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HEALTH ADAPTATION AND RESILIENCE TO CLIMATE CHANGE AND RELATED DISASTERS

A Compendium of Case Studies







2021

A Compendium of Case Studies under the project HER-CAP supported by WHO India

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Resilient India - Disaster free India

National Institute of Disaster Management (NIDM)
(Ministry of Home Affairs, Government of India)



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Health Adaptation and Resilience to Climate Change and Related Disasters

A Compendium of Case Studies

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Chief Editor

Major General Manoj Kumar Bindal, VSM
Executive Director, NIDM

Editors

Prof. (Dr.) Anil Kumar Gupta, Project Director & Head, Environment, Climate and Disaster Risk Management Division, NIDM, New Delhi.

Dr. Anjali Barwal, Research Associate, NIDM, New Delhi.

Dr. Aditi Madan, Associate Fellow, Institute for Human Development, New Delhi.

Ms. Atisha Sood, Junior Research Fellow, NIDM, New Delhi.

Guest Co-Editors

Dr. Jugal Kishore
Director Professor & Head, Community Medicine, Vardhaman Mahaveer Medical College & Safdarjung Hospital, New Delhi.

Dr. Surabhi Sethi
Assistant Professor, Community Medicine, NDMC College & Hindu Rao Hospital, New Delhi.

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This publication is based on the case studies and experience under the project 'Health Adaptation and Resilience: Advancing Strategies Knowledge and Capacities (HER-CAP)'. The document includes a range of information based on case studies and experiences from different parts of India. This compendium partly or fully can be freely referred, cited, translated and reproduced for any academic or non-commercial purpose, with appropriate citation of authors, editors and publishers.

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सबका साथ, सबका विकास, सबका विश्वास
Sabka Saath, Sabka Vikas, Sabka Vishwas



डॉ हर्ष वर्धन
Dr Harsh Vardhan
स्वास्थ्य एवं परिवार कल्याण, विज्ञान और प्रौद्योगिकी व पृथ्वी विज्ञान मंत्री, भारत सरकार
Union Minister for Health & Family Welfare, Science & Technology and Earth Sciences Government of India

MESSAGE

It gives me great pleasure to note that the National Institute of Disaster Management with the support of World Health Organization, India has prepared a Compendium of Case Studies on Health Adaptation and Resilience with reference to Climate Change and Related Disasters.

The compendium showcases the studies that address climate and disaster induced health impacts and highlights lessons learnt from different parts of India facing impacts of changing climate and disasters such as floods, heat wave, air pollution and water contamination. This compendium also showcases various initiatives undertaken in recent years, focusing on valuable lessons drawn from studies and experiences contributed from several cities across the country.

India is party to the Sendai Framework for Disaster Risk Reduction (SFDRR) to implement disaster risk reduction strategies at national and sub-national levels. For this global treaty on disaster risk reduction under the United Nations International Strategy for Disaster Risk Reduction, Government of India formulated the National Disaster Management Plan in 2016 for achieving substantial reduction in disaster risk and losses in lives, livelihoods, health and in the economic, physical, social, cultural and environmental assists of persons, businesses and communities.

In its pursuit of excellence, the Government of India endeavours to emulate and even improve upon the best practices in various types of resilience building measures to disaster risk reduction and climate change impacts. This can be achieved firstly by documenting the knowledge of best practices and understanding of climate change and disasters to provide a competitive advantage for organizations and departments to make India disaster and climate resilient.

I wish great success to the compendium and hope this publication would be useful to a wide range of readers from academia, research, policy and practice to share knowledge and experience.

(Dr. Harsh Vardhan)

कार्यालय: 348, ए–स्कंध, निर्माण भवन, नई दिल्ली – 110011 • **Office:** 348, A-Wing, Nirman Bhawan, New Delhi - 110011
Tele.: (O): +91-11-23061661, 23063513 • **Telefax** : 23062358 • **E-mail** : hfwminister@gov.in, hfm@gov.in
निवास: 8, तीस जनवरी मार्ग, नई दिल्ली – 110011 • **Residence:** 8, Tees January Marg, New Delhi - 110011
Tele.: (R): +91-11-23794649 • **Telefax** : 23794640

Dr. Roderico H. Ofrin
WHO Representative to India

World Health Organization
India

MESSAGE



The COVID-19 pandemic has led to unparalleled social and economic disruptions across the world, but it has also provided us the opportunity to work together to rebuild a more resilient world on sustainable foundations.

The world must leverage recovery from the pandemic to advance the rapid decarbonisation of the global economy to mitigate the impacts of potential health and natural disasters as well as climate change.

The Government of India has been leading the way for clean and green development. India is on the path to achieving its ambitious target of 40 percent non-fossil-based power capacity by 2030. Over the years, Ministry of Health and Family Welfare has also increased the focus on building climate-smart and resilient health infrastructure. These initiatives will help in reducing the country's vulnerability to natural and other disasters to protect lives and livelihoods and build a resilient nation.

I congratulate the National Institute of Disaster Management for this initiative to document best practices from examples of recovery and resilience across the country. The Compendium of Case Studies on Health Adaptation and Resilience to Climate Change and Related Disaster encapsulates real-life examples of progress being made to reduce the impacts of climate change on human health.

The document highlights how different stakeholders and sectors can drive positive change and improve health outcomes. These case studies have a strong scientific basis and are well evidenced and compelling. This documentation provides us with an excellent opportunity to share sustainable best practices on climate change and public health.

I commend the authors of these cases studies who, through their work, have advocated for more decisive actions on building resilience to climate change. This effort will benefit policy makers, city administrations and community leaders to develop resilient plans to protect people's health and livelihoods from climate and other adverse impacts to meet the UN Sustainable Development Goals of health and prosperity for all by 2030.

(Dr. Roderico H. Ofrin)

Dr. Akhilesh Gupta
Senior Advisor (DST) &
Head, Strategic Programmes, Large Initiatives and Coordinated Action Enabler (SPLICE) &
Climate Change Programme

सत्यमेव जयते

Department of Science and Technology (DST)
Government of India
Technology Bhavan, New Mehrauli Raod,
New Delhi - 110016

MESSAGE



Climate change is known to have deleterious effects on human health and wellbeing. India with a diversity of agro-climatic systems suffers climate risks like temperature extremes, precipitation extremes, cyclones, windstorms, hails, frost, etc. and a number of disasters including secondary ones like forest fire, landslides, pest attack, disease outbreak epidemics, etc. Any delay in action for climate change will only increase the risks and its impact on the human health. Over the past few years, interest in climate change and health research has grown substantially among the public health community which has led to better understanding of the overlapping domains of climate change and health, sensitisation on specific health risks and finding sustainable solutions keeping in mind the mitigation costs.

National Institute of Disaster Management, New Delhi has developed the Compendium of Case Studies on Health Adaptation and Resilience to Climate Change and Related Disasters with the support of World Health Organization, India. I complement the editorial team led by Prof. Anil K Gupta who is also implementing the CAP-RES project supported by DST, Govt. of India, in which 'Health' is also one of the important components. This compendium documents the knowledge of best practices and case studies done by imminent scientists and researchers which not only focuses on the climate change related disasters and public health issues but also talks about scientifically and technologically advanced solutions for it to make our country disaster and climate resilient. I am sure that this publication would be useful to a wide range of readers covering academia, research, policy and practice.

(Dr. Akhilesh Gupta)

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राष्ट्रीय आपदा प्रबंधन संस्थान
(गृह मंत्रालय, भारत सरकार)

Maj Gen Manoj Kumar Bindal
VSM
Executive Director

National Institute of Disaster Management
Ministry of Home Affairs, Govt. of India
Plot No. 15, Block B, Pocket 3, Sector 29, Rohini, New Delhi 110042

FOREWORD



India is one of the most multi-hazard prone countries in the world. These hazards include earthquakes, cyclones, droughts, extreme heat, landslides, floods etc. which have resulted in large economic losses, socio-cultural and health services disruptions. The health risks of climate change occur through gradual changes in average conditions, but also in variability, such as more frequent and/or severe heat waves, floods and storms. These are of particular concern, as they are often far less predictable than changes in mean conditions; they have the potential to cripple health facilities, social systems and key infrastructure; and they may result in irreversible shifts. There is only one way to tackle such climate variability. One must plan proper climate adaptation strategies and do everything possible to implement them without delay.

While there is significant scope and opportunities from technological advances, local and traditional knowledge and innovations of simpler but effective roles in climate and disaster resilience of communities exist in almost all parts of India. Such endeavours and lessons need to be documented as case studies to support policy process and capacity building process.

