ASSESSING THE IMPACTS OF CLIMATE CHANGE ON URBAN SECTOR IN MADHYA PRADESH

Page intentionally left blank

Inside cover

A Paper on

Assessing the Impacts of Climate Change on Urban Sector in Madhya Pradesh

Submitted to

Development Alternatives
eco-solutions for people and the planet

Development Alternatives, New Delhi

Submitted by

Maulana Azad National Institute of Technology, Bhopal

Page intentionally left blank

List of Contents

List of Figures

Page intentionally left blank

1. Background

Urban areas hold more than half the world's population and most of the built assets and economic activities are exposed to climate change. In Asia the population growth in urban areas is the highest as compared to the rest of the world and India has been a leading example of fast pace urbanisation over last several decades.

There is a high agreement amongst IPCC experts, based on robust evidence that urban climate change-related risks are increasing with widespread negative impacts on people and on local and national economies and ecosystems.

The cities will be affected by climate change in many ways. The climate change may cause increased flood risk, storm water drainage being overwhelmed, increased risk of subsidence, increased risk to health, reduced comfort in buildings, increased risk of infrastructure damage and increased maintenance costs and many other impacts.

In general, world over there are limited studies available that present a detailed picture of climate change impacts at urban level. The studies in India are very few and in case of Madhya Pradesh there are no detailed studies available that analyse climate change impacts at settlement level. This paper attempts to assess the available information on the climate change impacts with special focus on Madhya Pradesh and caries out the ground work for city level case studies for Bhopal and Ujjain.

1.1. Climate Change and Urban Sector

The world has been experiencing high rate of urbanization since early 20th century. Urban growth rates averaged 2.6% per year between 1950 and 2007. This period witnessed a quadrupling of the world's urban population from 0.7 to 3.3 billion, thus increasing the level of urbanization from 29% in 1950 to 49% in 2007. Perhaps more noteworthy is that in 2008, the proportion of the world's population living in urban areas exceeded 50%.

In India too, it is expected that more than two third of the population will be living in urban areas by year 2050. Thus, climate change impacts for urban areas will be of greatest significance for a majority of population in India.

In climate change discussions, urban areas are very often discussed as the major cause of emissions and the responsibility of mitigation is entrusted on the large urban centres. We have to consider that the cities will also be facing the problems associated with impacts of climate change and it is noted that urban centres around the world face severe constraints in raising and allocating resources to implement adaptation. In most low and middle-income country cities, infrastructure backlogs, lack of appropriate mandates, and lack of financial and human resources severely constrain adaptation action. Small urban centres often lack economies of scale for adaptation investments and local capacity to act, as they have relatively low national and international profiles (IPCC, 2014a).

IPCC experts also agree that action in urban centres is essential for successful global climate change adaptation. Urban adaptation action that delivers mitigation co-benefits is a powerful, resource-efficient means to address climate change and to realise sustainable development goals (IPCC, 2014a).

1.2. Vulnerability of Urban Population

Cities across the globe, particularly those with urban poor communities, face long-term challenges in ensuring the wellbeing of their inhabitants. These challenges are partly a result of direct and indirect impacts of climate change, and are often compounded by pre-existing vulnerability (ADB, 2014).

The risks to illness, injury, loss or damage to property, etc. due to climate change are more to certain groups of urban dwellers. Similarly, factors like age, gender, state of health, economic status of dwellers also have a bearing on the quantum of risk faced by the impact of climate change (IPCC, 2014a) Such groups are termed as vulnerable groups.

Economic, including insured, disaster losses associated with weather, climate-related events, and geophysical events are higher in developed countries. Fatality rates and

economic losses expressed as a proportion of GDP are higher in developing countries. Deaths from natural disasters occur much more in developing countries. From 1970 to 2008, for example, more than 95% of deaths from natural disasters were in developing countries (IPCC, 2014b).

Studies of larger settlements indicate that climate change is likely to increase heat stress. Informal settlements within urban areas of developing-country cities are especially vulnerable, as they tend to be built on hazardous sites and to be susceptible to floods, landslides and other climate-related disasters (IPCC, 2007b).

1.3. Impact on Various Sectors

It has been predicted in a study by planning commission that the drought-affected areas will likely increase creating more stress on already stressed ecosystems of India. This also includes reduced groundwater due to reduced recharge.

Flood risks are likely to increase in some areas due to increased frequency and intensity of extreme precipitation events. In India, the northeastern systems of Mahanadi and Baitarni rivers are expected to come under this category. Increase of frequency and severity of floods and droughts will have implications on the safety of the manmade structures such as dams.

Water volumes stored in glaciers and snow cover are very likely to decline, reducing summer and autumn flows in the Himalayan river systems in the long run. This shall be a major impact on the breadbasket of India since the Himalayan glaciers feed many major systems of India.

The sources of water; surface or sub-surface, face depletion due to increase in population (IPCC, 2014c). Increased temperatures and changes in precipitation can contribute to increase in water demand, for drinking, for cooling systems and for garden watering. Changes in precipitation patterns may lead to reductions in river flows, falling groundwater tables. The water supply systems might also be damaged due to unusually heavy rainfall.

Some of the considerations applying to water supply also apply to sewer sanitation and drainage systems, but in general the effect of climate change on sanitation is likely to be less than on water supply (IPCC, 2007b).

With projected rise in temperatures, mortality is expected to rise due to heat waves. Increased temperatures are also likely to cause increase in eye diseases like cataract, dry eyes, and skin diseases. VBD like Dengue, Chikungunya, and Malaria are also likely to increase. Allergenic pollens grow more profusely in a warmer climate leading to respiratory disorders and allergy problems. Changes in the climate also affect diseases like chronic obstructive pulmonary disease and respiratory infections in children. There are also indications of relationship between air pollution and tuberculosis. (Singh and Dhiman, 2012)

1.4. Resilience and Adaptation

The IPCC defines resilience as 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity of self-organization, and the capacity to adapt to stress and change.' (IPCC, 2007a).

The concept of building climate-resilience from micro- to macro- level is increasingly gaining currency as disaster risk reduction has progressively moved away from a 'predict and prevent' paradigm in the evolving context of rapidly transforming complex urban systems and increasing frequency and magnitude of disasters due to climate change. (GEAG, 2014)

Well governed cities with universal provision of infrastructure and services have a strong base for building climate resilience if processes of planning, design, and allocation of human capital and material resources are responsive to emerging climate risks (IPCC, 2014a).

When resilience is considered for cities, certain systemic characteristics are highlighted—for instance flexibility, redundancy, responsiveness, capacity to learn, and safe failure as well as taking account of the multiple interdependencies between different sectors. (IPCC, 2014a)

The role of urban planning and urban planners in adaptation to climate change impacts has been emphasized by Tyler and Moench. Adapting through physical infrastructure in urban areas requires complementary adaptation planning, management, governance, and institutional arrangements to be able to deal with the uncertainty and unprecedented challenges implied by climate change. (IPCC, 2014c)

Good quality, affordable, well-located housing provides a strong base for city-wide climate change adaptation minimizing current exposure and loss (IPCC, 2014a).

2. Problem Statement

With the fast pace urbanisation, there is a need for developing the cities so as to give a better future to urban dwellers. In this endeavour, understanding the impacts of climate change on urban sector is a major concern. As already stated, for Madhya Pradesh there are no detailed studies available that analyse climate change impacts at settlement level. For this purpose the following study is being carried out by Maulana Azad National Institute of Technology, Bhopal in collaboration with Development Alternatives, New Delhi under the project 'Technical Support for Building the Capacities of State Knowledge Management Centre on Climate Change- EPCO' Government of Madhya Pradesh.

2.1. Aim

The study aims to assess the impacts of climate change on urban sector in Madhya Pradesh with special focus on two selected case study cities of Bhopal and Ujjain. The findings and recommendations of the study will be summarised in the form of a technical paper.

2.2. Objectives

The work of writing the impact assessment paper was started by looking at the literature on current impacts of climate change on urban sector. During the process of reviewing the literature it was realised that the impact assessment studies in India are

limited and there is a virtual absence of any climate change impact studies that specifically analyse the situation in Madhya Pradesh.

Impact assessment of climate change on urban sector in Madhya Pradesh with two city case studies has helped in coming up with some evidence based recommendations.

The following objectives were formulated to accomplish the aim:

- Documenting current impact of climate change on urban sector and consequently identifying the existing stresses posed on urban sector along with the future trends.
- Studying [vulnerabilities arising due to] impact of climate change on urban areas of Madhya Pradesh as a consequence of variations in temperature, rainfall and extreme events through case study of two cities. Direct and indirect impacts like urban floods, heat islands, increased number of diseases, impacts on local economy will also be looked into.
- Adaptation options [for building resilience] for implementation by identifying issues that a) need further research; b) can be incorporated in policies; c) can be formulated as developmental activities.

