Urban Heat Island: Its Causes And Impact For Depletion Of Resources

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Abstract: Increase in temperature is one of the trending topics over few years. The impact is mostly observed in urban areas (also known as "Urban Heat Island") due to anthropogenic activities. This paper aims to study causes behind rise of temperature in different areas within city bifurcated by Central Business Districts (CBD) and non-CBD areas of Karachi city, it also focuses on remedial actions of increase in temperature. Anthropogenic activities create a temperature difference of 0.5°C to 5°C depending upon their intensity. Types of data, like; questionnaire, real air time temperature, city temperature and population growth, were analyzed using simple frequency method in SPSS to analyse questionnaire and results were plotted on graphs to compare the degree of fluctuations. The results were in favor of the study and showed that there is rise in temperature with increasing trend of anthropogenic activities, which is very useful to our industries and governmental organizations for implementing various mitigation measures more importantly awareness towards increasing trend observed in air temperature; which further enhances the impact of urban heat island (UHI) on individuals.

Index Terms: Rise in Temperature of Karachi, Urban Heat Island, Urban Heat Island in Karachi, Minimum 7 keywords are mandatory, Keywords should closely reflect the topic and should optimally characterize the paper. Use about four key words or phrases in alphabetical order, separated by commas.

1 INTRODUCTION

MORE than 50% of people around globe are urban dwellers and Asia has almost 49.6% of its population living in cities, which is estimated to rise up to 70% by 2050 [1]. Increase in population growth is causing rapid urbanization, almost 828 Million people are living in slums, which are increasing rapidly, affecting land cover and land use pattern. These changes impact local biodiversity, ecology and urban green spaces. Urban areas cover around 3% of Earth's land but are responsible for around 75% of energy consumption and carbon emissions; presence of carbon-dioxide has increase up to 30% in last one and a half century, while half of this increase was observed in last 3 decades. Change in climate is a serious concern nowadays and its impacts can be observed in urban areas [2]. A degree increase in weather temperature can cause alarming situation in any part of the world, this change in climate is not limited to lands but oceans also get affected [3]. This increase in temperature has caused increase in extreme weather events and possibilities of natural disasters, like; air pollution, increase in sea level, fatal heatwaves, water scarcity, inland and coastal flooding, etc. [4]. Rise in temperature is mostly observed in southern Asian region, including Pakistan. This frequent rise; escalate the baseline temperature and unplanned urbanization is reason of UHI effect, which ultimately is threat to developing nations. In natural disasters related to weather, rise in temperature is becoming a prime cause to mortality. Irregular increase in heat-wave is part of global warming effect which show a negative impact on society [5].

As per National Disaster Management Authority if temperature is greater than 45°C for two days continuously, then this condition is called heat-wave condition [6]. There is a positive relationship between mortality and sufferings due to rise in temperature [7]. Heat-wave indicate that change in climate globally causes extreme weather conditions, causing delay in monsoon and rainfall cycle, these delays become more critical due to urbanization and industrialization [8]. UHI is a general phenomenon used for higher temperature area within city, described as "Urban Heat Island can be referred to as metropolitan area that is lot warmer than its nearby surroundings" [9].

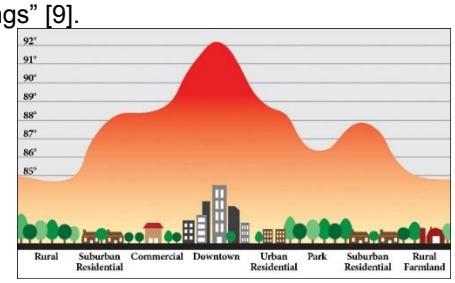

Figure - 1

Urban Heat Island Profile [10]