I complement Prof. Anil K. Gupta and the HER-CAP project team for this important contribution. I also thank WHO-India for supporting this endeavor. I feel happy in presenting this document entitled 'Health Adaptation and Resilience to Climate Change and Related Disasters - Compendium of Case Studies'. The compendium has been designed to bring in a comprehensive package of examples and illustrations. I am of the opinion that it would serve its purpose and would be found useful, to all practitioners of climate change, disaster management and health professionals.

MK Bindal

(Manoj Kumar Bindal)

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Prof. Anil K Gupta
Project Director, HERCAP
Professor & Head
Division of Environment,
Climate & Disaster Risk Management

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PREFACE



Climate change is a major threat to the health of the people. Human health has always been influenced by climate and weather. The world is severely affected with climate variability and change, and threatening to undermine progress towards human development if substantive action is not taken. This compendium developed with the invited case studies on different aspects covering four main themes of water related (flood, cyclones and droughts), temperature related (heat wave, cold wave) air related (air pollution) and cross cutting issues.

The compendium highlights lessons learnt from different parts of India facing impacts of changing climate and disasters such as floods, cyclones, heat wave, droughts, air pollution, water contamination etc. It also discusses various initiatives undertaken for achieving health resilience by mainstreaming safety within hospitals, institutionalizing the practice of emergency preparedness in the healthcare sector, development of health action plans, developing vulnerability index to assess climate related health impacts, intricacies of water health systems and strengthening of water utilities under climate variability, consequences of disaster on women health and livelihood practices health response during emergencies. It may be used as a resource for future initiatives moving towards enhancing the capacities of stakeholders and people to withstand the effects of extreme weather events by taking timely and proactive measures. It also showcases various initiatives undertaken in recent years, focusing on valuable lessons drawn from studies and experiences contributed from several cities across India.



(Prof. Anil K Gupta)

Acknowledgement

The Compendium of case studies was compiled by the Health Resilience and Capacity Building (HER-CAP) team-members at National Institute for Disaster Management (NIDM) New Delhi with support from the World Health Organisation (WHO) India. First and foremost, I would also like to thank World Health Organisation (WHO), India for providing funding through the HER-CAP project titled "Health Adaptation and Resilience: Advancing Strategies Knowledge and Capacities" especially Ms. Paydan, Deputy Country Representative; Sh. Manjeet S. Saluja, National Professional Officer and Ms. Renuka Saroha from WHO. I would like to express my heartfelt thanks to Major General Manoj Kumar Bindal, Executive Director, NIDM for his kind encouragement and support in revising and updating this compendium. I would like to place on record my appreciation to the steering committee, namely Dr. Jugal Kishore, Director Professor & Head, VMMC & Safdarjung Hospital, Dr. Aditi Madan, Associate Fellow, IHD and Dr. Surabhi Sethi, Asst. Professor, NDMC & Hindu Rao Hospital, for their strategic guidance through the process of planning, implementation and execution of the project. My special thanks goes to Dr. Sujeet K. Singh, Director, National Centre for Disease Control (NCDC), Dr. Aakash Shrivastava, Joint Director and Head, NCDC and Dr. Shikha Vardhan, Deputy Director, NCDC for consistently providing their advice and encouragement throughout the project.

None of this would have been possible without the valuable contribution made by my team and co-editors namely Dr. Anjali Barwal and Ms. Atisha Sood from NIDM and Dr. Aditi Madan from IDH for the overall process of reviewing and coordinating with the authors. I am thankful to all the authors for their contribution and cooperation extended during various stages of processing of the papers. Since reviewing is an essential part of the publication process, I am also thankful to all the internal reviewers especially Dr. Jugal Kishore, Dr. R.C. Dhiman, Dr. Surabhi Sethi, Prof. Jayant K. Routray, Dr. Sunita Reddy, Dr. Donald Christian, Dr. B.C. Sabata, Dr. Bhavik Rana and Dr. Rujul P. Shukla for providing substantial suggestions for improving the quality of submitted articles. The support and encouragement from Prof. Santosh Kumar, Head, G&IDRR Division, Prof. Chandan Ghosh, Head, Resilient Infrastructure Division, NIDM and Dr. Pawan Kumar Singh, Joint Advisor, NDMA, is also acknowledged.

It also gives me an immense pleasure in acknowledging the cooperation of Sh. S.K. Tiwari, Ms. Sonali Jain, Ms. Karanpreet Kaur and other supporting staff at NIDM.



(Anil Kumar Gupta)

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Chapter 1

CLIMATE CHANGE RELATED DISASTERS AND HEALTH RESILIENCE - AN OVERVIEW

Anil Kumar Gupta, Aditi Madan and Anjali Barwal

Environmental changes particularly the climate change coupled with growing population, high rates of urbanization, land-use changes, natural resource degradation and anthropogenic factors, is known to aggravate disasters and their impact. Increased frequency of disasters such as cyclones, heat waves, floods, droughts, sea-level rise is some of the effects of climate change. The aftermath of such disasters and extreme events is resulting in major health related issues with the vulnerable and marginalized population bearing the brunt of it. Besides this, climate change has also aggravated the existing risk as well as extent of disaster epidemics and outbreaks across the globe.

Climate change is the defining issue of our time. It includes both the global warming due to anthropogenic causes, and the resulting large-scale shifts in weather patterns. This changing climate and consequent rise in disaster risks has resulted in people getting more exposed to harmful events (IPCC, 2012) due to more intense, severe and frequent events such as droughts, heat waves, floods, hurricanes, food insecurity etc. Some of the impacts of such disasters primarily on health include injuries, emotional stress, epidemic, loss of life, houses, possessions, livestock and livelihood with an increased vulnerability to water-borne (Fox, 2003) and other indigenous diseases.

Health Resilience to the ability of community/individuals to utilize its existing assets to strengthen the public healthcare systems and to improve the overall physical, behavioral, and social health of the community to withstand, adapt to, and recover from adverse situations without compromising on long term prospects of development. Developing or building upon the existing resilience allows for better anticipation and planning for reduced impacts from future disasters.

Anil Kumar Gupta
Professor & Head, ECDRM Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi

Aditi Madan
Associate Fellow, Institute of Human Development, New Delhi

Anjali Barwal✉

Research Associate, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi
anjali.barwal@gmail.com

Disasters not only threaten the population but can also result in rapid loss of development gains and failure of emergency responses. Intergovernmental Panel on Climate Change (IPCC) forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century. The impacts of climate change are global in scope and unprecedented in scale. This increasing risk from disasters calls for immediate preparedness of all the stakeholders engaged in managing disasters during different phases. Without immediate action today, adapting to the adverse impacts in the future will be more difficult and costly.

Centre for Excellence on Climate Resilience (CECR) and National Institute of Disaster Management (NIDM) jointly with the World Health Organization (WHO) and other collaborating partners including Dept. of Science & Technology, Ministry of Health & Family Welfare, National Centre for Disease Control, Ministry of Agriculture & Farmers Welfare, Ministry of Environment Forests & Climate Change, and international agencies like IUCN-CEM, UNICEF, UNEP, GGGI, GIZ, etc. are working towards addressing the growing risk through timely planning and knowledge initiatives. National Health Adaptation Plan (w.r.t. disaster related illnesses) is being developed as a part of the National Action Plan on Climate Change (NAPCC), under its National CC Mission on Health. Springer Nature (Publishing) has recently joined hands and has launched a Global Book Series on Disaster Resilience and Green Growth (DRGG) under which 'Resilient Health' is a specialized theme.

This Compendium of Case Studies on Health Adaptation and Resilience to Climate Change and Related Disasters showcases case studies that address climate and disaster induced health impacts. The compendium highlights lessons learnt from different parts of India facing impacts of changing climate and disasters such as floods, cyclones, heat wave, droughts, air pollution, water contamination. It also discusses initiatives undertaken for achieving health resilience by mainstreaming safety within hospitals, institutionalizing the practice of emergency preparedness in the healthcare sector, development of health action plans, developing vulnerability index to assess climate related health impacts, intricacies of water health systems and strengthening of water utilities under climate variability, consequences of disaster on women health and livelihood practices health response during emergencies. It may be used as a resource for future initiatives moving forward towards enhancing the capacities of stakeholders and people to withstand the effects of extreme weather events by taking timely and proactive measures. This compendium showcases initiatives undertaken in recent years, focusing on valuable lessons drawn from 22 case studies and experiences contributed from several cities within India.