2.3. Scope of Work

As a global issue, climate change is increasingly being linked to urban concerns pertaining to all the sectors. Similarly, there are discussions concerning mitigation and adaptation strategies and their relationship. A complete assessment of impacts should ideally address all the sectoral concerns along with integrating mitigation and adaptation under one umbrella. However, this being a short term study scope of paper is limited to only select sectors of urban infrastructure and health. Given that Madhya Pradesh does not have a coast line and thus would be unaffected by sea level rise and due to limited history of cyclonic activity only two parameters of climate components, i.e. Temperature and Rainfall have been considered. Though generalizable recommendations for whole of Madhya have been given, however, the evidence based analysis has been carried out only for the case study cities of Bhopal and Ujjain. (Figure 2.1)

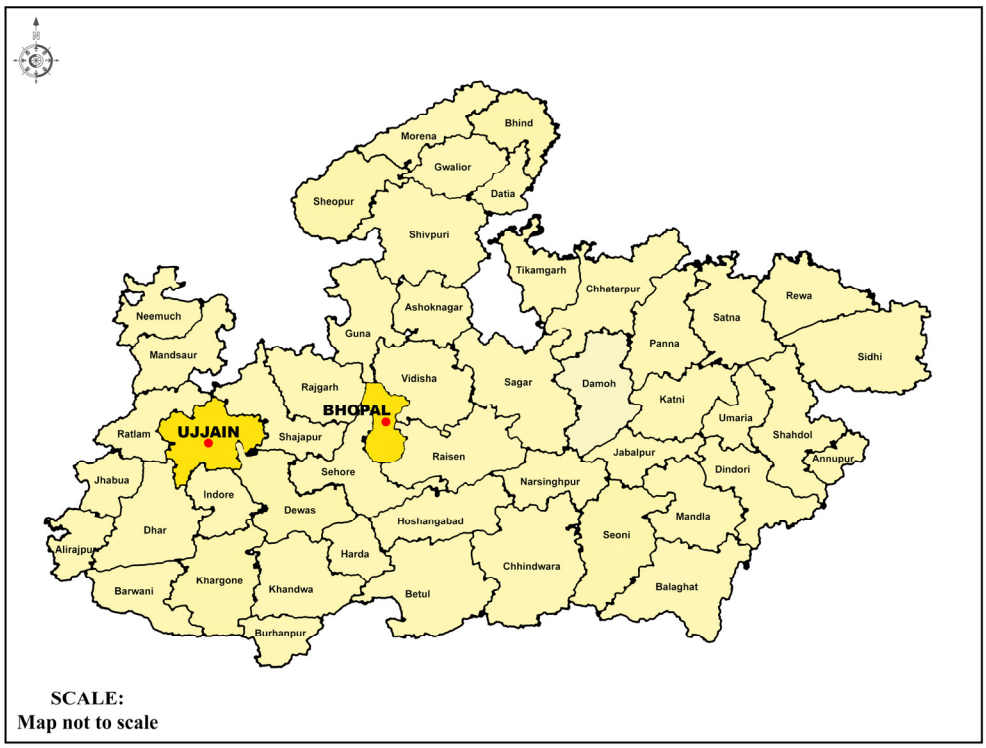

Figure 2.1: Location of Case Study Towns in Madhya Pradesh

3. Methodology

Methodology for assessing impact of climate change on urban sectors in Madhya Pradesh consists of three distinct phases.

Phase – 1 includes literature review on climate change and urban sectors for understanding vulnerability due to climate change and impacts of climate change, resilience and adaptation, etc. along with finalization of aim, objectives and scope based on Terms of Reference. Conceptual framework and outline of the paper will then be prepared.

Phase – 2 of methodology consists of data collection from secondary and primary sources for assessing impact of climate change on urban sectors of Madhya Pradesh and its two cities viz. Bhopal and Ujjain.

First the infrastructure vulnerability assessment for urban sectors in Madhya Pradesh will be carried out for eleven selected indicators. Within each indicator districts having values less than the average will be counted to calculate the score of each

district which ranges from 0 to 11. Higher score for a district represents more vulnerability of the infrastructure. Districts will then be clustered in three groups based on the calculated score viz. most vulnerable, vulnerable and least vulnerable. Same methodology will be followed for accessing vulnerability on two identified cities where in place of district level ward level data shall be used.

In Phase – 3, after conducting survey and analysis, evidence based recommendations will be given along with conclusions and discussions on adaptation options, policy main streaming and development proposals, etc. Figure 3.1

3.1. Identification of Parameters for Study

Following eleven parameters are identified for infrastructure impact assessment based on the indicators used in the Census of India 2011 (for Urban Sector).

- Percentage of households with good housing condition
- Percentage of households having tap water from treated source
- Percentage of households having drinking water within premises
- Percentage of households having electricity
- Percentage of households having latrines
- Percentage of households with piped sewer system
- Percentage of households having bathrooms
- Percentage of households having drainage
- Percentage of households having covered drainage
- Percentage of households having kitchens
- Percentage of households having permanent houses

It is assumed that if the existing infrastructure is insufficient or is already stressed then it would be not be able to take the additional stress of climate change and is likely to be more vulnerable to impacts.

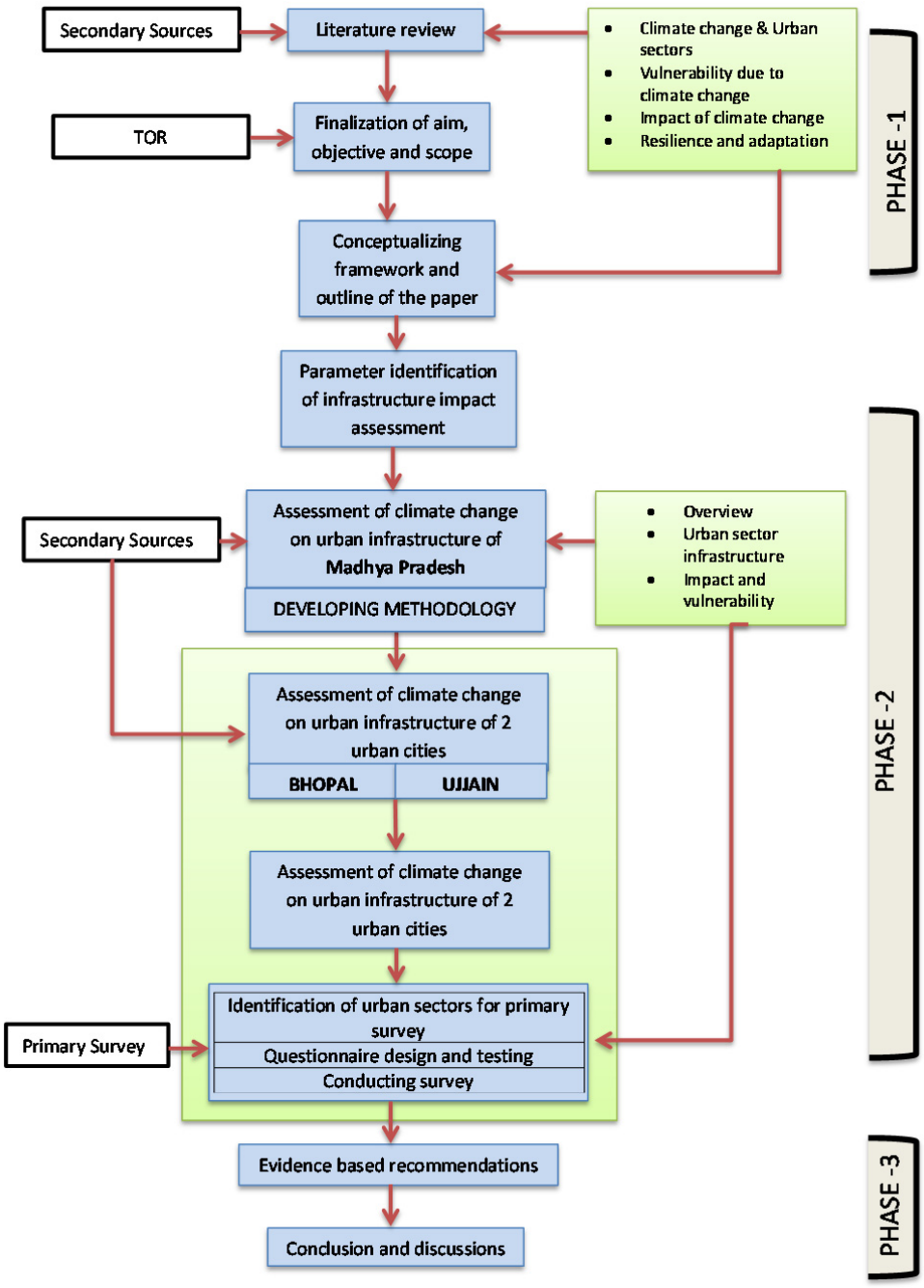

Figure 3.1: Methodology for Assessing Impacts of Climate Change

3.2. Framework for Conducting Field Studies

A questionnaire for officers of water supply, sanitation and health department is developed. The survey is conducted to get first-hand information about their

respective fields in the context of impact of climate change. The answers will be analysed to find out if there is a consensus in their assessment**.**

For city level assessment on two identified cities, primary surveys will be conducted using structured questionnaire. Water supply system, sewage system, storm water drainage system and health are the identified urban sectors for primary survey. For this purpose at Bhopal and Ujjain, assistant engineers, superintendent engineers, executive engineers, project directors and head of institutions of public health and engineering department, municipal corporations and department of health will be surveyed. It is also proposed to take the opinion of two officials for each sector at Bhopal and Ujjain.

Different questionnaires were then prepared for all identified urban sectors and then tested to estimate the time required to interview an officer. Following information was collected at the time of interview.

- Details of the officer to be interviewed
- Qualitative aspects of sources of water supply with comments on quality of water in past, present and future on five point Likert scale.
- Measures taken to ensure quality of water in past and present with measures to ensure quality of water in future (if any) along with problems faced in ensuring quality.
- Quantitative assessment for sources of water on nine point Likert scale for past, present and future.
- Measures taken to ensure quantity of water in past and present with measures to ensure quantity of water in future (if any) along with problems faced in ensuring quantity.
- Judging overall water supply, sewage and storm drainage system of a city on a scale of excellent / good / satisfactory / bad / worse along with reasons for judgment. For health Water borne, air borne and vector borne diseases are taken into consideration for judging health status of the city with special reference to Malaria and Dengue.
- Identification of three most vulnerable wards / localities for urban sectors along with reasons for their vulnerability.

- Identification of reasons for vulnerable wards and measures taken in past and present to improve them. To identify any planning for future to improve the vulnerable wards in future.
- Which three resilient wards / localities for urban sectors and their reasons for Resilience.
- To identify why reasons of resilience cannot be adopted in vulnerable wards under technical, financial, administrative and other reasons.
- Are any problems / issues faces in urban sectors due to seasonal variation with special reference to increase in temperature and to change in rainfall pattern
- To identify and rank other vulnerability issues related to urban sectors in the city
- To know the point of view about impact of climate change on urban sectors of the city and to identify measures which they like to adapt to handle this impact.
- To identify the expectations form Government, Administrators, Public and other agencies.
- To understand their awareness level and preparedness with respect to vulnerability due to climate change.

After conducting the census data analysis to identify most vulnerable wards in a city, primary survey through structured interview provided further evidence based on local knowledge. It also provided insight about the preparedness of the city in facing the climate change impacts in future.

