries, deaths and other infectious, mental and health disorders.	Varied to none.
Food Poisoning	Greater risks at high temperatures.	Varied to none.
Water-Borne Diseases	Diseases such as cholera amplified by warming of water bodies.	Less risk in heavy rainfall regions.
Vector-Borne diseases	Increase in vector borne illness like malaria, dengue in hot climates.	Survival of vectors impaired by excessive heat and altered rainfall.
Crop Yields	Reduced in many low latitude and low rainfall zones.	Increase in cold regions.
Fishery Stocks	Declines in fishery stocks, and loss of livelihood of inhabitants.	Latitudinal shift in fisheries, ocean warming, invasive species.
Sea Level Rises	Health concerns, population displacement, lost livelihoods, floods.	Varied to none.

In general the result of these related hazards will impact on human health and well-being. Consequently, urgent low carbon mitigation tactics are needed to halt the potential effects of climate change. Section 4 will briefly highlight these strategies with specific emphasis on its effects on thermal comfort, human health and the environment.

3. Low Carbon-Cost Mitigation Strategies

The thermal comfort of building occupants will adversely be affected by the global rise in temperatures due to climate change. As outlined in section 2 and 3, this will potentially result in adverse effects on human health, safety and the environment. As a result, there is an urgent need to identify, examine and highlight potential strategies for mitigating the effects of global climate change. According to various studies [3, 6, 7, 10, 28], this will be achieved by using Low Carbon Materials (LCM), Building Solar Shading Strategies (BS3), Renewable Energy Technologies (RET) and Sustainable Design Practices (SDP).

a. Low Carbon Materials (LCM)

The integration of low carbon materials (LCM) in buildings will play a significant role in reducing the potential effects of climate change and global warming [29]. In addition, the choice of building materials also influences the indoor conditions, thermal comfort and overall carbon emissions of the building. The sum total of all the carbon emissions from building materials and construction products is termed the building embodied carbon (BEC). Typically, the BEC accounts for 20% of all carbon emissions from buildings [30, 31]. Therefore, lowering BEC using carbon sinks and low carbon materials is an important mitigation strategy for climate change abatement. Carbon sink materials can be sourced from sustainable wood, wood based products [32, 33] or substitutes such as bamboo [34]. Low carbon materials on the other hand can be obtained from sustainable processes such as recycling, and bioremediation among others. Examples of low carbon materials include low carbon bricks from coal or biomass conversion fly ash, green concrete, green tiles and recycled metals [29, 35]. Other LCM technologies include the use of locally available waste agricultural residues and earth building materials as low cost, low carbon roof, floor and bricks [36-38]. Empirical findings show that an estimated 10.75 metric tonnes of CO_2 emissions can be saved by substituting bricks, carpets and aluminum with wood in buildings [33]. In addition, the extensive exploitation of LCM can promote environmental and socio-economic development. In general, LCMs must be low cost, locally available and have low BEC to ensure sustainable integration into future buildings. Consequently, this will decrease the need for high-energy consumption required for cooling, heating and operating future buildings to enhance the thermal comfort of building occupants.

b. Building Solar Shading Strategies (BS3)

One of the ideal ways to reduce over dependence of mechanical cooling due to the direct solar insolation on building envelop is through shading of buildings. This strategy protects the building from the direct effect of solar radiation into buildings; consequently reduce the carbon footprint and enhance energy efficiency. Previous studies have also revealed that exterior shading system is the best way of controlling solar radiation [39]. Solar shading can simply be known as solar control or protection against the direct solar heat radiation effect on buildings. It is also the term used to identify various strategies to control the quantity of light and heat from solar insolation on buildings Figure 3.

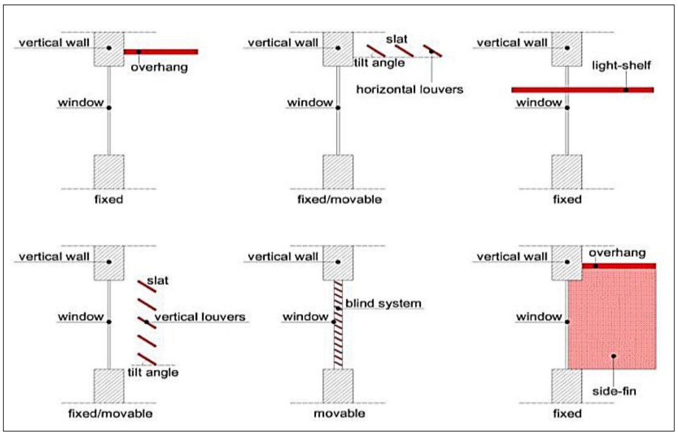

Figure 3: Various shading devices [39]

Therefore, solar shading strategy can lower the energy consumption of buildings, as minimum fossil fuel will be required and invariably reduce CO_2 emission. Shading of buildings can provide substantial energy saving in many areas by:

- Reducing the cooling and heating energy demand by intercepting the direct solar transmission into buildings to avoid indoor thermal discomfort.
- Reducing the quantity of energy needed for electricity through admittance of quality and quantity daylight into the interior.
- Reducing solar heat thereby improving thermal comfort and employees' task performance.

Buildings that utilize passive solar cooling or day lighting mostly rely on a good design solar control system. In doing this, architects or building engineers must take into cognisance of the data obtained from sun path and it diagram.

c. Renewable Energy Technologies (RETs)

The use of RETs in future buildings can potentially reduce carbon footprint and lower energy consumption in buildings. Currently energy consumption in buildings is significantly high resulting in low carbon footprint and GHG emissions. However, with the current climate of stricter building codes companies have been forced to reduce energy consumption. In addition, increasing global energy prices have necessitated the search for more sustainable or renewable sources of energy. Consequently, integrating RETs such as solar, wind, fuel cells and biomass technologies can potentially address the challenges of climate change and global warming [40]. Furthermore, incorporating RETs in buildings will increase energy efficiency and significantly lower BECs resulting in higher thermal comfort [41, 42]. The use of RETs such as hybrid ventilation, passive solar cooling and natural or daylighting are also known to increase thermal comfort in buildings [43].

d. Sustainable Design Practices (SDPs)

Integrating sustainable building design practises can significantly lower energy consumption buildings. Similarly, thermal comfort is dependent on energy consumption in buildings. Therefore, sustainable building designs aim to ensure that occupants are thermally comfortable with minimal auxiliary heating or cooling [44, 45]. Examples of SDPs are passive design, and climate responsive or eco designs. Others are incorporating kinetic architecture, use of daylighting and natural ventilation designs in future buildings. These SDPs utilize minimal materials, LCMs and energy [18, 43].

III. CONCLUSION

The paper examined the role of heat index on the thermal comfort and health of building occupants. In addition, perspectives on the potential health related illnesses that can potentially arise from soaring global temperatures, global warming and climate change were also presented. Lastly, the paper briefly highlighted some potential low cost strategies and carbon technologies for mitigating the effects of climate change. The findings showed that the application of Low Carbon Materials (LCM), Building Solar Shading Strategies (BSSS), Renewable Energy Technologies (RET) and Sustainable Design Practices (SDP) can potential address the challenges of global rising temperatures and climate change. The defined strategies can also to improve, preserve and protect human health, safety and thermal comfort of building occupants against the adverse effects rising global temperatures and climate change.

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