The compilation of the compendium screened relevant case studies on the topics concerned with climate change and health sector. Case studies were systematically collected from different parts of India. Those with expertise on the subject were initially requested to submit their abstracts and after through

screening, authors of selected abstracts were asked to submit full length papers of relevant case studies. Once collected, the case studies were then organized into several subthemes under these categories and arranged alphabetically, to facilitate easy access and usability. The compendium is structured around four main themes; Water related (flood, cyclones and droughts), Temperature related (heatwave, cold wave) Air related (air pollution) and Cross cutting issues such as mainstreaming safety within hospitals, keeping health facilities functional during disasters, spatial modelling for predicting malaria risk map, intricacies of water-health systems, gender differentiated impact of floods on health and livelihood and others.

There have been unpredictable changes in local weather conditions across the globe. 'Natural disasters and vulnerabilities: A case study of Bihar floods 2019' attempts to explore the intricacies of the havoc caused by the sudden advent of floods in a State grappling with a poor health care system, feeble disaster management architecture and endemic poverty. In a similar manner, paper titled 'Floods in hilly areas require a different approach' discusses challenges faced during multi-day cloudburst in Uttarakhand due to heavy rainfall, very cold temperature and fog during rescue and relief activities.

Since flooding disrupts everyday life; it can be very distressful, particularly for socioeconomically and psychologically vulnerable population. 'A study to assess psycho-social correlates of urban flooding in Hyderabad, India' assesses the effect of socioeconomic vulnerability to urban flooding and self-efficacy on mental health of people residing in frequently flooded sites in Hyderabad, using hierarchical regression analysis. The findings are important for city flood management, psycho-social interventions and structuring preparedness-mitigation strategies. Similarly, paper on 'Health response during emergencies: A case study of Yamuna Flood' highlights the influence of social and economic vulnerabilities of communities in aggregating the hazards risk. Since climate change impacts human health directly and indirectly paper titled 'Developing vulnerability index to assess climate related health impacts in Andhra Pradesh' aims at developing a health vulnerability index for climate change in Andhra Pradesh, enabling formulating a targeted approach based on gaps identified in climate based health vulnerability of each district and to strengthen the healthcare system of the state.

With high population density, India is prone to experiencing grave human health effects because of climate change with certain medical specialties likely to be more significantly burdened based on their clinical activity, ease of public healthcare access and public health roles. Paper on 'Extreme weather events, its effects and health resilience' points out that monitoring the spread of infectious diseases will require early warning systems, capacity building and health sector preparedness. Another paper on 'Keeping health facilities functional during and in the aftermath of disaster emergencies: A case of Kerala floods 2018' presents a case study on the Kerala floods of 2018, its impact on

hospitals including safety as well functionality of hospitals, during and post flood situations. It also discusses the need to ensure continuity of essential services to be prepared to respond effectively to mass casualty incidents.

Another study 'Gender differentiated impact of 2013 flashfloods on health and livelihood in Rudraprayag' evaluates climate-induced natural disaster event to establish an understanding of how gender-based vulnerabilities influence health and livelihoods practices. The study recognizes an emerging narrative of socially constructed gender role determining access to resources, adaptive capacities and influencing an individual's vulnerability.

Another interesting paper titled 'Post disaster waste management during the 2014 Srinagar flood' stresses on the critical need for early implementation of sanitation, cleaning and disinfecting operations for effective waste handling, collection, and disposal of huge layers of garbage to reduce risk of epidemics. It documents post-flood waste management operations carried out by Urban Local Bodies and Disaster management authorities after the floods in Srinagar in 2014.

Climate change is a major threat to the health of the people. Human health has always been influenced by climate and weather. The world is severely affected with climate variability and change, and threatening to undermine progress towards human development if substantive action is not taken. Study titled 'Impacts and implications of extreme weather events: Latur water crisis 2016' focuses on the drought conditions in Latur, a district in Maharashtra state of India, and how water shortage has been contributing to many infectious diseases and other health related issues. It presents challenges faced in effective drought management and suggests recommendations for breeding more drought-resistant animal and plants varieties that will play a key role to balance the ecosystem. Heatwave is an extreme weather condition, and adversely affecting human health and its ecology. 'Does heatwave definitions signify public health concern?' study analyses diverse heatwave definitions from literature and national weather forecasting systems and compared the public health significance of each definition to identify the most suitable scientific definition for Indian context. Supporting this, study titled 'Impact of dust storms on air quality and human health in Delhi' evaluates the impact of dust storms on the air quality at selected sites of Delhi by analyzing the nature of particulate matter (PM_{10} and $PM_{2.5}$) concentrations in the year 2018. The study also focuses on health risk assessment due to dust storms (PM_{10} and $PM_{2.5}$) particularly in relation with relative risk and cardiopulmonary mortality at the selected sites of Delhi.

Since heat wave events are rising across the globe, it is critical for the cities to adapt to the rising heat stress given cities have high concentration of vulnerable urban poor. 'Climate adaptive heat action plans to manage heat stress in Rajkot

City' provides insights about the research approach and analysis to evolve Climate Adaptive Heat Stress Action Plan (HSAP) at ward level for the city of Rajkot. HSAP identifies ward level heat hotspots, vulnerability assessment of the urban poor and provides framework for implementation, coordination and evaluation of extreme heat response in Rajkot. The Plan supports Rajkot city in prioritizing targeted action through understanding adaptive deficits and strategies to evolve adaptation strategies. In this context, paper titled 'India's Heat Action Plan: A successful public policy response to extreme-heat events' discusses how Ahmedabad low cost Heat Action plan, being implemented in a low- or middle- income setting has proven highly impactful in preventing and controlling morbidity and mortality due to heat related illnesses. 'City heat and health action – A case of convergence and local capacity building' presents local evidence based, the first coastal city plan in India, "Heat and health Action Plan- Surat 2014", and discusses institutional sensitization along with community based interventions.

Quote by Benjamin Franklin that 'an ounce of prevention is worth a pound of cure' stands true today. Preparedness does not pay off instantly. A perfect example of this is paper titled 'The Fani: A case study of Odisha disaster management' which shows how despite high level of preparedness, Odisha was able to minimize loss of life but not the material, economical and environmental loss. It points out to the need for hazard reduction strategies in tune with the international framework to build disaster resilience community, infrastructure and environment. Further, since the AMRI hospital Fire to the most recent AIIMS (All India Institute of Medical Science, New Delhi) hospital fire, Bihar and Chennai flooding to hospital handling CBRN emergencies various incidents have brought in light a different hospital safety aspects and has made one thing quite clear that one size doesn't fit all and each plan should be unique in nature as per its local vulnerabilities and hazards. 'Mainstreaming Safety within hospitals and Institutionalizing emergency preparedness in healthcare sector' discusses aspects of mitigation such as structural and non-structural safety to ensure the safety, business continuity and resilience of a healthcare facility.

Many studies have shown that air pollution levels inside the house may be two to five times higher than the outside owing to indoor contaminants such as outdoor air, biologic agents (molds) dust, aerosols, asbestos, ozone, environmental tobacco smoke, wood stoves etc. 'Study identifying sources and effects of indoor air pollution in Dhanas, Chandigarh' studied household level data for identification of possible sources of indoor air pollution in a densely populated village with around 56% population non-working (low per capita income) including 14% population comprising under 6 years of age, making them highly vulnerable to ill effects of indoor pollution such as pneumonia, chronic obstructive pulmonary disease (COPD), lung cancer and other acute respiratory tract infections. Furthermore, another paper 'Combating air pollution in Delhi: course to clean air and blue skies' discusses the strategies adopted by the government over last 5 years and their impact on air pollution in Delhi and

stresses on the need to restore air quality parameters to safe levels to ensure health of the citizens and tourists.

Contaminants can reach environmental water bodies through natural and accidental incidents causing risk of ecological damage, public health issues, and diverse environmental risks. The study of 'Emergencies and crisis management for the contamination of water bodies' draws cases of water crisis that occurred in India including cloudburst in Leh, molasses leakage from a sugar mill in Punjab, and mercury contamination of Kodaikanal lake by Hindustan Unilever. It addresses the causes and long term impacts of crisis on public health and the environment.

Recent focus on climate variability has added another dimension of water-health complexities to research in on water related issues. The consequences of climate variability and induced water insecurity will be more severe for water sustainability and health risks. In this background, the paper 'Intricacies of water-health systems and strengthening water utilities under climate variability' adopts a case-study approach to understand the complexity of the water-health system and capabilities required for implementing climate integrated WSP in the Indian context. The study shows that performance-based public-private partnership was effective in identifying and assessing risks at earlier stages and improving the capabilities to integrate climate variability in planning.