4. Madhya Pradesh

4.1. Overview

Madhya Pradesh lies in the central region of India. The states of Uttar Pradesh, Chhattisgarh, Maharashtra, Gujarat and Rajasthan surround it. Thus, it is one of the few land locked states in India that do not have coast line. It is the second largest state in terms of area and sixth largest by population. It lies between latitude 21°6' N and 26°54' N and longitude 74°E and 82°47'E. The state has an area of 308,245 sq.km,

which is about 9.38% of the total area of India. As per the Census 2011, Madhya Pradesh has population of 7.25 crores. It is divided into ten administrative divisions with a total of 50 districts. The capital city is Bhopal and the largest city is Indore. Other important cities of Madhya Pradesh are Gwalior, Jabalpur and Ujjain.

4.1.1. Physiography

Madhya Pradesh is divided into four major regions; Northern Plains, Central Highlands, Eastern Plateau, and Deccan Plateau. Parts of central highlands covering Gird region fall in Northern Plains. Central Highlands comprises of Malwa plateau, parts of Bundelkhand upland, Vindhyan scraplands, Madhya Bharat plateau, and parts of Aravalli range. Eastern Plateau includes parts of Baghelkhand plateau (Madhya Pradesh & Chhattisgarh), parts of Chhota Nagpur Plateau, Mahanadi Basin and Dandakaranya plateau (Chhattisgarh). Major parts of Nimar Valley, Satpura plateau and adjoining areas fall in Deccan Plateau.

4.1.2. Demography and Economics

As per census 2011, population of Madhya Pradesh is 7,25,97,565 comprising 3,76,12,920 males and 3,49,84,645 females, contributing 6% to India's total population. In terms of population size, the state has moved up to 6th rank in census 2011 from its 7th position in Census 2001. The growth rate w.r.t. 2001 is 20.30% and the density is 236/sq.km which is much less than 382/ sq.km of India. The rural population is 52,537,899 and urban population is 20,059,666.

In 2011, literacy rate of Madhya Pradesh was 70.6% as compared to 63.7% in the year 2001. Female and male literacy rates in 2011 are 60.0% and 80.5% respectively. In 2001, female literacy rate was 50.3% whereas male literacy rate was 76.1%. In Census 2001, Madhya Pradesh stood 24th in the country in literacy whereas in 2011 it has slipped to 28th position. The estimated per capita income is Rs. 32,453 and the per capita GSDP is Rs. 36,281 for year 2010-11. The contribution of the primary sector is 25%, secondary sector is 29% and tertiary sector is 46% towards the GSDP of Rs. 26339573 (in lakh rupees).

4.1.3. Climate

Madhya Pradesh falls under the 'Composite Climate' type. This type of climate has three distinct seasons; summers, rains and winters. Average annual rainfall for the state is 1160 mm with the heaviest rains in the south-eastern parts which decreases towards north-west. Most of the rainfall is received from the south-west monsoon during June to September.

4.1.4. Climate Change and Madhya Pradesh

India Meteorological Department (IMD) has carried out a detailed study for identifying the change in climatic parameters across various states in India. Indian state wise averaged annual mean maximum temperature time series has shown significant increasing trends over Madhya Pradesh [Figure 4.1]. However, Madhya Pradesh did not show any trend in annual mean minimum temperature during last six decades. Similarly averaged annual mean Daily Temperature Range did not indicate any trends in Madhya Pradesh.

Madhya Pradesh showed no trend in winter and summer mean maximum and minimum temperatures during 1951-2010. State averaged monsoon season mean maximum temperatures have shown significant increasing trends over Madhya Pradesh. Monsoon mean minimum temperature over Madhya Pradesh has shown significant decreasing trends. Annual rainfall has decreased over Madhya Pradesh. Decreasing trend in monsoon rainfall has been observed over Madhya Pradesh [Figure 4.2].

4.1.5. Climate Extremes in Madhya Pradesh

There are many recorded incidences of climatic extremes in Madhya Pradesh over the years. However, there is no reliable data available which records these incidences systematically. Some of the popular media reports have been given below that have appeared from time to time. There is an urgent need to systematise the documentation related to the extreme events and the impacts of these events.

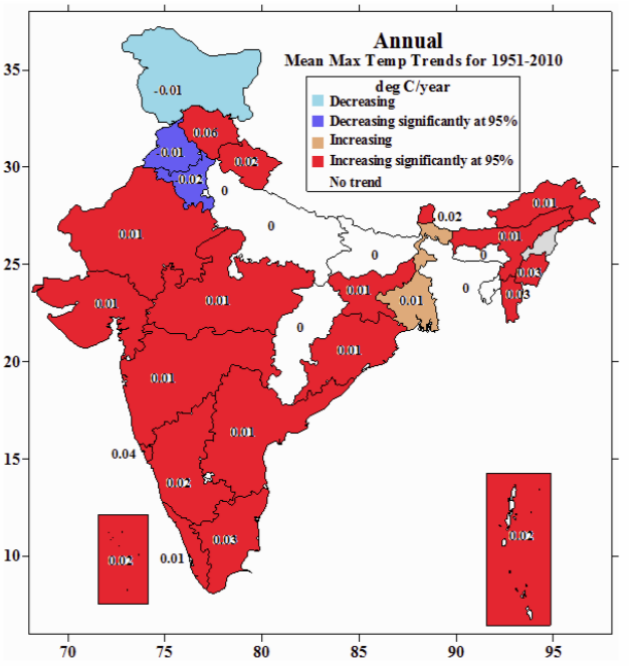

Figure 4.1: State Level Annual Mean and Max Temperature Trends

Source: IMD, 2013

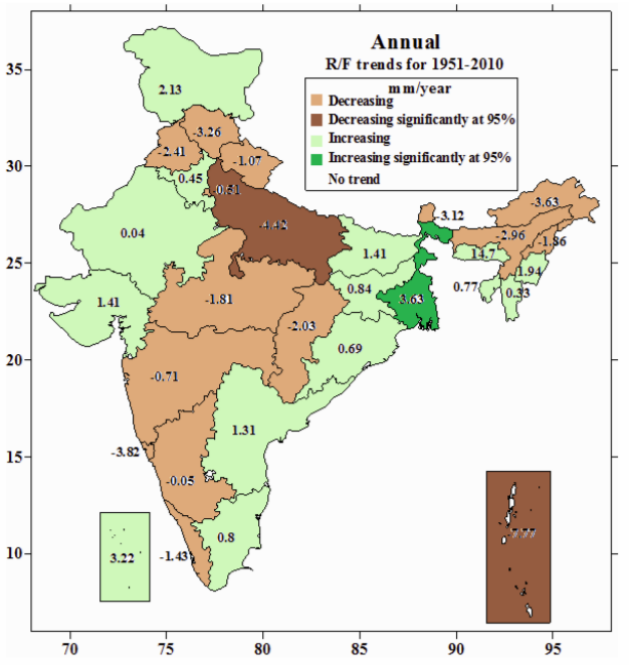

Figure 4.2: State Level Annual Rainfall Trends

Source: IMD, 2013

Events related to heat wave

- [8 May 2006, The Hindu]. In Madhya Pradesh, Gwalior was the hottest followed by Khajuraho at 45.7°C, Hoshangabad 45.5°C, Sagar 44.4 °C, Bhopal 43.5°C and Indore at 43.3°C.
- [25 May 2010, Zee News]. MP reels under heatwave conditions. The maximum temperature in the state, 47.6 °C was recorded in Guna and Gwalior. The mercury climbed to 47.1 °C in Hoshangabad, while Rajgarh and Shajapur districts recorded 47°C respectively. High temperatures were also recorded in Narsinghpur (46.6 °C), Rewa and Satna (46°C each).
- [22 May 2012, NDTV]. the temperatures range between 47 to 41°C in the state.
- [01 June 2014, TOI]. Damoh remained hottest place in state at 46.0 °C. Gwalior recorded a maximum temperature of 44.8 (+2) °C.
- [18 May 2015, Pioneer]. The city (Bhopal) was scorching on Sunday as the temperature shot up to 43.3 °C, the season's highest here. Among the nearby areas, Hoshangabad recorded the highest day temperature at 44.7 °C.
- [2 June 2015, TOI]. Number of cases of people with heat-related ailments is on the rise in the state capital that witnessed an unprecedented summer with mercury crossing 45°C on two occasions. Problems like sunstroke and dehydration have been reported regularly at the city hospitals.

Events related to cold wave

- [5 January 2011, NDTV]. Large parts of Madhya Pradesh have been swept by a severe cold wave as the minimum temperature in Umaria district touched zero degree mark and the state capital recorded lowest temperature of 2.3°C -- seven degrees below normal. Other major cities - Indore, Gwalior and Jabalpur, had minimum temperatures at 5.0°C, 5.2°C and 3.6°C respectively. At Malajkhand in Balaghat district, the minimum temperature of 0.4°C was recorded followed by 0.6°C in Mandla, 0.7°C in Naogaon in Chhatarpur, 1.0°C in Tikamgarh, 1.2°C in Damoh and 3.4°C in Ratlam.
- [8 January 2013, TOI]. The entire state has been reeling under cold conditions with mercury hovering between zero and one degree Celsius at seven places

including Pachmarhi, Satna, Rewa, Umaria, Guna and Damoh. Pachmarhi was the coldest on Monday with a minimum temperature of 0°C, while Satna district recorded 0.4°C. The minimum temperature recorded at Gwalior was 2.2°C, while Ujjain recorded 4.5°C, and Indore stood at 6.2°C.

- [29 Dec 2014, HT]. Many parts of Madhya Pradesh are experiencing bitter cold conditions with Pachmarhi recording the lowest temperature at minus 0.4°C early morning on Sunday. Additionally, in Umaria and Dindori districts of the Shahdol division, minimum temperature dipped to 1°C, almost freezing the water at some places. While a minimum temperature of 4.8°C was recorded in Jabalpur district, Bhopal, Indore and Gwalior shivered at 6, 8 and 3.6°C respectively.
- [21 Dec 2015, TOI]. Gwalior was the coldest on Sunday with a minimum temperature of 4°C while Khajuraho recorded a minimum temperature of 4.6°C. Weather office has issued a warning of cold wave for Gwalior, Chhatarpur, Tikamgarh, Panna, Ratlam and Umaria districts and the entire Rewa division for the next 24 hours.