Can also be explained as "Man-made areas: CBD; within a city which are hotter than their surrounding areas non-CBD. The annual mean air temperature of city with population more or equal to 1 million can be 1-3°C warmer than its surroundings" [11]. The desirability to live an urban lifestyle and need of individuals to work in industries apart from agriculture has increased number of urban dwellers. This increase in population growth has caused difficulty for cities local administration to control or facilitate individual with basic necessities. Apart from basic issues like population growth, transportation, industrialization, waste generation and high-rise buildings; climate change is playing a vital role in enhancing the intensity of these problems; which ultimately are giving rise to UHI effect resulting in positive and negative impacts. Objectives of this research are; to study causes behind UHI, to recognize impacts of UHI and to identify remedial actions to decrease intensity of UHI and depletion of resources. The scope for this study is limited to Karachi being the CBD of Pakistan, in which the causes that are to be identified restricts to; climate change, urbanization (population growth, increase in transportation, increase in industrialization, increase in waste generation, increase in high rise buildings). Further, their impacts are to be identified which are confined to; positive impacts (increase in sales of cooling equipment, cold consumable goods and maintenance of cooling devices)

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and negative impacts (health issues, traffic congestion, anti-social behavior, energy consumption, infrastructure problem, water and sanitation issues). In last remedial actions are be identified in order to decrease depletion of resources. Karachi being the CBD and hub of industries in Pakistan has welcomed every individual; this increase in population growth (trend in urbanization) has brought numerous issues for local administration, particularly in summer season where already weather is hot and UHI plays a vital role in increasing the temperature in city centers resulting in, health issues, traffic congestion, anti-social behavior, energy consumption, infrastructure problems and water and sanitation issues. Therefore, it is essential for every individual to have a clear idea of how they are contributing towards UHI and what remedial actions could be taken to at least minimize resource depletion.

Following research model has been developed in order to achieve the objectives of the study.

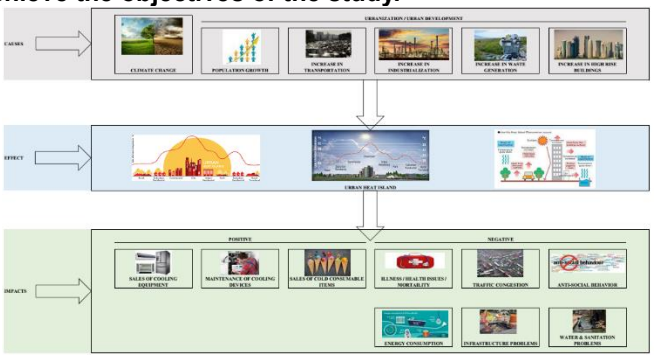


Figure - 2
Research Model

2 LITERATURE REVIEW

2.1 Urbanization

There is drastic increase in urbanization globally, which is expected to reach 70% by the end of 2050 [12]. Thousands of people are migrating on regular basis to cities [13], this increase in population is cause to several negative socio-economic and environmental impacts [12]. This growth in urbanization is not only affecting growth in population but cities land cover is also increasing [12], leading towards various issues, like; densely populated areas, non-used structures, impervious surfaces, changes in climate, hydrological demand, etc. [14]. These issues bring with themselves scarcity of basic resources, which ultimately increase problems for government like; inadequate delivery of basic services as provided by government, traffic issues, scarce housing resources, education, health and unemployment [15], increase in non-effective residential communities (slums), increase in crimes, scarcity of clean water and energy, metrological issues [16], improper disbursement of solid waste management [17]. These issues lead to difficulties in leading an urban life [18].

2.2 Urban Developments in Pakistan

Pakistan has gained its growth in both promising and problematic scenario's; which is caused due to population growth and relocation/internal migration [19]. The years of Pakistan migration can be differentiated as follows [20];

- Partition Age (1947) – Millions of people migrated from India to Pakistan especially Sindh and Punjab
- Post Partition Age (1965 & 1971) – Migration from East Pakistan (currently known as Bangladesh)
- Anti – Soviet Era (1980's) – Millions of Afghan refugees crossed border in search of better urbanized life and resided in Khyber Pakhtunkhwa and Baluchistan.
- War against Terrorism (2010's) – Millions of dwellers from Northern Pakistan shifted to major cities of Pakistan for better opportunities.
- In contrast to above, majority of families are migrating on daily basis to urban areas in search of better livelihoods; including, healthcare services, educational opportunities and jobs.