Malaria poses immense economic and public health burden based on the prospective climate change variability. This in turn affects the distribution of health burden and risk spatially as not all locations are prone to higher incidences of malaria outbreak 'Climate- based spatial modeling for predicting Malaria risk map of Andhra Pradesh' aims to identify, classify and map the potential malaria hotspots along with the health centres to improve health resilience using targeted interventions in Andhra Pradesh using a GIS-based spatial tool. The study will help in implementation of climate- based targeted interventions at malarial hotspots for its elimination and better control.

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WATER RELATED DISASTERS

(FLOODS, CYCLONES & DROUGHT)

Chapter 2

A STUDY TO ASSESS THE EFFECT OF SOCIO-ECONOMIC VULNERABILITY TO URBAN FLOODING AND SELF-EFFICACY ON MENTAL HEALTH AT HYDERABAD CITY, INDIA

Vikas Sehra

ABSTRACT

As many cities around the world, Hyderabad has been facing increasing frequency of floods. Flooding disrupts everyday life; it can be very distressful, particularly for socio-economically and psychologically vulnerable population. To understand these factors, present study assesses the effect of socio-economic vulnerability to urban flooding and self-efficacy on mental health. Socio-economic vulnerability is measured by considering demographic factors (education, income, assets etc.). Self-efficacy and mental health is measured using General Self-efficacy questionnaire and WHO self-reporting questionnaire respectively. 211 people residing in frequently flooded sites in Hyderabad, were administered the questionnaires. Hierarchical regression analysis revealed that socioeconomic vulnerability and self-efficacy, significantly related and predictive of mental health. Hence, psychosocially vulnerable populations to floods are more likely to have poor mental health. These findings are important for city flood management, psychosocial interventions and structuring preparedness-mitigation strategies.

Keywords: *Socioeconomic Vulnerability, Self-efficacy, Mental Health, Urban Flooding.*

Vikas Sehra✉
Research Scholar, Centre for the Study of Regional Development (CSRD), Jawaharlal Nehru University, New Delhi
sehravikas@gmail.com

1. INTRODUCTION

Vulnerability means "the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard" (Wisner et al., 2003). Socio-economic and psychological factors, both impact one's vulnerability to natural hazards. Hazard researchers recognize that socio-economic differences play a key role in governing the risks people encounter, their preparedness for disasters, how they face and recover from disasters (Mileti, 1999). Socio-economic conditions is also important as one's frame of reference is dictated by one's location in socio economic structure which influences the way one interprets and responds to hazard event (Edwards, 1993). Varied socio-economic factors as income, assets, social class and education can be central to differential levels of vulnerability (Peacock, 2003).

Mental health is also influenced by pre-existing psychological vulnerability. Psychological studies have pointed out that certain mental health issues, such as anxiety and depression, result from failure to cope up with a stressful event as natural hazards (Pa†rida, 2015). Subjective severity of the disaster event can have severe impact on mental health. Hence, it is important to consider psychological factors, which may be useful for mental health professionals and emergency healthcare providers in intervention and recovery from disasters (Rhodes & Tran, 2012). Social cognitive theory contributes by explaining the interactive coping process between the individual and the traumatic event (Benight & Harper, 2002). Self-efficacy is described as one's judgments of capabilities to attain preferred results (Bandura, 1986, Pooley et al., 2013). People with a high and low sense of efficacy differ in terms of their belief in ability to perform and succeed. Highly self-efficacious person have high confidence in their ability to perform than a person with low self-efficacy (Nygaard et al., 2016). Such belief in one's ability has central role in appraisal, and consequently coping with, a threat (Bachrach & Zautra, 1985).

Hyderabad has been exposed to increasing frequency of floods, more recently in 2016 and 2017. Frequent encroachments of riverbed, lakebeds and an inadequate drainage system have left Hyderabad vulnerable to floods even with limited rainfall (Ramachandraiah & Prasad, 2004). Studies on urban flooding have been carried out in some of the cities of India like Bangalore, Mumbai and Chennai, but there is very less literature on Hyderabad on the current topic. To understand the interaction of psychosocial factors, present study takes up the case study of urban flooding in Hyderabad. Through the data collected from field survey of frequently flooded low lying areas in Hyderabad, relationship of socioeconomic vulnerability, self-efficacy and mental health is assessed. Higher socioeconomic vulnerability to floods was hypothesized to be positively associated and predictive of poor mental health. And self-efficacy was hypothesized to be negatively associated and predictive of mental health.

2. METHODOLOGY

Frequently flooded localities were identified from newspaper and reports of 2016 and 2017 floods. One area near the Hussain Sagar lake (Himayat Nagar and Domulguda) and another near river Musi (Old Malakpet, Chaderghat and nearby Kachiguda area) were finalized for the field survey. Following criteria was followed for the inclusion of respondents in the survey.

- Individuals must have been residing or working in the selected flood prone area in Hyderabad at least before the last urban flood event i.e., September 2017.
- Participant's giving informed consent.

Following Cochran (1977) a minimum of 196 samples were estimated with confidence level of 95% margin of error of 0.07. A total sample of 211 participants in the age range of 16 to 68 years was taken for the purpose the current study. Among the 211 participants 121 were from near the river and 90 were from the area nearby lake. Initially 224 individuals participated but 13 of them either exited survey after filling socio demographic information or left many of the columns blank, responses for such participants were excluded from the study.

2.1 Procedure

Respondents meeting above criteria participated in the study. American Psychological Association (APA, 2017) guidelines were followed and participants were informed about the objectives and questionnaires used in the study. After obtaining their consent one socio-demographic and two self-reporting questionnaires were administered. Survey was conducted after 16 months of last reported floods in the city i.e., September 2017. Convenient sampling was adopted for the survey. And the two recent floods were pointed out as references for responding to the questionnaires. Psychometric tools used in the study are originally developed in English and cannot be used with non-English speaking populations as such. Hence dual-language experts translated the tools in Hindi and Telugu which is understood by most of the residents in the city. To ensure the validity of the translations, translated tools were back translated to English by another bilingual expert.

2.2 Scales descriptions

2.2.1 Socioeconomic Vulnerability

Socio economic vulnerability index was conceptualized based on other studies of urban flood vulnerability (Abbas & Routray, 2014; Rana & Routray, 2018). It was measured by taking into account type of house (rented, structure, height), assets (TV/radio, mobile, bank account, transport vehicle as four wheeler, two wheeler etc.), cleanliness in locality, availability of drinking water, any

chronic illness, distance of nearest medical facility, occupation, education level and income per month. Participants were asked to tick in appropriate box of option for example yes/no in owning any assets or applicable box of income or education level. Weights were assigned to each variable ranging from 0 (less vulnerability) to 1 (high vulnerability). For e.g. in case of building height single story was assigned '1', double story was assigned '0.67' and triple or more, was assigned '0.33'. Similarly in case of reporting any chronic illness as 'Yes' was assigned '1' and 'No' as '0'. Average of total score was taken, for final socioeconomic vulnerability. Higher score represented high socioeconomic vulnerability.

2.2.2 Self-Reporting Questionnaire

Self-Reporting Questionnaire-20 (SRQ-20) recommended by the World Health Organization (WHO, 1994) has been used in many studies for measuring individual's mental health, level of stress and emotional problems. SRQ is designed as a screening tool for psychiatric morbidities and consists of 20 questions. It is to be answered by the subjects as affirmative or negative. The score in each case is represented by the total number of affirmative answers given by the subjects concerned. Higher total score on the questionnaire represented poorer mental health.

2.2.3 General Self Efficacy Scale

Schwarzer & Jerusalem (1995) developed and validated the scale of self-efficacy. It assesses general perceived sense of self efficacy in handling daily struggles and facing distressful life events. Scale has ten items, each item probing one's general belief in successfully coping and adapting to the adverse situations in life. Responses are given on four point Likert scale; total sum of the responses gives the final composite score which ranges from 10 to 40. Higher total score on the scale represent better self-efficacy.

3. RESULTS

Analysis of data collected from low lying flood prone sites in Hyderabad is presented below. The mean (± SD) age of participants was 27.6 (±11.7) years, ranging from 16 to 68 years. There were 91 females (43%) and 120 males (57%) among total participants. Most of the residents (92%) reported living in pacca houses and 17 (8%) reported living in katcha houses. Out of the total 44 lived in triple or above stories building, 71 lived in double story building and 96 participants lived in single story building. 75 participants were living in buildings which were up to 10 years old, 77 were living in 10 to 20 years old buildings, 26 were living in 20 to 30 years old buildings and 33 were living in buildings older than 30 years.