4.2. Urban Infrastructure

Although few publications suggest specific operational strategies, they do stress the importance of the link between climate adaptation and development. As per IPCC, 2014a the urban infrastructure and other development deficits can contribute to adaptation deficits, therefore as a first priority this deficit should be reduced by project proposals for urban water supply, sanitation and drainage. We take a look at the urban infrastructure condition in Madhya Pradesh to assess the vulnerability of the urban areas to climate change.

4.2.1. Water Supply

In urban areas of Madhya Pradesh 62.2% households have tap water (treated and untreated) as the source of water in 2011, which is less than 67.9% share in 2001. The national share of tap as a source in 2011 is 70.6% which is up from 68.7% in 2001.

In terms of changes in percentage share of urban areas of Madhya Pradesh, there is an increase in use of hand pump (1.1 percentage points) and decrease in use of both tap

water (5.7 percentage points) and well (4.4 percentage points) as main sources of drinking water. Even though the numbers of households having access to tap water has increased in absolute numbers, it has gone down in percentages. That is the water supply is not able to cope up with the increased population and thus making the remaining population vulnerable.

In terms of divisions, the percentage is the lowest in Rewa division which has 38.7% in 2011, which is less than 46.4% of 2001. Next is Sagar division with 44.2% in 2011, which is 2.0% higher than in 2001, but still very low.

In urban areas of Madhya Pradesh 55.4 % households have availability of Drinking Water Source within the premises in 2011, which is marginally less than 55.2 % share in 2001. The national share of availability of Drinking Water Source within the premises in 2011 is 71.2% which is up from 65.4% in 2001. The sources near the premises (within 100 metres) in 2011 are 30.1% and away are 14.5%., which are marginally better than 29.4% and 14.5% respectively.

In terms of divisions, the percentage is the lowest in Sagar division which has 43.4% in 2011, which is more than 41.5% of 2001. Next is Rewa division with 50.1% in 2011, which is less than 50.9 in 2001. The percentage of away sources are also the highest in these two divisions.

4.2.2. Sanitation

In urban areas of Madhya Pradesh 74.2 % households have latrine facility within the premises in 2011, which is more than 67.7 % share in 2001. Out of the 74.2% latrines only 20.2% are connected to piped sewer system. The national share of latrine facility within the premises in 2011 is 81.4% which is up from 73.7% in 2001.

In terms of divisions, the percentage is the lowest in Rewa division which has 57.6% in 2011, which is more than 50.9% of 2001. Next is Sagar division with 58.6% in 2011, which is more than 54.5% as in 2001.

4.2.3. Drainage

In urban Madhya Pradesh, the number of households where wastewater is connected to closed drainage is 31.9% and open drainage is 50.4% in 2011. In 2001 this share

was 24.5% and 51.4% respectively. 17.7% households are not connected to any drainage in 2011 which is better than 24.1% of 2001. The national share for closed drainage is 44.5% and 37.3% for open drainage respectively in 2011. The same for 2001 was 34.5% and 43.4%. In 2001, 22.1% households were not connected to drainage system and in 2011 it is 18.2%.

In terms of divisions, the percentage of households not having drainage connection is the highest in Rewa division which is 39.0% in 2011, which is less than 45.3% of 2001. Next is Shahdol division with 37.4% in 2011, and 40.8% in 2001.

4.2.4. Housing Infrastructure

In urban Madhya Pradesh the percentage share of good condition houses in 2011 is 67.6% which was 63.4% in 2001. Liveable houses are 29.7% in 2011 and were 28.6% in 2001. For India the percentage share of good condition houses in 2011 is 68.5% and in 2001 it was 64.0%. for liveable houses the figure in 2011 it is 28.6% and in 2001 it was 32.3%.

In terms of divisions, house with good conditions were lowest in Chambal division at 59.2% in 2011 and 55.5% in 2001. The next lowest is Sagar division with 65.5% in 2011 and 63.6% in 2001.

The houses in dilapidated condition are 4.5% in 2011; in 2001 this share was lower at 3.8%. Thus the condition of urban houses is overall satisfactory.

Materials for Roof: In urban Madhya Pradesh 46.7% of houses have concrete roof in 2011. 4.9% of houses had thatch and plastic roofs and remaining 48.4% had tiles, stone, AC/GI sheets as roofing material. Thus 95.1% of houses have roof of permanent nature.

Materials for Walls: in urban Madhya Pradesh, 96.9% of houses have brick or stone or concrete as wall material, which are of permanent nature.

4.3. Vulnerability and Impact Assessment

Infrastructure vulnerability of the urban areas in Madhya Pradesh has been assessed on the basis of the data for urban areas for various districts from census of India.

Eleven indicators as listed in the methodology were considered for assessing the infrastructure vulnerability.

For scoring, average of each indicator across all districts was calculated and then compared across the districts. Within each indicator districts are categorized as having values less than average and more than average. Districts with lower than average values are considered as more vulnerable and are highlighted. Highlighted cells are then counted to calculate the score of each district. Thus, higher score represented more vulnerability.

The analysis indicates that piped water supply is most vulnerable among all indicators taken into consideration. As per the census data electricity connection comes out to be a good indicator. However, it does not consider the availability of electricity supply.

Figure 4.3 shows the infrastructure vulnerability of the various districts based on the calculated score. It can be seen that Bhind, Ashoknagar, Damoh, Panna and Tikamgarh appear to be most vulnerable in Madhya Pradesh due to infrastructure stress whereas districts with larger urban centres namely Indore, Gwalior, Bhopal and Jabalpur appear to be resilient with better infrastructure provision.

If we aim at ideal infrastructure conditions that can provide the best resilience then all the population should have treated tap water as the main source as it would make them less vulnerable to the impacts of climate change. In case of Madhya Pradesh even the all the urban population does not access to treated tap water. Thus, there is a need to augment water supply both in terms of source and availability. As 30%-80% urban population has piped water supply there is some resilience capacity in large urban centres.

Similarly all the population should have latrine within premises as it would make the living conditions more hygienic and less vulnerable to the impacts of climate change. Secondly, these latrines should be connected to a piped sewer system. In case of Madhya Pradesh even all the urban areas do not have all the population with the facility of latrine within premises connected to a piped sewer system. Thus, there is also an urgent need to improve the urban sanitation facilities.

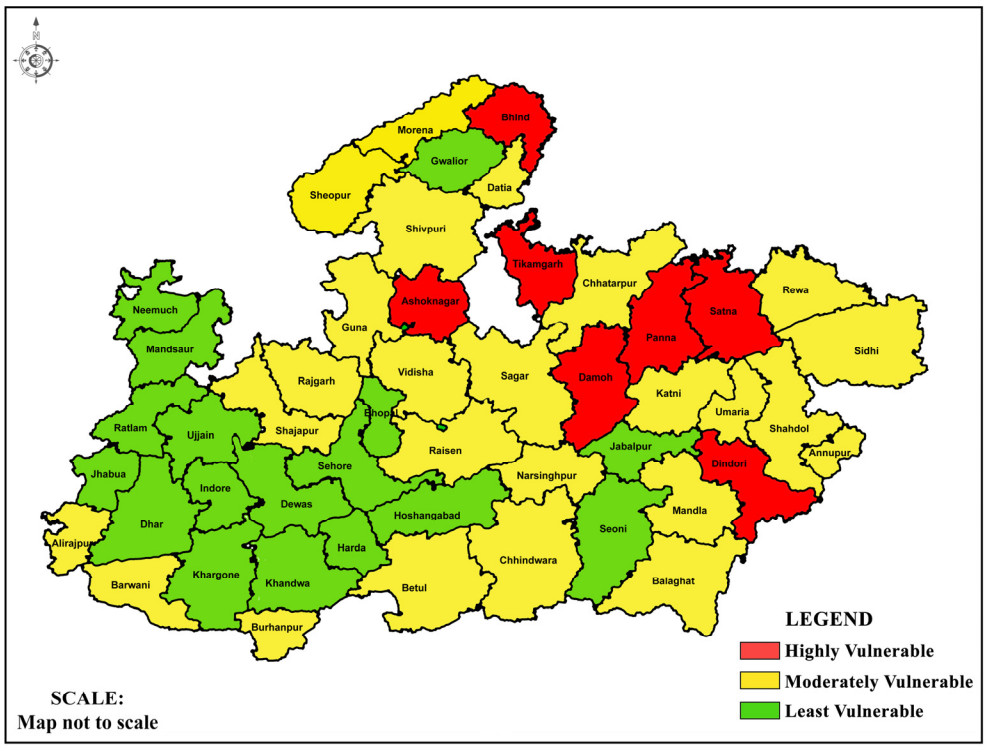

Figure 4.3: Madhya Pradesh Urban Infrastructure Vulnerability

5. Bhopal

Bhopal is the capital of Madhya Pradesh and administrative headquarter of Bhopal district. It is founded by Raja Bhoj in 11th century, as Bhojpal. The two lakes of Bhopal still dominate and the city is also known as City of Lakes. Bhopal today presents a diverse profile with old city having marketplaces and fine old mosques as well as new city with its verdant parks, gardens and broad avenues. Bhopal is located at 23°15′N and 77°25′E in the central part of India. It is well connected by rail, road and air to all parts of the country. Area of Bhopal metropolis is 285.88 sq.km with average density of 6,288 persons /sq. km.

5.1. City Characteristics

5.1.1. Demography

According to the 2011 census, the population of the Bhopal city is 1,798,218, with 936,168 males and 862,050 females. The total literacy rate (aged 7+ years) was

85.24%, with male (89.2%) and female (80.1%). In the city 71% are Hindus, 27% are Muslims and rest are Jains, Christians, Sikhs and others.

5.1.2. Governance

Bhopal Municipal Corporation is the urban body which oversees the needs of Bhopal city and spread over an area of 285.88 sq.km. The city is divided into 70 wards. The Commissioner is the highest officer of Municipal Corporation, responsible for the departments of public works, planning and development, etc.