2.3 Urban Development in Karachi

Karachi holding the top urbanized city of Pakistan [21], is also positioned at 20th number for being the most populated city in world [22]; as described in below figure – 8; there is an increase of over 15 million population over a period of 7 decades [23]. With a growth rate of around 5.2% per year [24] and these statistics are expected to increase to 20 million by 2025. Karachi has expanded from 104.258 km2 to 820.052 km2 in 5 decades and is still increasing over a period of time. During this time period the increase in land cover area observed is around 715.794 km2 with a growth rate of 13.35% per year on average [25]. These statistics result in an unorganized expansion of urban area, with more than 50% of inhabitants living in informal urban built-up [26]. These dwellings have brought deficit to basic urban necessities; like, water for drinking, sanitation issues, solid waste management facilities, shortage of basic infrastructure, non-regularized transportation issues, environment pollution and poor governance, etc. [27]; if these issues are not tackled Karachi will be at verge to deterioration in coming decades.

2.4 Urban Heat Island

Main reason for masses to migrate to urban cities is search of basic needs of life [28], this urbanization has transformed metropolitan area into heat islands [29] and term used for this change in temperature is known as urban heat island (UHI) [30]. Urban heat island (UHI) is a terminology in urban climate, which defines warm weather of cities in comparison to their surrounding neighbourhood. UHI plays a vital role in planning phase of cities / urban areas especially where climate is hot. The world is changing and UHI analysis is being importance throughout the world [31]. An increase in temperature at night is being observed due to urban infrastructure, having capacity to absorb temperatures at night and revert after the sun sets. UHI is indirectly connected to climate change and greenhouse impact [32]. Most of the countries are trying hard to adapt strategies helpful in reducing the UHI effect. UHI depends upon; urban structure, ground cover, urban fabric and urban metabolism [33]. It can be observed that effect of mitigation measure cannot be easily assessed [34]. [35] Living organisms live in troposphere, one of the layers of atmosphere. Urbanization pollutes the layer, for which there are different atmospheric properties in an urban area. It nullifies natural heat and hydrological balances. These characteristics of troposphere produce different urban layers which are related to intensity of UHI. The area within a city which is warmer than surrounding area due to atmospheric and surface modifications which is caused by urbanization is known as UHI [36]. In UHI temperature at night is warmer than its surroundings which can also be considered as one main

characteristics of urban area. Urban area is full with anthropogenic an activity which is a cause to heat and pollution release in atmosphere causing major modification in troposphere [37]. UHI thus, can be linked with city development and urban growth [38]. UHI has direct effect on various factors, including; energy efficiency, environment and on human physically and psychologically. Temperature of cities is dependent on factors like population, number of concrete structures, energy consumption and density of re-creational areas [39]. [40] described that albedo of urban materials, reduction in green lands and increase in traffic significantly contributes in UHI occurrence. Luke Howard was the first person to investigate UHI in 1833, in which he concluded that London was 1.48°C higher than its surroundings, his study was based on monthly average temperature from 1807 – 1816. [41]Radical increase in urban population has given rise to anthropogenic activities, leading to development of urban microclimates [42]. The increase in temperature at microclimate is due to many factors like; vehicle emissions, industrial effluents and domestic works [36]. Increase in above factors further enhances greenhouse gases and Chloro-floro-carbons (CFC) in environment, causing absorption of long wave radiations and increasing the temperature within its boundary [42].

[42] There are two types of UHI

1. Atmosphere Heat Island; further divided into; a. Urban Canopy Layer & b. Urban Boundary Layer; where urban boundary layer can be defined as layer in troposphere above city impacted due to urban activities, which is approximately ten times higher than height of highest building in the same city [43].
2. Surface Heat Island; can be further explored due to availability of online remotely available sensed datasets [30]. Researchers now can investigate main sources of UHI currently available worldwide [44].

[42] UHI can be analysed by extracting Land Surface Temperature (LST) through satellite data. Land use and land cover (LULC) has a strong relationship with LST and any change is later is directly proportional to spatial arrangement of urban settlement [45]. Green-spaces are considered to be main source for depletion of carbon from environment [46].

The policies and decision made by government plays a vital role on Urban Heat Island [47]. The reason for acceleration of UHI are ability of urban material to absorb atmospheric radiations, transpiration from buildings and infrastructure, release of anthropogenic heat from inhabitants and appliances and unstructured development causing blockage in airflow [48], among all these some factors are uncontrollable in nature [49] which are climatic conditions, metrological and geographical features [50]. Fortunately, some controllable features, like; urban design, building geometry, urban density, built-up ration, roughness length, canyons aspect ratio, sky-view factor, vegetation, water bodies, surface characteristics and building materials and transportation are also present [51], whereas, government policies and actions control these factors. Which ultimately point out that UHI is prime product of urban development, in particular to land use and land cover, urban structure and building configurations [52].