In terms of education level, 190 participants had been to college/university, 4 people went to high school, 11 of them studied till middle school, 5 participants just studied till primary school and only one of them reported to have no formal schooling. As for the employment status, 103 participants were unemployed, 23 people were working as daily wagers in different economic sectors, 4 of them reported to be involved in agricultural related activities, 55 of them have been involved in trade and commerce of different goods and services, and lastly 26 of them were working in various positions in government sector.

Means, standard deviations, median, minimum and maximum values were calculated for the total sample. Descriptive statistics for the variables is presented below in Table 1. Mean of self-reporting questionnaire scores for mental health is 6.15; standard deviation is 4.27 with median value 6. The minimum and maximum value is 0 and 18 respectively. Mean of general self-efficacy scale scores is 30.83; standard deviation is 5.96 with median value 31. The minimum and maximum value is 12 and 40 respectively. Mean of socio-economic vulnerability score is 0.40; standard deviation is 0.10 with median value 0.39. The minimum and maximum value is 0.18 and 0.70 respectively.

Table 1 Descriptive Statistics for Study Variables

	Mean	Std Dev	Median	Minimum	Maximum
Mental Health	6.15	4.27	6	0	18
Socioeconomic Vulnerability	0.40	0.10	0.39	0.18	0.70
Self-efficacy	30.83	5.96	31	12	40

A test of the Pearson correlation was used to address the relationship between mental health, socioeconomic vulnerability and self-efficacy (Table 2). The relationship between mental health and socioeconomic vulnerability was significantly positive ($r = 0.296$, $p<0.01$). Hence, socioeconomically vulnerable population to floods is more susceptible for poor mental health. The relationship between mental health and self-efficacy was found to be significantly related ($r=-0.4037$, $p<0.01$). Indicating that self-efficacy has significant negative relation to mental health. Relationship between socio-economic vulnerability and self-efficacy was also found to be significantly negatively related ($r=-0.1587$, $p<0.05$). Hence, socio-economically vulnerable population reported to have poorer self-efficacy.

Table 2. Correlations Between Variables

	Mental Health	Socio economic Vulnerability	Self-efficacy
Mental Health	1		
Socioeconomic Vulnerability	0.296**	1	
Self-efficacy	-0.4037**	-0.1587*	1
*p<0.05, **p<0.01			

Further to examine the unique contributions of socioeconomic vulnerability and self-efficacy to mental health of residents in flood prone areas, hierarchal regression analysis was carried out as presented in Table 3.

Table 3. Hierarchical regression results for Mental Health in Flood prone areas

	ß	b(SE)	R^2
Step 1			0.01
Age	-0.04	0.03	
Gender	-0.1	0.59	
Step 2			0.09
Socioeconomic Vulnerability	11.47**	2.69	
Step 3			0.22
Self-efficacy	-0.27**	0.05	
*p<0.05, **p<0.01			

The demographic information (age and gender) were entered in step one, socioeconomic vulnerability and self-efficacy scores were entered in step two and step three respectively. For the total sample N=211 the model accounted for 1% of variance for the initial block of predictors i.e. age and gender. The

second model accounted for 9% of the total variance in mental health, with the addition of next predictor i.e. socioeconomic vulnerability, implying 8% increase that was statistically significant ($F = 18.19$, $p < 0.01$). The third model with addition of self-efficacy accounted for 22 % of the total variance in mental health, implying 13% increase that was statistically significant ($F = 34.71$, $p < 0.01$). The findings suggested both the variables significantly predict mental health. Self-efficacy contributed most in predicting mental health, followed by socioeconomic vulnerability. Hence, the analysis gives support to research hypotheses.

4. DISCUSSION

Primary purpose of research was to assess the impact of socioeconomic vulnerability to urban flooding and self-efficacy on mental health among residents of low lying flood prone areas in Hyderabad. In assessing the relationship among the variables it was found that gender and age didn't predict mental health. The socioeconomic vulnerability was found to be significantly positively related and predictive of mental health, i.e., people socio-economically more vulnerable to urban floods are prone to poorer mental health. Preexisting socio-economic vulnerability to floods intensifies the distress and prevalence of mental illness (Lamond et al., 2015; Rufat et al., 2015). The mental health and well-being consequences of climate change related extreme events do not occur in isolation, but in interaction with socio-economic factors (Crimmins et al., 2016).

Psychological health impacts from the stress of the flooding can be long term ranging from months to even years, it particularly has severe impact on socio economically vulnerable population as they have to cope with lesser resources at their disposal (Tapsell et al., 2002). Vulnerability to mental health challenges after floods is associated with both the level of exposure and pre-existing mental health conditions (Hetherington et al., 2018). (Zahran et al., 2010) reported that there was significant increase in mean number of poor mental health days in population with higher vulnerability status, exposed to hurricane Katrina or Rita. Hazard event in association with socio-economic circumstances may lead to differential disaster experiences. People frame environmental risk situations in varied ways which reflects in their relative valuation of environmental outcomes (Vaughan, 1995). People from lower socio-economic strata have higher level of risk perception as they have little power and control over the world (Flynn et al., 1994). Mental health interventions, integrated with disaster preparedness plans have the potential of mitigate disaster impact among especially vulnerable populations and expedite recovery (James et al., 2019).

Although researchers may differ on the degree to which socioeconomic factors impact mental health. It is widely recognized that socioeconomically

marginalized people have different risk event histories, as well as unequal access to economic and other resources that may be relevant in coping with any particular risk event (Fothergill & Peek, 2004). Environmental risks are unequally distributed and it becomes important to understand the coping capacity of people from different socioeconomic background. It is especially important to understand the psychological impact of extreme events as urban flooding on vulnerable people. To further understand this aspect, the present study explored the relationship between self-efficacy and mental health.

The self-efficacy was found to be significantly negatively related and predictive of mental health. This is in line with the earlier literature findings, as the study on hurricane Katrina survivors pointed out that self-efficacy may be helpful for survivors of severe trauma, as the beliefs in their ability to deal with negative stressful experiences is challenged by such extreme events (Luszczynska et al., 2009). Pritchard & Gow (2012) in their study found that flood victims, who perceived greater levels of flood-related coping self-efficacy, reported decreased levels of general and traumatic distress, such participants felt capable of dealing with demands resulting from the floods. Even in case of healthcare workers working with survivors of traumatic events, enhancing self-efficacy helps in long-term adaptation process (Shoji et al., 2014). In the present study self-efficacy was also found to be significantly negatively correlated with socioeconomic vulnerability, which is consistent with previous research (Bubeck et al., 2018).

These findings can be explained as per social cognitive theory which points out the key role of self-efficacy in facilitating adaptation to stressful events. While there may be many factors that can help favorably mediate one's thoughts and actions in adverse situation, they are all rooted in belief of producing change for desired outcomes (Bandura, 2002). According to self-efficacy theory, people with high sense of self efficacy make effort through strategies and actions to change adverse situations (Mystakidou et al., 2015). And by self-evaluation of environmental and internal feedback of their efforts for desired outcomes, people construct perception of self-efficacy (Benight & Harper, 2002). People with higher level of self-efficacy are able to manage internal and external resources effectively, to recover from losses with lower psychological distress, consequently better mental health (Benight et al., 1999).

The conditions accompanying traumatic events as urban flooding can easily overwhelm ones' coping capabilities. People's judgments on their capabilities impacts their thought patterns as self-hindering or self-enhancing in the face of adverse event (Bandura, 1989). Some people may recover, some may rebound and others may be unable to come out of it. The variable effects point out that disaster events alone are not capable of producing enduring impact on mental

health. Hence, it is the product of the interplay of environmental stressors and psychosocial factors (Benight & Bandura, 2004). And improving socioeconomic condition and self-efficacy is likely to facilitate psychological well-being when responding to the inherent stressors of disasters.

Results of the study have to be interpreted with some caution as there are some limitations to the study. First it's the cross sectional study, therefore has its handicap and a perfect cause effect relationship may not be generalized. Hence is less informative than a possible longitudinal investigation of the disaster. Secondly the nature of sampling as convenience sampling was used but efforts were made to reflect the demographics of total population of city. Lastly, data was collected after more than year of last flooding event so it is possible that time would have influenced the mental health issues faced during the disaster.

Future, research must explore the interaction between mental health, socioeconomic vulnerability and self-efficacy. While socioeconomic vulnerability to flood index was prepared based on earlier studies, many factors may overlap with general vulnerability. Hence future studies may investigate for confounding variables. The mediating role of each of them in affecting and predicting the relationship between the other two will give interesting insights. The possibility of exploring the mental health and self-efficacy in terms of various subcomponents will be enriching for deeper understanding. Present research also points out the need for integrating mental health aspects in disaster preparedness with involvement of mental health professionals.