5.1.3. Economy

The Govindpura industrial area has small and medium-scale industries involved in various production activities. BHEL the largest engineering and manufacturing enterprise in India, has a unit in Bhopal. The residents of Bhopal also engage in large retail businesses, Handicrafts are some of the products of the Old City. Mandideep is an industrial suburb of Bhopal and it is the largest industrial area in Madhya Pradesh.

5.2. Climate and Extreme Events

5.2.1. Climate

Bhopal has a composite climate, with cool, dry winters, a hot summer and a humid monsoon season. Summers start in late March and go on till mid-June, the average temperature being around 30°C, with the peak of summer in May, when the highs regularly exceed 40°C. The monsoon start in late June and ends in late September with 1200 mm of precipitation, frequent thunderstorms and flooding. The average temperature is around 25°C and the humidity is quite high. Temperatures rise again up to late October when winter starts, which lasts up to early March. Winters in Bhopal are cool, sunny and comfortable, with average daily temperatures around 16°C and little or no rain. The winter peaks in January when temperatures may drop close to freezing on some nights. Lowest temperature ever recorded was 0.3^{o}C.

5.2.2. Climate Change in Bhopal

Comparisons of the month-wise mean temperature and rainfall for two periods, 1931-1960 and 1971 to 2000 for Bhopal shows variations in both parameters [Figure 5.1]. In general, there is an increase in the annual mean minimum temperature by 0.2°C and mean maximum temperature by 0.1°C. Months from December to March have lower mean maximum temperatures and the remaining months have higher temperatures. The annual rainfall also shows an increase of 9.7 mm and the peak of monsoon season has shifted from July to August.

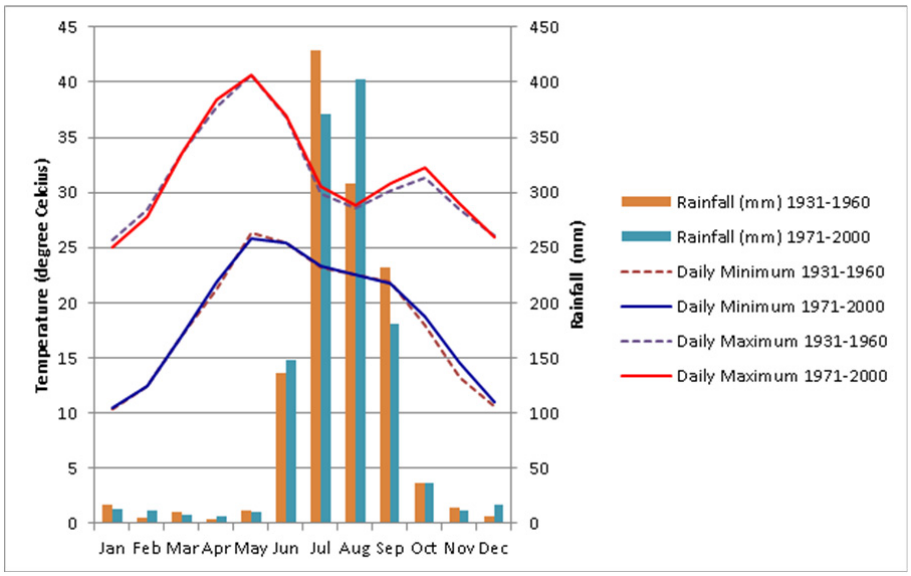

Figure 5.1: Comparison of month-wise mean temperature and rainfall - Bhopal

5.2.1. Climate Extremes Bhopal

In case of Bhopal, there are many recorded incidences of climatic extremes in over the years. However, similar to the state situation there is no reliable data available which records these incidences systematically. Some of the popular media reports have been given below that have appeared from time to time.

Events related to heat wave

- [25 May 2010, Zee News]. Madhya Pradesh reels under heatwave conditions; Bhopal records temperature of 46°C degree Celsius, highest in 63 years.

- [18 May 2015, Pioneer]. The city was scorching on Sunday as the temperature shot up to 43.3^{o}C, the season's highest here. Among the nearby areas, Hoshangabad recorded the highest day temperature at 44.7^{o}C.
- [2 June 2015, TOI]. Number of cases of people with heat-related ailments is on the rise in the state capital that witnessed an unprecedented summer with mercury crossing 45^{o}C on two occasions. Problems like sunstroke and dehydration have been reported regularly at the city hospitals.

Events related to Rainfall

- [Oneindia, Aug 16 2006] Army has been deployed in the state capital today to assist the civil administration due to a grim situation caused by overnight heavy rains, killing at least 11 people and disrupting normal life across Madhya Pradesh. Several hutments had collapsed as the city received record 30 cm rainfall overnight.
- [The Hindu Sep 2, 2006] Heavy rains battered several parts of Madhya Pradesh including state capital Bhopal where an alert was sounded on Friday throwing normal life out of gear besides affecting flight operations and road traffic as death toll in current monsoons mounted to 134 with seven fresh casualties. Worst-hit were districts like Hoshangabad, Jabalpur, Sagar, Balaghat, Sehore and Datia besides the state capital.
- [TOI Aug 7, 2012] After a long spell of rain of varying intensity beginning from Sunday, residents on Monday faced problem of water-logging in several localities of old and new Bhopal. When rains stopped in the afternoon, residents began to pick threads of normal life disrupted by rains lasting over 34 hours. Late on Monday night, rains lashed the city again. Water-logging was experienced at the 10 No. bus stop, 11 No. stop, link road Nos. 1 and 2, New Market, Ban Ganga square, Habibganj under-bridge, Habibganj railway crossing, MP Nagar and important junctions, including Jyoti talkies and other major areas in Arera Colony, creating traffic jams . "Over-flowing nullahs caused waterlogging on the roads. Water also entered our homes. It happens every year," a resident of Gulmohar (Trilanga) said. The City recorded 175.02 mm of rainfall from 8.30 Sunday morning till 8.30 pm on Monday.

- [TOI Jul 16, 2014] Two-and-half hours of heavy downpour in the evening brought the city to a grinding halt on Tuesday. It was second consecutive day of mayhem on the streets after the skies opened up with fury. More than 83 mm of rainfall was recorded in Bhopal in 24 hours till 5.30 pm on Tuesday. Long queues of vehicles were witnessed till late evening in every corner of state capital.

5.3. Climate Change Impacts on Urban Infrastructure

5.3.1. Water Supply

Over the years the Upper Lake has been the major source of water supply for Bhopal urban area. Along with the Lake, bore-wells and hand-pumps are also used for places where water distribution network is not available. With increasing urbanisation and increased water demand need for new resources are felt and Narmada River water is being used to cater the needs of urban Bhopal. Available water in the various sources has been of good quality that can be easily treated for water supply. With increasing urbanization the quality of water is degrading and from time to time cleaning is required to maintain water quality in lake and river. The major threat to quality of water is disposal of sewage and other waste. At present quantity of water is sufficient due to availability of Narmada river water with Kolar having capacity of 34 MGD, Upper lake 25 MGD and Narmada 40 MGD. For improving the situation, some new treatment plants were provided under JNNURM scheme, lake conservation with arresting of sewage that was mixing with lake through provision of treatment plants under Bhoj Wet Land scheme has been done. Initiatives are also taken to maximize the extent of water supply from Narmada water under AMRUT.

In the discussions through structure interview, engineers of BMC rate overall supply system of city from Good to Satisfactory (rating from Excellent / Good / Satisfactory / Bad / Worst) because of sufficient availability of water, good distribution network and government projects are under implementation.

Most resilient localities reported by engineers are Arera Colony, Char Imly and Shyamla Hills. Whereas most vulnerable wards are newly added areas of Bhopal

Municipal limits such as Kolar area and beyond. To improve the water supply system in vulnerable areas provisions are being made under AMRUT.

In the opinion of engineers increase in temperature will affect water supply of Bhopal due to increase in evaporation loss and more need of water. According to them, there is an increase in demand of water by 30% in summers and this demand will further increase with rising temperature and lengthy summer durations. During rainfall top layer of soil mixes with water degrading its quality. Further in their opinion climate change will not impact the water supply system of Bhopal due to availability of Narmada water. Officers at higher level are aware of the issue of climate change though no formal training program on climate change impacts has been organised. Engineers rate illegal connection, water theft and non-payment of water charges as some of major issues related to water supply. For improving water supply water metering should be done, public should be made aware for conserving water and paying taxes on time.

5.3.2. Sewerage Disposal

In Bhopal, Sanitary system is available only in 30% of the areas and rest 70% areas are dependent on open drains. Arera colony, Char Imli, 1250 and 74 quarters are considered as resilient localities in terms of sewage disposal as they are posh areas of Bhopal and proper network is available. Ashoka Garden, Sunder Nagar and some areas of old Bhopal are considered as most vulnerable. Especially in old areas, a lot of illegal construction has taken place and plots are not properly planned therefore it is difficult to provide sewage disposal system. In past with schemes of Capital Project Administration (CPA), Bhoj Wet Land (Upper and Lower Lake Catchments) and Asian Development Bank (ADB) Projects government is able to provide sewage disposal system for 30% of areas of Bhopal. For future one DPR is being prepared by WEDCOS Gurgaon to provide sewage disposal system to rest 70% of Bhopal. Under AMRUT scheme some funds for maintenance and repairs are also allotted.

Reasons for vulnerability of sewerage include inadequate network, absence of proper place for garbage, improper planning, old areas with dilapidated conditions, insufficient funds, delay in project approvals, lack of skilled staff, high density, etc.

Interestingly, engineers rate overall sewerage disposal system of as Satisfactory (rating from excellent / Good / Satisfactory / Bad / Worst) though only 30% city area is covered with sewage network.

A major problem faced during rainy season is mixing of storm water to sewage resulting in overflow of sewers and overflow of open drains, making the situation unhygienic.

Vulnerability issues listed by engineers are absence of proper network, improper maintenance, delay in project implementation, lack of funds, and availability of funds for maintenance and not for providing new lines. The officers and staff are mostly unaware about the impact of climate change on sewerage.