3 METHODOLOGY

As the research is explanatory, hence inductive approach was used to further explain and strengthen the studies already carried out by different researchers over a period of time.

3.1 Area of Research

Karachi, a beta global city and economic hub of the country is selected as the study area. Geographically, city extends from 24°51 ′36″North latitudes and 67°0 ′36″East longitudes with an area of 3, 780 km2. The city is the largest metropolitan of Pakistan, and is sixth populous city worldwide. City is the capital of the Sindh province, located on the costal line, and has an arid climate. Karachi is growing at higher rates in terms of urbanization and population in recent years. The city hosts more than 18 million populations with a density of 4,115 persons per square kilometre. The urban area density has increased from 233 km2 with a population size of 0.4 million in 1947 to 3,566 km2 with a population size of 14 million in 2004 [53]. The level of humidity remains high from March-November followed by tropical climate encompassing hot summer and warm winter. Extreme weather events (EWEs) particularly heat-waves affects local communities followed by escalating temperature. Severe heat-waves (HV) struck the Karachi city and southern parts of Pakistan during the last five years [54]. It caused the deaths of about 2,200-2500 people due to dehydration and heat stroke during 2015-2018. In 2017, a severe heat-wave with 51 °C temperatures hit southern parts of the country and broke the old temperature records of many cities during the month of April [55].

The area of observations is further limited to following areas only;

- DHA / Clifton (DHA Phase-2; location near Rahat Milk)
- Gulistan-e-Johar (Flats adjacent to Perfume Chowk)
- Saddar (Apartments opposite radio Pakistan)
- Gulshan-e-Hadeed (Gulshan-e-hadeed, near Karachi Haleem)

3.2 Data Collection

Two different types of data are acquired which are;

a. Primary Data

- Questionnaire [56]: It is obtained by floating to different residents of Karachi via online sources and acquiring online data
- Air Temperature: It is identified with the help of Air Thermometer available with different observers (friends) living in different places of Karachi (as per scope of study)

b. Secondary Data

It includes extraction of already available data. [57]

- Karachi Population [58]
- Population of different areas of Karachi (Specific to Research Requirement) [59]
- Ambient Temperature of Karachi at different time periods [54], [60], [61]

3.3 Data Sample Selection

There are two primary data available for this research, one will be collected by floating questionnaire to different individuals living in Karachi, using non-probability convenience sampling method. The questionnaire will be floated via internet and their responses will be awaited. The sample size for this research will be around 200 respondents [62], keeping the time frame in mind. While the other are observations of respondents at different time periods, these observations are acquired with

the help of air thermometer; few observers (friends); which are selected on the basis of convenience sampling method; living in different areas of Karachi helped in gathering the data. After acquiring the observations, the data was sent through mobile and was recorded in excel file.

Whereas secondary data will be collected using non-probability purposive sampling, from internet as this will be purely related to data of Pakistan; specifically, Karachi and designated areas of Karachi. The sample size will be different for different forms of data, which can be explained as below;

- Data for Population of Karachi will be collected for 5 years.
- Data for Temperature of Karachi will also be for 5 years, in which average mean temperature is used.
- Population density for specific study areas will be for single year.

Temperature of Karachi for finding relation with specific study areas will be for two months, namely; June, 2019 and March, 2020.