5. CONCLUSION

This study contributes to the broader research on psychosocial vulnerability to disasters. It examined mental health, socioeconomic vulnerability and self-efficacy after urban floods in Hyderabad. The study found that mental health in aftermath of floods is positively associated and significantly predicted by socioeconomic vulnerability. Further self-efficacy was negatively associated and most predictive of mental health. Hence psychosocially vulnerable populations are most adversely affected by disasters. These findings are important for disaster preparedness, psychosocial interventions and structuring mitigation strategies especially for vulnerable population to aide in the recovery process.

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Chapter 3

POST DISASTER WASTE MANAGEMENT DURING THE 2014 SRINAGAR FLOOD

GN Qasba, Rohit Magotra, Sonika Rajput and Ananya Bhatia

ABSTRACT

Post-flood sanitation, waste handling, collection, and disposal is a major challenge for any city. Huge layers of garbage including the carcasses of animals threaten the outbreak of epidemics of vector-borne diseases and water-air borne infections. Post disaster waste management is thus a crucial step in restoring cities back to their normal livability. Early implementation of sanitation, cleaning and disinfecting operations will enable the affected communities to return to normal life. This paper documents post-flood waste management operations carried out after the flood in Srinagar (Jammu and Kashmir, India), in September 2014. Post-flood waste management operations in Srinagar involved collection of 85,157 metric tonnes of waste material and 17,836 truck trips to the city landfill site at Achan, Srinagar. 11.90 lakh litres of disinfectants and 29,500 kgs of anti-odor formulation were used to improve the level of cleanliness, livability and control odor. 1686 animal carcasses were removed and disposed of as per standard protocol. This paper highlights procedures, processes and practices to be followed during post flood waste management operations by urban local bodies and disaster management authorities.

Keywords: *Disaster Response, Epidemics, Srinagar Flood, Waste management.*

GN Qasba
Former Commissioner, Srinagar Municipal Corporation, Senior Advisor, Integrated Research and Action for Development (IRADe)
gnqasba@irade.org

Rohit Magotra
Deputy Director, Integrated Research and Action for Development (IRADe)

Sonika Rajput
Intern, Integrated Research and Action for Development (IRADe)

Ananya Bhatia
Research Associate, Integrated Research and Action for Development (IRADe)

1. INTRODUCTION

Climate change has magnified the frequency and severity of natural disasters over the last decade globally. Rapid urbanisation leads to loss of vegetation, topography, over concretisation, effecting natural drainage and intensive use of hydrocarbons. Unplanned development and encroachment on water bodies such as canals, lakes, streams, and wetlands are further deteriorating the sustainable ecosystems. The recent calamities of flood in India in Kerala, Uttarakhand, Ladakh, Mumbai, Gurgaon, Chennai, and Srinagar are enlisted in the table below (Refer Table 1). Approximately 20,000 people have lost their lives due to floods and cyclones alone in India during the past 15 years (NDMA, 2019).

Name of event	Year	State & Area	Death toll
Flood	2018	Kerala	438
Flood	2015	Tamil Nadu	500
Flood	Sept, 2014	Jammu & Kashmir	248
Flood/ Landslides	June 2013	Uttarakhand & Himachal Pradesh	4,094
Flood	July- Aug 2012	Assam	-
Cloudburst	2010	Leh, Ladakh in J & K	257
Flood	2009	Andhra Pradesh, Karnataka	300
Flood	2008	North of Bihar	527
Flood	2005	Maharashtra	1,094
Tsunami	2004	Coastline of Tamil Nadu, Kerala, Andhra Pradesh, Pondicherry and Andaman and Nicobar Islands of India	10,749
Retrieved from https://ndma.gov.in/en/			

Table 1: Recent Calamities of Flood in India

There is a need to develop sustainable resilience to minimize the adverse effects and enable fast recovery to normalcy through policy and infrastructural initiatives. In Srinagar, the September 2014 flood was declared as a National Disaster (calamity). The floods were the first instance, in recent times, where 70% of the city was submerged by the flood. Srinagar floods have now become a reference point for urban flood response and management in the country, as many post-flood management practices were successfully implemented in Srinagar city. The success of the waste management drives lead to the speedy recovery to normalcy from devastation and prevention of any major health and environmental crisis.

1.1 Background

Waste management is a perennial problem in developed and developing countries (UN Habitat, 2010). Solid waste management and liquid waste management are an important component of the complex urban management system. Before and after the disasters, the absence of a robust waste management system can increase the damage by blocking the drainage, accumulation of debris and harboring of diseases and vectors. During a flood, waste and other debris carried by floodwater can cause increased damage to property and lead to higher flood losses (Nichols J et al, 2002). Floods can also have an impact on waste management systems leading to leaching of toxins into groundwater (Pilapitiya, et al., 2006).

During the flood of 2018, Kerala had a spurt in communicable diseases and in August 2018 alone, the state government's Integrated Disease Surveillance Project recorded 171 cases of leptospirosis with four deaths (Livemint, 2018). Following the flood of 2019, Patna registered almost 250 dengue cases between September 27 and October 10, which is more than half of the entire dengue cases the city registered in that year until the floods (News 18, 10 October 2019). An explosive epidemic of cholera in the district of Malda in the state of West Bengal was induced by devastating flood resulting from overflowing of the two main rivers of the district, at the end of July 1998, affecting 15 blocks and 2 municipalities (Sur, D. et al., 2000). These are some of the many cases which highlight the importance of post flood waste management.

1.2 Brief on Srinagar City

Srinagar is the summer capital of the Indian state of Jammu and Kashmir (now a union territory). It lies in the centre of the Kashmir valley on the banks of the Jhelum River (Figure 1). Geographically, it is located between 33°59′14″N to 34°12′37″N and 74°41′06″E to 74°57′27″E at an average elevation of 1600 meters

above mean sea level. There are several world-famous lakes and swamps in and around the city. The city is the most urbanized in the state with population of 12.06 lakhs (with additional 5 lakh floating population) and an area of 294 Sq.km as per census of India of 2011.



Figure 1 Location of Srinagar District within Jammu & Kashmir union territory Retrieved from https://en.wikipedia.org/wiki/Srinagar_district

1.3 History of flood events in Srinagar

Location of Srinagar in Kashmir Valley, with large pockets of low-lying areas, makes it prone to flooding and water logging almost every year. History of Kashmir Valley's flooding dates back since the year 1841. The 1902 flood was considered an unprecedented event when the valley was converted into a lake.

Figure below shows some major flood events in the valley (Refer Figure 2)

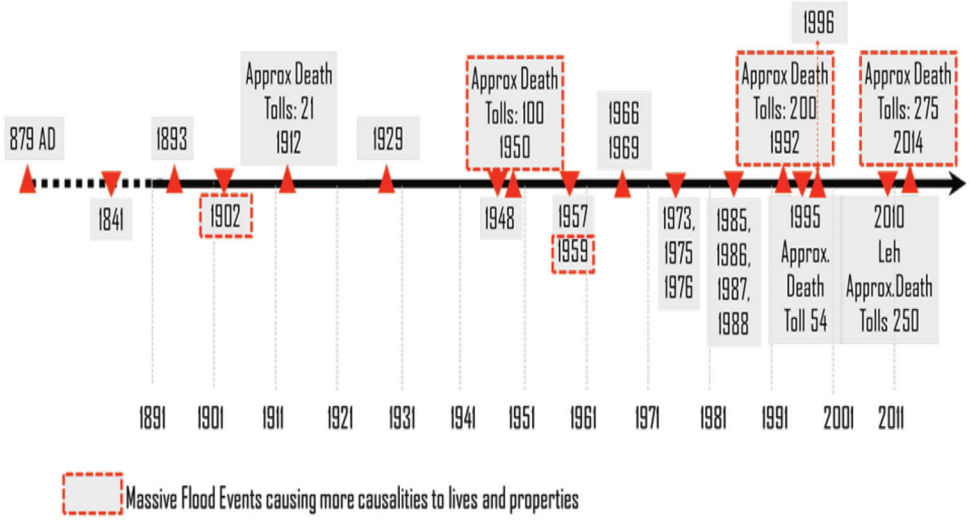


Figure 2 History of Major Flood Events in Kashmir Valley

Source: Srinagar Municipal Corporation, 2015

In the year 1981-1991, four flood events occurred on consecutive years causing high economic losses. The flood event of September 2014 killed around 275 people in the J&K state with 45 in Srinagar city. The increased frequency of the floods could be attributed to the rapid and unplanned urbanization in the city to accommodate the soaring population, including huge migration from rural areas in the last 3 to 4 decades. The south of Srinagar has been traditional "flood sponge" and acted as a barrier to the flood waters. But the built-up area in this region has increased in last few decades, resulting in increased exposure to potential floods. Besides the unprecedented intense rainfall around the first week of September 2014, Encroachment on river banks, natural drainage and wetlands and reduction in carrying capacity of Jhelum River and its tributaries - were the main cause of flooding during 2014 Srinagar flood.