5.3.3. Storm Water Disposal

Storm water network is not available in most of the city. Only open nullah (boundary walls) and natural drainage is provided wherever necessary. Char Imli, Shyamla hills, Arera colony, 74 bunglows and BHEL are considered as resilient due to high topography, less encroachment and available nullahs. Chandbad (old railway station), Aishbagh, Dwarka Nagar, Banganga are most vulnerable as they are located on lower plains and have high density with problem of flooding. Furthermore, no major measures are taken at present to improve the storm water drainage system of these areas. One DPR of Rs 1800 crore was prepared but could not be sanctioned due to paucity of funds. In future 10% funds are provided under AMRUT which are insufficient. In vulnerable areas resilience cannot be achieved due to lack of funds, nonpaying capacity of dwellers, lack of administrative and political support, high density, etc.

Engineers rate overall storm water disposal system of from Satisfactory to Bad (rating from excellent / Good / Satisfactory / Bad / Worst) though proper network is not available just because they are of the opinion that even without network storm water drainage system is working fine with problems in few areas that too in rainy season only. It is also told that encroachment on nullahs and narrow drains are major concerns. Due to urban flood water logging is frequently observed at Banagnag, Ashbagh, old city area, kotra nullah, and few more. The major causes identified are encroachment, narrow and blocked nullahs, improper cleaning, etc. Change in climate

would cause overflow in choked drains during heavy rains and chances for mixing of sewage water and storm water. To avoid the problem removing of illegal construction over drains, cleaning of natural drains and awareness for not throwing garbage in drains should be encouraged. It is also suggested that separate funds should be allocated for storm water drainage.

5.4. Climate Change Impacts on Health

Health status of the city is rated as neither good nor too bad at 5 point likert scale with reference to air borne diseases. City is comparatively better in air and vector borne diseases. Malaria is more prevalent in comparison to dengue. Numbers of patients reported as dengue positive are less in comparison to other cities of Madhya Pradesh.

M.P. Nagar, Areas near Kerwa, areas along VIP road and wards 44, 47 and 27 are resilient areas as they are posh (people are educated and aware), clean and well planned. All slum areas and wards 68, 52 and 69 are most vulnerable due to presence of open drains and garbage dump areas. These wards are located at old Bhopal area. Some workshops on health awareness camps are organized to educate the people but they are very limited in number. At present NVBDPC scheme (National Vector Borne Disease Control Program) is going on to improve the health status. Identified causes for health vulnerability are improper management of old city areas at large scale and difficulty in proposal of new scheme / system that could be implemented easily. Cooperation form public and delay in administrative procedures are the major reasons identified for health vulnerability.

5.5. Vulnerability and Impact Assessment

Infrastructure vulnerability at ward level in Bhopal has been assessed on the basis of the data from census of India. Eleven indicators as listed in the methodology were considered for assessing the infrastructure vulnerability.

Figure 5.2 shows that only about 40.5% (SD=21.7) households are connected to piped sewer system making it most stressed infrastructure whereas 97.3% (SD = 5.0) households connected to electricity supply lines is least stressed infrastructure. Households that are connected to piped sewer system has maximum standard

deviation indicating maximum variations whereas households connected to electric supply lines has least standard deviation showing consistency among 70 wards of Bhopal Municipal corporation.

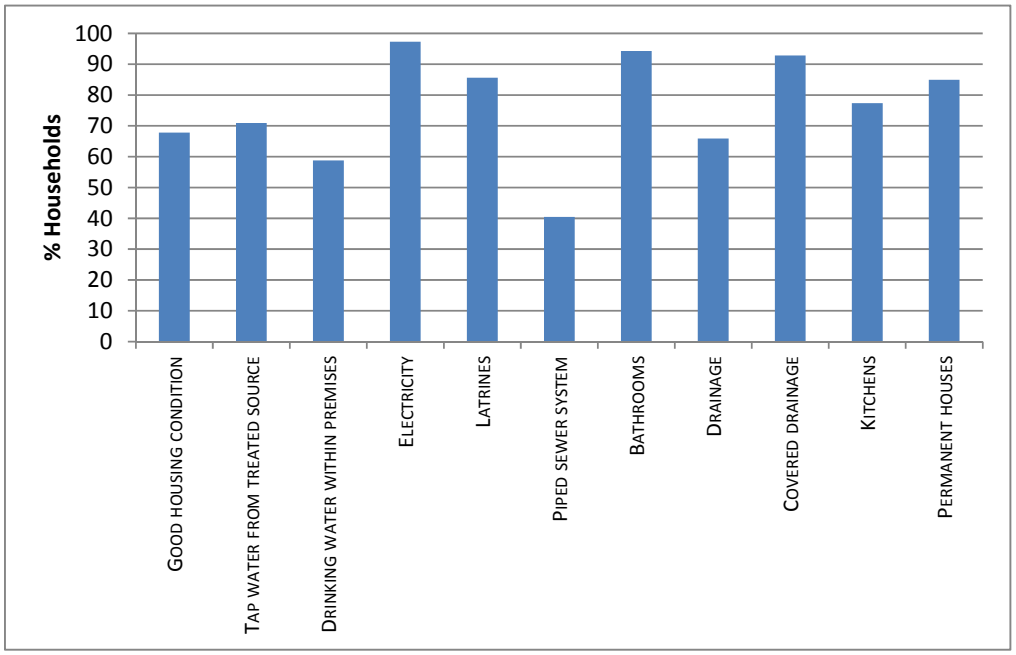

Figure 5.2: Infrastructure Indicators for Bhopal

For scoring, average of each indicator across all wards was calculated and then it was compared across the wards. Within each indicator wards are categorized as having values less than average and more than average. Wards with lower than average values are considered as more vulnerable and are highlighted. Highlighted cells are then counted to calculate the score of each district. Thus, higher score represented more vulnerability.

Out of total 70 wards as per Census 2011, ward 54, 60 and 69 acquired score of 11 (maximum vulnerability score) whereas wards 3, 6, 19, 20, 27, 29, 44, 47,51 and 60 acquired score of 0 making them resilient with reference to impact of climate change on infrastructure. Figure 5.3 shows the infrastructure vulnerability of the various wards of Bhopal based on the calculated score. More than 50% wards are in vulnerable category and about 25% wards are in critical condition and can be classified as most vulnerable.

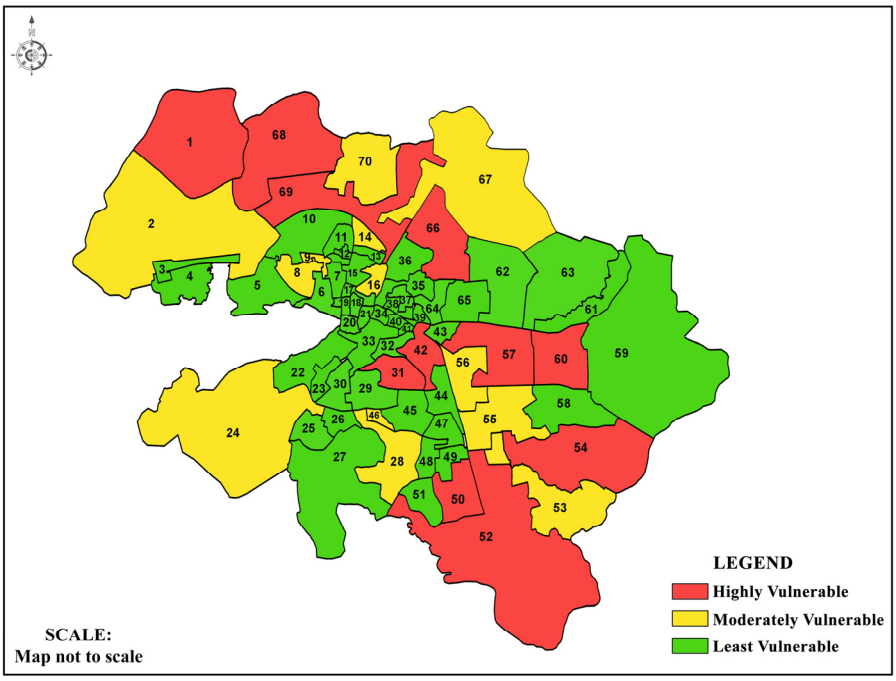

Figure 5.3: Bhopal Ward Wise Urban Infrastructure Vulnerability

When we analyse the primary data collected with the help of structured interview then we come to know that at present water supply is resilient in comparison to other services in Bhopal urban area. To some extent officers dealing with water supply are aware about climate change issues.

It is realised that the sewage disposal system is one of the most vulnerable among other services. The storm water disposal system also emerges as one of the most vulnerable. Due to presence of open drains which are also used as storm water drains during rains in most of the areas with only 30% provision of piped sewerage system, urban floods due to climate change will make the city living unhygienic and administratively unmanageable. Lack of awareness among the staff and officers is likely to aggravate the situation.

It is interesting to note that the health officers are not aware about the ill effects of climate change on health. It is also reported that with increase in temperature water borne diseases will increase and change in rainfall pattern will also increase different diseases. It is opined by the authorities that climate change will not make any significant effect on the health status. However, it is recognised that to improve the health status of the city emphasis should be given on awareness programs, Overall the

officials concluded that infrastructure development, availability of funds, public support and cooperation is required for facing the climate change related impacts in Bhopal.

6. Ujjain

Ujjain is the largest city and administrative center of Ujjain district. It is an ancient city situated on the eastern bank of the Kshipra River and is the most prominent city on the Malwa plateau of central India. Around 600 BC, it developed as the political center of central India with capital of the ancient Avanti kingdom. It continues to be an important place of pilgrimage for Shaivites and Vaishnavites. It is situated at 23°10′N and 75°46′E on a unique geographic location from where tropic of cancer passes. Ujjain has good road and rail connectivity to all parts of the country. Area of Ujjain is 152 sq. km. with average density of 3400 persons / sq.km.

6.1. City Characteristics

6.1.1. Demography

Ujjain has a population of 5,15,215 (According to the 2011 census) of which male are 2,64,871 and female are 2,50,344 respectively with sex ratio of 945 per 1000 males. As literacy wise, total literates in city are 3,85,193 and average literacy rate of city is 84.43% of which male and female literacy was 89.66% and 78.90 %. The floating population is about 50 to 75,000 for the duration of smaller events to several lakhs during Maha Shivratri, and to several crores during to the Sinhastha.