3.4 Analysis Technique

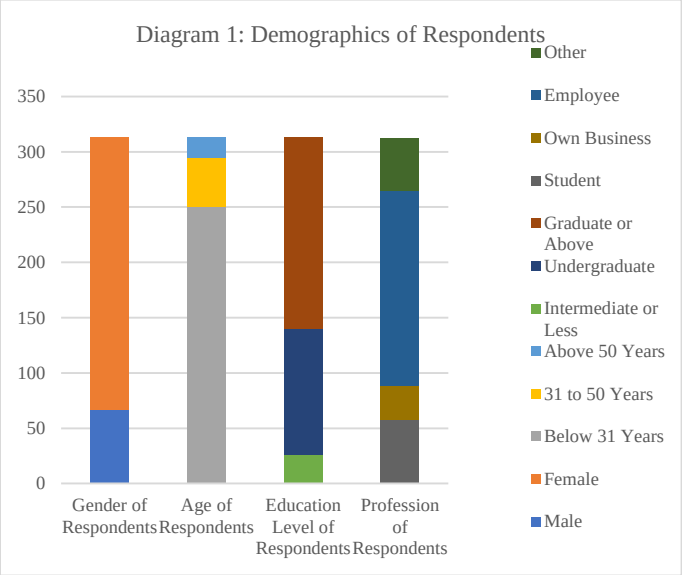
As there are different types of data being utilized in this research, therefore different types of analysis techniques will be used, which are described as follows;

1. For Primary Data
   The data acquired from questionnaire will be downloaded in excel format and will be analyzed using SPSS software in order to acquire frequency table / percentages of each indicator. Indication of these will provide clear idea about majority of person's knowledge about urban heat island living in different areas (specifically selected for this research).
   Whereas, observations for ambient temperature taken in different time periods of different locations, will be matched with each other and then contrasted with the Karachi city average mean temperature extracted from website in that time period.
2. For Secondary Data
   Trend of population and temperature will be used to plot a line graph.

4 RESULTS

Following are the results obtained from questionnaire;

It can be concluded that people are getting more aware about the rise of temperature due to increasing global climatic conditions. As discussed in literature review, almost all the researches on UHI till now discuss on numerous mitigation measures which include but not limited to; tree plantation, expansion of green spaces, use of high reflective materials and planning of urban geometry in way that no congestion is encountered. Likewise, everyone does discuss about the pros and cons with mitigation measures but forget to mention the management part to mitigate impacts of urban heat island.