2. SRINAGAR FLOOD 2014 AND ITS EFFECT

On 2nd September 2014, a continuous spell of heavy rainfall for 5 days flooded Srinagar and most parts of the city were submerged as the river Jhelum spilled over its normal water level, flowing at 23 feet above normal (5 ft. above danger mark). The Flood Control department recorded discharge rate in the river as 70,000 cusecs, which was three times more than the normal discharge. On



Figure 3: People walking in Knee deep water,
Source: Greater Kashmir Archives, 2014

the second consecutive day of heavy rainfall Pahalgam, Kulgam, and Qazigund were inundated. Fearing widespread flooding, the Government sounded alert on the second day of heavy rainfall. Rescue operations were initiated

around the same time, evacuating the people from flood-affected areas to safer places. According to the Indian Meteorological Department (IMD), the weekly cumulative rainfall (4-10 Sept 2014) exceeded the average rainfall of the entire monsoon season (Jun-Sept) in the state (Ray, et al., 2015). Medical infrastructure, hospitals, houses, schools and government offices in localities like Sonawar, Indira Nagar, Raj Bagh, Jawahar Nagar, and Gogji Bagh were all submerged underwater. Some low-lying areas in the Srinagar city like Rajbagh, Kursoo and Jawahar Nagar remained under floodwater for over 4 weeks. In many areas, the speed with which the water entered the city was alarming, giving no time for residents to flee or plan for evacuation before being trapped by gushing floodwater. Figure 3 shows the situation during the flood (Refer Figure 3).

The magnitude of catastrophe prompted the Govt. of India to declare it as a 'National Disaster'. An estimate is that the flood caused losses worth INR 40,000 crores (Srinagar Municipal Corporation, 2015). A preliminary survey by the Government revealed that in worst-hit regions of Kashmir, 2.60 lakh structures got damaged with 95,000 houses in Srinagar alone.

As per Srinagar Municipal Corporation (SMC) data, by 7th September, out of the total of 34 municipal wards, 12 wards were fully submerged (Refer Figure 4). These wards are mostly located along the flood channel, River Jhelum (its

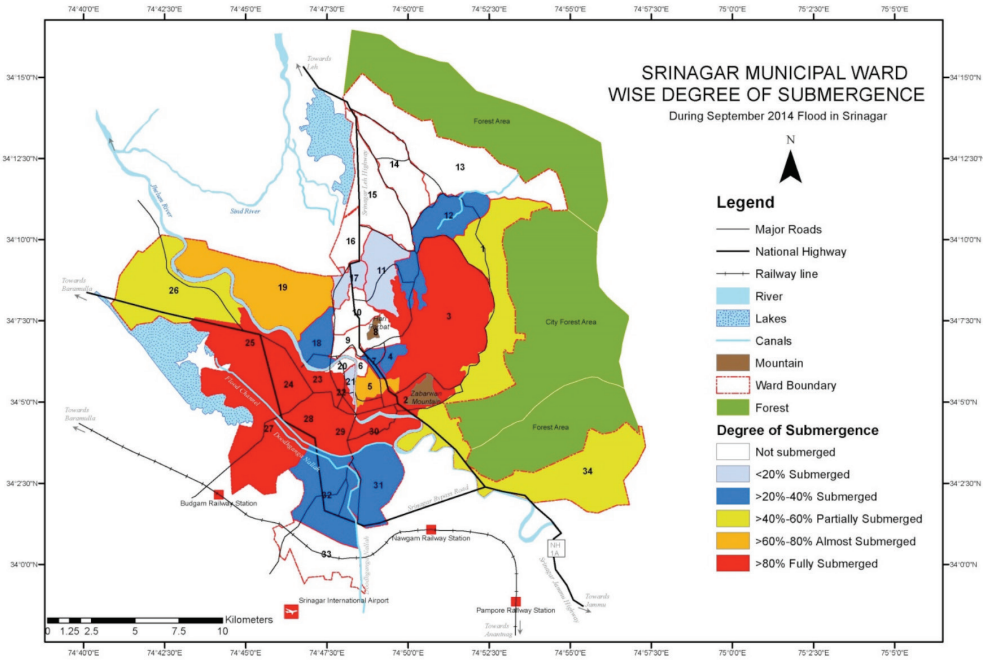


Figure 4 Ward wise degree of submergence in Srinagar during the 2014 flood

Source: Prepared by IRADe

other tributaries/canals) and the Dal lake. 7 municipal wards were partially submerged. Seventy-seven percent of the city area was inundated, out of which, 47% of the area was fully or partially affected. (Refer Figure 5 and 6).

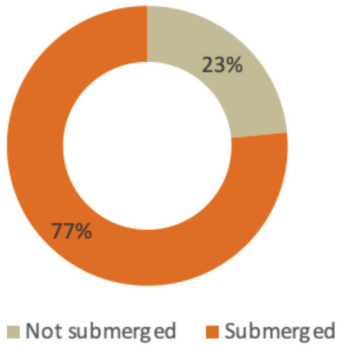


Figure 5 Area under water in Srinagar during flood

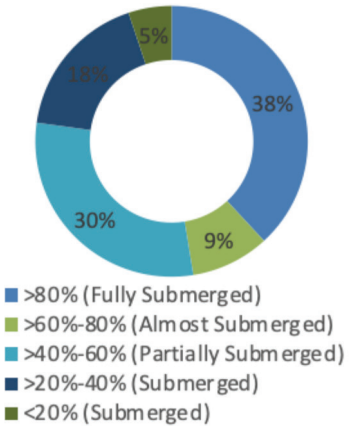


Figure 6 Proportions of areas of land submerged during the Srinagar flood

Source: Prepared by IRADe

2.1 Effect on Critical Infrastructure

All emergency services and critical infrastructure like roads, transport, water supply, hospitals, power, fuel, and telecommunications were paralyzed in the city. Roads and bridges were either damaged or were washed away (Refer to figure 7 and 8), resulting in shortage of medicine and allied provisions. Breakdown of telecommunication and power was directly impacting the relief measures. The dearth of clean portable water caused severe health threats. Most hospitals like SMHS (Shri Maharaja Hari Singh) hospital, Government Medical College, SKIMS (Sher-e-Kashmir Institute of Medical Sciences) Medical College in Bemina, LD (Lal Ded) Women Hospital, Children Hospital and Bone Joint Hospital were flooded, causing the patients to be evacuated/ relocated. This resulted in a virtual collapse of health-related infrastructure in the city.

The only functional hospitals were Sher-e-Kashmir Institute of Medical Sciences (SKIMS), Soura, Jawahar Lal Nehru Memorial Hospital (JLNMH), Rainawari and Chest Diseases Hospital, Drugjan Buchwara (located on hillocks, however was rendered inaccessible due to flooding of the entire surroundings and connecting roads). SKIMS, A Tertiary Care Hospital at Soura, bore the brunt of the entire patient load including the patients who were relocated from inundated hospitals of the city (Refer to Figure 9). The condition was worst for the patients who were on life support systems, suffering from chronic and life-threatening diseases, patients with medical emergencies and pregnant women.

Schools and colleges remained closed as floodwater damaged the buildings and its infrastructure. Srinagar-Jammu Highway (lifeline for Kashmir and Ladakh) part of NH7, was damaged at many places, due to deluge and with heavy landslides on the 300 km long highway.

Seventy percent of the core area of Srinagar got submerged under flood water and the minimum recorded highest flood level (HFL) was between 10 to 20 feet. The administrative centres like Civil Secretariat, Divisional Civil / Police Headquarters, SMC head office, police control room, District Administrative head offices, major hospitals, and fuel stations were all submerged, leaving the people and the authorities scattered and disconnected (Refer to Figure 10). The J&K High Court Complex along with Lower Court Premises at Momina Abad, Bemina in the city came under floodwater.