6.1.2. Governance

Ujjain Municipal Corporation spread over an area of 152 Sq. km is the governing body which administers the needs of Ujjain city. The city is divided into 54 wards. The Commissioner is the highest officer of Municipal Corporation, responsible for the departments of public works, planning and development, etc.

6.1.3. Economy

The prime carters of the economy of Ujjain are the primary sector, service sector, trade and commerce. Ujjain which is a regional and tourist centre has grown to become a trading centre in the region. The industrial character has been waning during the last two decades. A significant percentage of the city's workforce is involved in such establishments, whereas a large proportion of population is involved in trade and commerce.

6.2. Climate and Extreme Events

6.2.1. Climate

The city of Ujjain permits normal activities throughout the year. Ujjain experiences a warm sub-tropical climate, typical of the interior Indian subcontinent [Figure 6.1]. Summer starts in late March with temperatures rising to 45°C at its peak in May. In addition, hot winds may blow in the afternoons, adding to the discomfort. The monsoon arrives in the middle of June and continues till early October. About 870 mm of precipitation is received during those months. However, in some years it crosses more than 1016 mm.

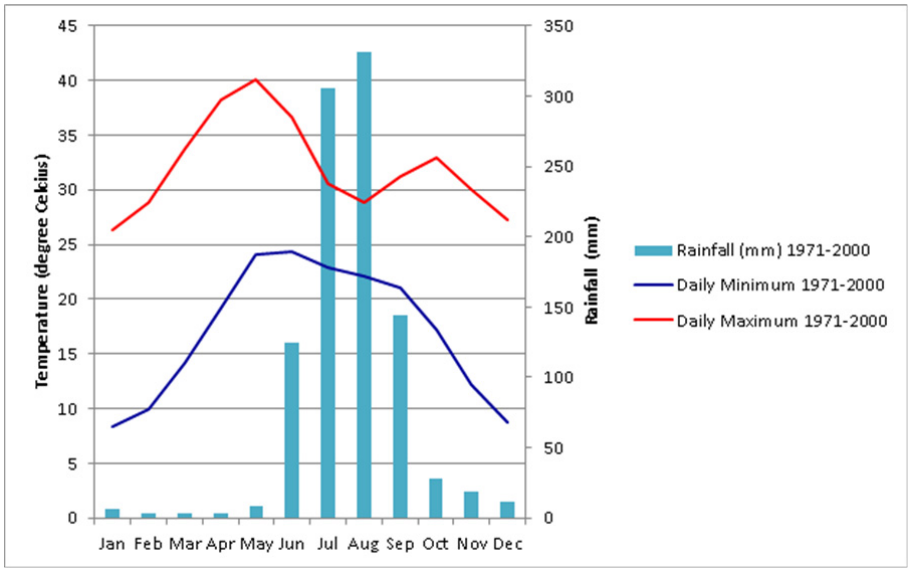

Figure 6.1: Month-wise mean temperature and rainfall - Ujjain

6.2.2. Climate Extremes

Ujjain enjoys a moderate climate in comparison to other areas in Madhya Pradesh. There are very few reported incidences of very high or very low temperature. However, there is a major problem of urban flooding reported in connection with the high amount of rainfall.

Events related to Rainfall

- [05 July 2013, Free Press]. The incessant rains, which continued for more than 30 hours in the neighbouring places and districts, caused flood in Kshipra and submerged Bada Pull for the first time in the season. Only 16 mm rainfall was recorded in the city during last 24 hours. But during the same period water level in Kshipra rose rapidly submerging the bridge for the first time in the season. There was waterlogging in Ramanujkot, Harsiddhi Ki Paal, Ekta Nagar, Parwana Nagar, Joona Somwaria, Madina Nagar, Gangaur Darwaja.
- [19 July 15, Indiatimes]. In July 2015, western parts of Madhya Pradesh have received heavy to extremely heavy rainfall at several places. In just 24 hours, Ujjain recorded 319 mm rain, Bhopal 149 mm, and Indore 129 mm.
- [22 July 2015, HT]. Due to the incessant rain in Ujjain, the Kshipra river has swollen and has also entered in renowned Mahakaleshwar Temple. Several other temples in the district are already under water.

6.3. Climate Change Impacts on Urban Infrastructure

6.3.1. Water Supply

The major source of water supply for Ujjain urban area.id river Kshipra. Along with river, bore-wells and hand-pumps were also used for places where water distribution network is not available. With increasing urbanization and increased water demand need for new resources are felt and dam (Gambhir Dam on Gambhir River, Tributary of Kshipra River) is constructed to cater the needs of Ujjain. Available water in the sources has been of good quality that was being easily treated for water supply. With increasing urbanization the quality of water available at different sources is degrading.

The major threat to quality of water is disposal of sewage and celebration of Kumbh that majorly pollute the sources. At present quantity of water is sufficient. It is told that Ujjain urban area is getting water supply of 200 lpcd which is more than the mandated 135 lpcd.

Engineers rate overall supply system of city from Good to Satisfactory (rating from Excellent / Good / Satisfactory / Bad / Worst) because of sufficient availability of water and good distribution network.

Most resilient localities reported by engineers are Freeganj, Vasant Vihar, Mahananda Nagar and Mahashweta Nagar. Whereas most vulnerable wards are Bilotipura, Janki Nagar, Mahakal Ghati and Begumpura as they are situated on high topography. To improve the water supply system in vulnerable areas no specific efforts are done presently. One scheme under AMRUT is being prepared. Lack of funds is considered as one the major reason for not improving the vulnerable areas.

In the opinion of engineers increase in temperature will not affect water supply of Ujjain due to its abundance. Change in rainfall pattern changes the turbidity and increases pollution in water. In their opinion climate change will not impact the water supply system of Ujjain and no special measures are required. Officers at higher level are aware of the issue but no formal training program or awareness camp has been organized.

6.3.2. Sewage Disposal

Sanitary system is not available in all the wards and most of the city is dependent on open drains. City has 9 treatment plants covering small areas with no proper network. Freeganj, Ramghat and Hariphatak are considered as resilient localities in terms of sewage disposal due to availability of proper treatment plants and pump house. Bherugarh, Kharakua, Bakshipura and Gopal Nagar are considered as most vulnerable. Location of printing press in Bherugarh makes it vulnerable due to discharge of untreated chemicals whereas others areas are vulnerable due to presence of open drains. In past, some efforts have been made to improve the sewerage disposal system of Ujjain under *Rastriya Jal Sanrakshan*. The scheme is still continued under JNNURM but provisions are not made for providing sewage disposal lines. A CM- Scheme of about 500 crores was proposed but not been sanctioned yet

due to lack of funds. In vulnerable areas non availability of pump house, lack of funds, low paying capacity of the poor, government attention towards posh areas, overcrowding are the major reasons.

Interestingly, engineers rate overall sewerage disposal system of as Satisfactory (rating from excellent / Good / Satisfactory / Bad / Worst) though proper network is not available. But in their opinion 9 tanks are sufficient to cater sewerage demand. It is told that BOD and COD is continuously checked and reduced to 20% and then treated water is discharged directly to river.

Problems are faced during seasonal variations such as overflow of open drains, non-working of pumps due to flooding of pump house, etc. making the situation worse and unhygienic. Storm water mixing with sewage during rains exerts pressure on septic tanks.

Vulnerability issues listed by engineers are absence of proper network, improper maintenance, lack of funds, problem during maha kumbh, availability of funds for maintenance and not for providing new lines.

In the opinion of engineers the problem will aggravate with increase in rains. The officers and staff are unaware about the impact of climate change on sewerage.

6.3.3. Storm Water Disposal

Storm water network is not available in most of the city. Only open drains for sewerage disposal are available. Storm water is dependent majorly on open sewerage network. Ramghat and Hariphatak are considered as resilient due to high topography and less density whereas Kharakua, Bakshipura and Bherugarh are most vulnerable as they are located on lower plains and have high density. Furthermore, no major measures are taken at present to improve the storm water drainage system of Ujjain.

It is again interesting to note that engineers rate overall storm water disposal system of as Satisfactory (rating from excellent / Good / Satisfactory / Bad / Worst) though proper network is not available just because it poses problems in rainy season only. Encroachment on nullah's and use of polythenes choking drains are major concern to administration.

6.4. Climate Change Impacts on Health

Health status of the city is rated as neither good nor too bad at 5 point likert scale with reference to water and air borne diseases as most of the people are living near water bodies and pollution in high density areas. City is comparatively better in vector borne diseases. Malaria is more prevalent due to water pollution and less cleanliness. Persons suffering from dengue are less in comparison to malaria. Cause of dengue is considered as lack of awareness by medical officers.

Freeganj, Mahananda Nagar and Vasant Vihar are resilient areas as they are posh (people are educated and aware), clean and well planned. Bakshipura, Gopal Nagar and Bherugarh are most vulnerable due to more water pollution, high density. No special measures are taken to improve overall health status of the city except to treat the patients. Identified causes for health vulnerability are improper city cleaning, ill maintenance of sewage tanks and drains and garbage. Lack of funds is also reported by the official to purchase better medicines.

It is also reported that with increase in temperature air borne diseases will increase and with increase in rainfall water borne diseases are more. It is also reported that change in rainfall pattern will definitely worsen the health status of the city.

6.5. Vulnerability and Impact Assessment

Infrastructure vulnerability at ward level in Ujjain has been assessed on the basis of the data from census of India. Eleven indicators as listed in the methodology were considered for assessing the infrastructure vulnerability.

Figure 6.2 shows that only about 13.8% (SD=11.7) households are connected to piped sewer system making it most vulnerable infrastructure whereas 98.3% (SD = 2.15) households connected to electricity supply lines is the least vulnerable infrastructure indicator. Households connected to piped sewer system has greater standard deviation indicating huge variations whereas households connected to electric supply lines has least standard deviation showing consistency among 54 wards of Ujjain Municipal corporation.