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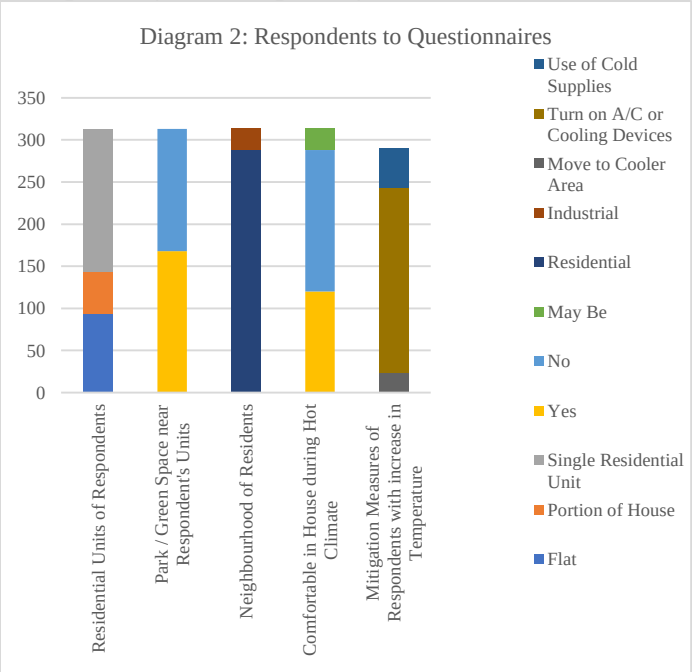
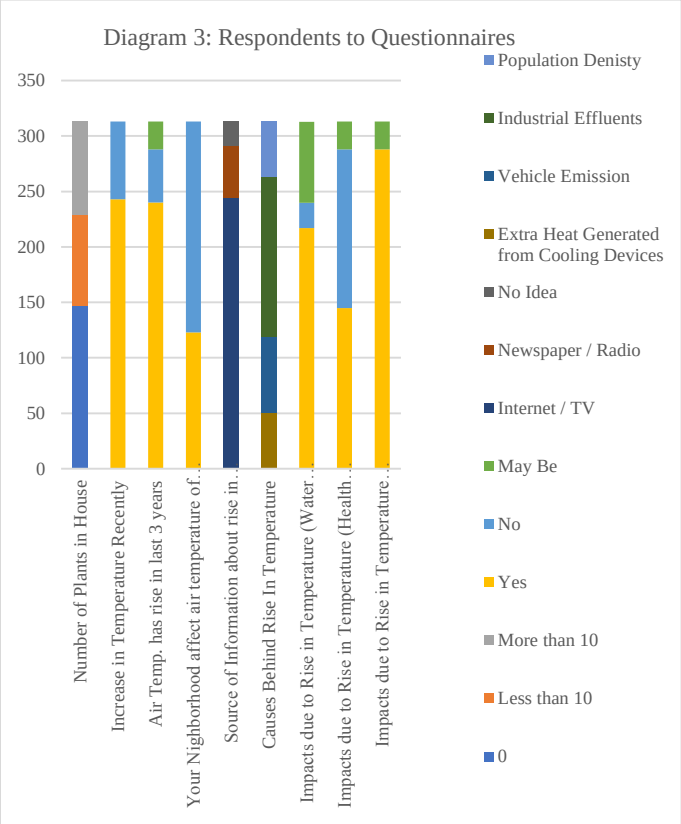
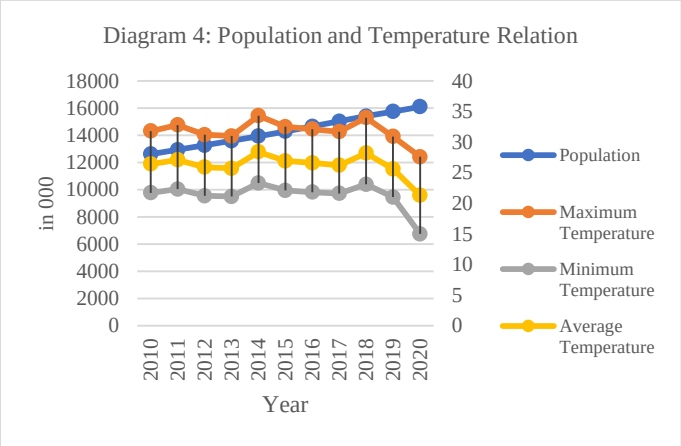
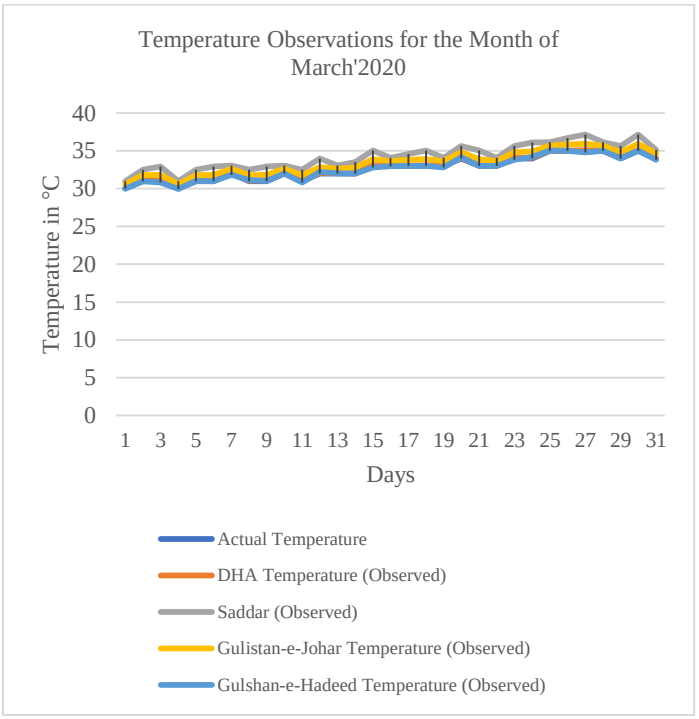




Engineering solutions are present and have far been studied over every scenario and in every country. The reason people are still facing urban heat island is due to lack of managerial decisions. These management deficiencies in system give rise to additional increase of anthropogenic activities. This paper discusses those factors which include;