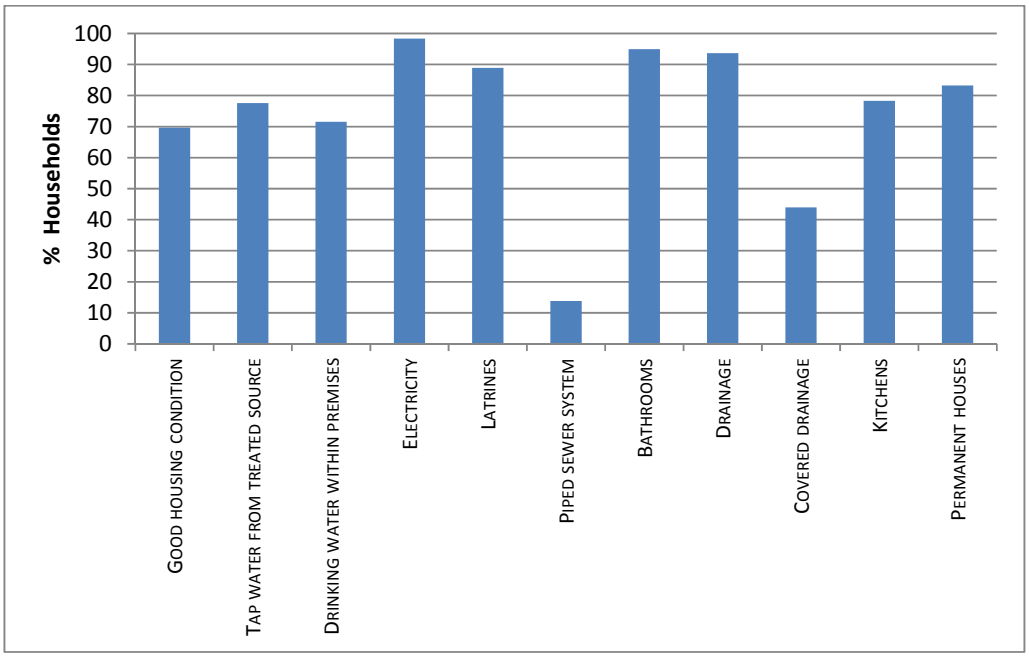

Figure 6.2: Infrastructure Indicators for Ujjain

When we analyse the primary data collected with the help of structured interview then we come to know that in Ujjain at present water supply is resilient in comparison to other services. But lack of awareness among the officers regarding impact of climate change on water supply is alarming and needs urgent attention.

Sewage disposal and storm water drains emerged as the most vulnerable services. Due to presence of open sewers which are also used as storm water drains during rains, urban floods due to climate change will make the city living unhygienic and administratively unmanageable. We did not come across any comprehensive proposal of providing piped sewerage system. It is necessary to note here that in the present condition of sewage and storm water disposal, special attention is required during kumbh mela. On the health front climate change will make the city more vulnerable with increasing cases of dengue and malaria apart from other diseases. Unawareness among the staff and officers about climate change impacts may aggravate the situation in future.

7. Conclusions and Recommendations

India is fast becoming urban. At this rate it is expected that more than two third of the population of India will be living is urban areas by year 2050. Thus, a majority of population will be affected by any climate change impacts for urban areas. Madhya Pradesh urbanisation scene is no different than national and by 2050 in Madhya Pradesh majority of population shall be living in the urban areas.

It has been concluded in many reports, including the IPCC reports, that in case of infrastructure impacts are more directly associated with climatic extremes rather than averages. While planning for infrastructure, there are codes and standards that ensure that the infrastructure is able to bear the normal variability of climate. However, there is no provision for anticipating the abrupt climate changes and extreme events and their impacts. More so, in case of large urban centres in Madhya Pradesh, a lot of new residential and commercial areas are coming up where huge amount of money is being committed for development. However, none of these developments have been analysed for the likely impacts of climate change. Negative impacts of climate change to infrastructure pose risks of higher economic damages in developed urban areas and higher human damages in less-developed rural areas or the areas inhabited by urban poor. At the same time development of good quality of infrastructure with consideration for the impacts of climate change can work as a suitable adaptation strategy.

Long life assets, having low autonomous adaptive capacity, are vulnerable to climate change. Therefore, there is a need of including risk assessment and vulnerability studies in infrastructure planning. Development of adaptation options such as ensuring high design standards for new infrastructure to protect against extreme events needs to be taken on priority.

There is an urgent need to integrate emissions mitigation and climate change adaptation strategies into policies that seek to promote industrial growth and urban development (e.g. industrial siting policies, developments of SEZs, proposals of IT parks, densification and redevelopment proposals, and slum upgradation / relocation with infrastructure development).

In addition to these state level policies and actions local area planning and proposals at the city level also need to be looked into.

Housing for the urban poor may be one of the most important areas of concern as they tend to occupy high risk areas which are low lying and un-buildable increasing their vulnerability to climate change impacts. Very often, vulnerable sites having less market value become slum and squatter settlements. Even when relocation and upgradation of slums is carried out it is seen that less preferred land with low market value is many times allocated for the relocation of slums as this segment of housing needs to kept more affordable. However, it implies that low income households will remain vulnerable to climate change impacts even after relocation and infrastructure provision. This is true both in case of Bhopal and Ujjain where many slum upgradation projects have been carried out without any specific attention to the future climate vulnerabilities of the relocated or upgraded slums.

It can be seen that infrastructure vulnerability to climate change is very much related to local geographic conditions. For example, infrastructure located on hilly areas or in areas with steep slope is likely to be more vulnerable. Similarly the infrastructure in flood prone areas of river catchment will face more severe impacts. Bhopal and Ujjain both have many times suffered in last one decade due to the heavy rain fall resulting in urban floods. Bhopal is affected due to the narrowing of the drainage channels whereas Ujjain suffers due to the development in low lying areas on the river bank with inadequate provision of storm water drainage.

While considering health related impacts, it is projected in many studies that diseases such as diarrhoea, leptospirosis, cataract, dry eye, pterygium, conjunctivitis and skin diseases like sun burn may increase. Dengue transmission might increase many times in certain locations. Transmission months of malaria may increase by 2-3 months in colder areas due to increase in lower limit of temperatures while there may reduction in warmer areas due to increase in upper limit of temperature and longer drier spells.

Increased disease incidence as an impact for health may true in shorter run whereas in longer run, ecological changes, socio-economic development and improved intervention measures may obviate the adverse impacts of climate change on many health related concerns. The shorter run impacts have already started showing in the

case study cities with increasing disease incidence due to longer duration of warmer months.

In longer run it can be seen that the projected climate change is likely to increase weather related mortality and morbidity due to heat strokes, floods and storms. The urban areas are more likely to suffer because of increasing temperature due to the already existing heat island effect.

Though each individual urban settlement has its uniqueness however some broad generalised strategies can be recommended for the urban areas in Madhya Pradesh. Each individual settlement can develop specific adaptation strategies within the broad categories suggested below.

- Long life assets (infrastructure), having low autonomous adaptive capacity, are vulnerable to climate change. Therefore, any new infrastructure project in urban areas should be analysed in detail for risk due to climate change.
- Many infrastructure projects are also part of adaptation strategies and any adverse impact on these could be adverse to adaptation itself. Therefore, it is necessary to ensure high design standards for new infrastructure to protect against extreme events.
- Adaptation of existing infrastructure needs to begin early as retrofitting requires considerable time and cost.
- Identification of process for including climate change scenarios into urban development plans is also needed. This would facilitate integration of mitigation and adaptation strategies into policies.
- More resources need to be committed for flood prevention and protection. Comprehensive analysis of the storm water drainage patter of all urban settlements may be needed to minimise future damages due to urban floods.
- Low-income households living in slums and squatters are more vulnerable to climate change impacts. Risk prone sites should be identified in cities and strict development guidelines need to be worked out for such sites.
- It is identified on the basis of the case studies that the officials in local government though are aware about climate change but lack any formal training. Thus, in addition to technology strategies, economic instruments and

development strategies; capacity building of the officials in local government is vital for minimising climate change impacts and promoting adaptation.

- A scientific evidence base with trained manpower in each urban centre is essential for effective implementation of adaptation actions. This includes local risk and vulnerability assessments and information and data with which to consider current and future risk and adaptation and development options.

8. References

ADB, 2014. Urban Climate Change Resilience A Synopsis. Asian Development Bank, Manila.

ARCC, 2014. Mali Climate Vulnerability Mapping African and Latin American Resilience to Climate Change, Tetra Tech ARD, funded by USAID.

ARUP, 2015. City Resilience Index, the Rockefeller Foundation & ARUP (United Kingdom).

BMC, n.d. Website of Bhopal Municipal Corporation. www.bhopalmunicipal.com

GEAG, 2014, Developing Climate Resilient Ward Plan: A Guidelline, published by GEAG, Gorakhpur (U.P.)

GoI, n.d. Web site of Open Government Data Platform. www.data.gov.in

GoMP, 2014. Madhya Pradesh State Action Plan on Climate Change Integrating Concerns-Converging Possibilities, Housing and Environment Department, Government of Madhya Pradesh.

IMD, n.d. Website of India Meteorological Department. www.imd.gov.in

IPCC, 2007a. *Chapter-10: Asia.* In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 469-506.

IPCC, 2007b. *Chapter-7: Industry, Settlement and Society.* In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK, 357-390.

IPCC, 2013. *Chapter-14: Climate Phenomena and their Relevance for Future Regional Climate Change.* In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC, 2014a. *Chapter-8: Urban Areas.* In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 535-612.

IPCC, 2014b. *Chapter 1: Point of departure*. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 169-194.

IPCC, 2014c. *Chapter 24: Asia.* In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370.

Singh P.K. and R.C. Dhiman (2012). Climate change and human health: Indian context, Journal of Vector Borne Diseases, (49) pp. 55–60.

TARU, 2009. City Level Vulnerability Analysis of Indore, Prepared for Rockefeller Foundation.

UMC, n.d. Website of Ujjain Municipal Corporation. www.nagarnigamujjain.org

Research Team:
Dr. Vinay Mohan Das
Dr. Yogesh Garg
Dr. Manmohan Kapshe
Dr. Navneet Munoth
Ms. Rudrapriya Yadav
Ms. Kanika Bimrah

Maulana Azad National Institute of Technology
Bhopal