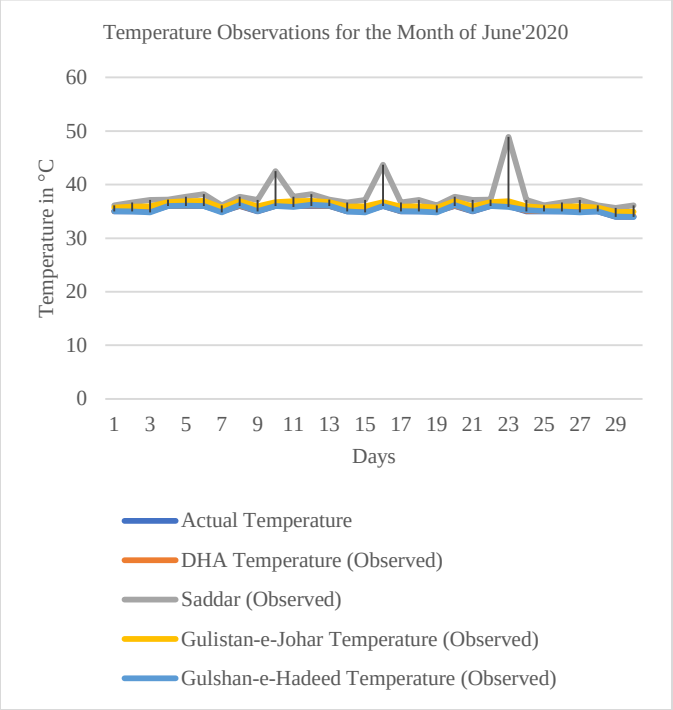
a. Involvement of individual towards social responsibility
b. Plan, Implement and Control of Government Agencies
c. Sensible planning toward urban development





First, a city which is already divided into several districts, among these some are business districts and an increase in population density is observed in these districts. These districts should be identified and reasons for people migration in these districts at different time periods need to be found out. After which major causes for anthropogenic activities are extracted from that data. Which will then help us to plan proper mitigation measures in order to restrict the migration of individuals in that particular area. If still, it is not the case we will be having data showing alternate facilitations to public in order to decrease the anthropogenic activities in particular area.

The next step is to identify the managerial decisions in favour of urbanization, industries and increase in population with increase in traffic congestion is observed around the globe and most of the cities in other regions of the world are hotter than Karachi city. But we are facing increase in temperature with every single day. This is because of lack of proper planning, implementation and control of government in this case. Effluents are observed in every part of world but there are laws which encounter the percentage of effluent of any industry or vehicle with strict control, unlike in developing country where the institutions and rules are present but are as per the standard practices of developed countries. Thus, creating a lag in its implementation and control.



5 CONCLUSION

A single cause cannot be related to Urban Heat Island, there are various number of causes, these causes are natural and man-made (created or arisen in result to anthropogenic activities) which include but not limited to; increase in climate change, increase of population growth of an area due to urbanization, in other words cities or areas being densely populated, increase in transportation or traffic congestion of an area or city, increase in industrialization and rise in gases like COx, NOx and Sox, increase in waste generation and last but not least increase in high-rise buildings or unplanned settlement in cities or an area. Whereas these causes bring various impacts in atmosphere, these impacts are positive and negative, positive in social and economic aspect only but the impact of same is too less that it cannot encounter all the negative impacts caused due to UHI. Negative impacts are of such intensity and density that their existence is felt over large amount of area and for a longer time duration. Hence, the conclusion of our research states that, there are numerous causes to urban heat island; which include but not limit to; increase in population growth in cities specifically in Karachi; which gives push to several other reason like industrialization, traffic congestion, waste generation and improper dwelling in different areas with irregular pattern increase. Though these irregular increase in temperature creates opportunities too for our service and manufacturing sectors. With additional degree increase in temperature there is need of sales of cooling devices, maintenance of these device and increase in sales of cooling eatables or drinkables. Theses indirectly give rise to energy demand which is a single source in Karachi that is K-Electric. But due to its out dated system it is nearly impossible for the organization to cater the needs of many. Being a developing country, the impact of positive opportunities seems to lose its sparkle when compared with negative impacts of urban heat island. With each increase in usage of cooling devices the increase in energy demand increase and thus resulting in additional amount of bills which are to be paid by an individual to survive the high temperature. If not capable of paying the bills, then there are numerous numbers of individuals which get chronic attacks due to high temperature. Productivity and health of individual is also compromised. Nonetheless in a city like Karachi, shortage of water is also observed. UHI is a rotary cycle which starts with increase in temperature and its mitigation measures adopted by various individuals again contribute to emerge the cycle with additional rise of temperature.

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