Figure 7 Inundated Batmaloo -Qamarwari road near Civil Secretariat, Srinagar



Figure 8 Municipal Transport Yard (Tattoo Ground), Batmaloo

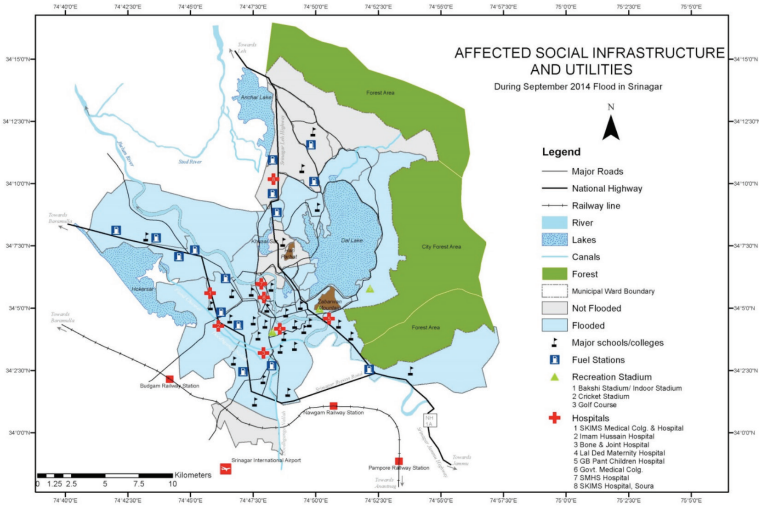


Figure 9 Map showing affected Infrastructure and Utilities during the flood

Source: Prepared by IRADe

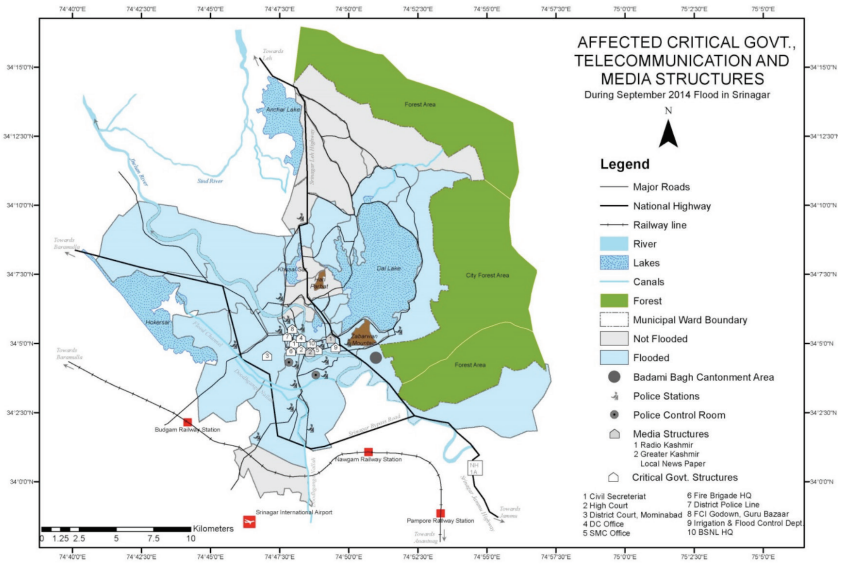


Figure 10 Map showing affected Government Structures

Source: Prepared by IRADe

3. POST FLOOD CHALLENGES- A FEAR OF EPIDEMIC OUTBREAK

After the rescue operations, the water level in deluged areas started to recede, exposing huge mounds of silt, mud, and stinking waste. SMC pooled in heavy-duty dewatering pumps (number of them dispatched from other states, Govt. of India corporations and Industrial houses) to de-water the low-lying areas. Besides the existing stationary dewatering stations (76 in number), most came under floodwater and needed immediate revamping and repairs. The fleet of SMC vehicles of all sizes and utility needed immediate repairs at the SMC Truck Yard at Tattoo Ground Batamallo, which was also under 3-4 feet flood water for less than one week. SMC, had a policy of updating readiness focusing on building middle-level leadership, training of the field staff including working during nights, vehicle repairs, operation of its dewatering pumping stations, and timely procurement and safe stocking of materials. SMC had procured and stocked safely 15,000 litres of diesel oil on the late evening of 6th of September, 2014. It was because of this diesel oil that initial rescue, relief and SMC operations were facilitated, for at least two weeks after September 7.

As the water started receding, Srinagar presented a very grim picture of blocked roads, lanes, bye lanes full of mud, garbage and malodor. Hundreds of tons of stinking garbage had piled up all over the flooded areas and more was expected to be thrown on roads as the exercise of cleaning homes, offices, and shops had started in areas that were out of submergence or were partially submerged. A huge quantity of post-flood trash and garbage, including collapsed buildings, mixed rotten house-hold items, food stocks, sewage waste, animal carcasses

and rotten packaged food items, threatened public health at large. Dewatering Pumping stations were totally blocked with garbage, dirt and siltation and needed immediate cleaning/drying and repairs of electromagnetic parts.

At Chattabal, Bemina (the Army Dairy Farm), hundreds of dead cattle were scattered within and outside the dairy farm premises, which posed a threat of an eminent epidemic in the city (refer Figure 11). The city sanitation, waste collection and disposal operations had to begin on war footing as the first priority of the SMC. It was at this point, that SMC took the charge of the situation to take on this challenge head on. Thus, began the operation "Mission Clean Srinagar".



Figure11: Images showing pile of garbage and dead animals and damaged buildings

Source: SMC, 2014

4. TACKLING POST FLOOD CHALLENGE

Initial steps of this mammoth and ambitious clean-up task was not easy as SMC's central office, sub offices, ward offices, and transport yard were under water. Vehicles parked at Municipal Transport Yard were also damaged. Breakdown in communication had further complicated the problem as people were stranded without any source of communication. Amidst these challenges, SMC had to begin the sanitization and cleanliness operations immediately. Army provided satellite phones and CDMA communication sets to the Civil administration. Jammu and Kashmir police's telecommunication wing, provided hand held communication sets to the SMC officers including fixed communication units on the vehicles. SMC municipal commissioner was also provided a satellite phone.

4.1 Operational Strategies

The measures adopted to provide post flood relief can be summarized by the following five steps (in their given order):

- Setting-up teams and assigning responsibilities
- De-odorizing/Disinfecting Strategy

- Lifting and disposal of garbage and animal carcasses
- Thorough cleaning of public and private premises to remove the accumulated soil
- Fogging and spraying of disinfectants

a) Setting-up teams and sub-teams

As an immediate step, the cleaning operation for Srinagar city was launched without any major resources such as equipment, vehicles and manpower. Under the supervision of Commissioner the operation began at the earliest and they were assisted by the Municipal Secretary from a makeshift office located at Buchpora in the northern part of Srinagar. Three to four days after the flood, a small group of employees managed to find their way to the SMC makeshift office, which later grew to a large group of around 3000 personnel's (Officers, engineers, technicians, and field staff) and an equal number of temporary sanitation staff. As the water level began receding on September 11, SMC established its Camp Office at its Truck Yard at Tattoo Ground, Batmaloo.

The expert teams supervised operations in various flood ravaged municipal wards, with the Ward Officers directly reporting to the respective team heads for drawing out required support for men, materials and machinery (Figure 12). The following units constituted the Special task groups:

- Hiring and Vehicle Deployment Unit
- Vehicles Repairs and Overhauling Unit
- Management and Procurement Unit
- Animal Carcasses Removal Unit
- Cleaning and Sanitation Unit
- Application of Disinfectants and Deodorizing Chemicals Unit
- Data analysis and recording Unit



Figure 12 The team of workers for the Cleaning Operation

Source: SMC, 2014

b) De-odorizing/ Disinfecting Strategy

As the putrefied garbage comprising of household items (also collapsed building materials), sewage, decomposed food items, commercial food stocks (including that of Food Corporation of India) and big/small animal carcasses (over 1,685) started stinking, it made cleaning and sanitation operations almost difficult. Thus to start working on the ground it became necessary to remove and disinfect the putrefied waste material and control the foul smell. Liberal use of disinfectants, phenyl (including black phenyl) and an anti-odor/deodorising formulation Sanitreet were used profusely. Tetanus Toxoid and Hepatitis-B injections were administered to the entire workforce and supervisors to ensure further safety (Refer figure 13). Mass distribution of chlorine tablets was undertaken by the Health Department and SMC health officer for mixing with drinking water, to check the possible spread of water-borne diseases in Srinagar City.



Figure 13 Workers being vaccinated
Source: SMC, 2014

c) Lifting and disposal of garbage and animal carcasses

For the operation, "Mission Clean Srinagar", SMC used over 5000 employees, 200 machines (JCB's, bulldozers, trucks, loaders, garbage compacters etc.) including a large number of trucks from the non-flooded areas and sanitation tools including disinfectants and anti-odour treatment. The field staff was provided safety clothing, gloves and gumboots. At various locations in Srinagar, SMC organized resting rooms with adequate provisions of clean water and hot meals (Dal and rice).

The sanitation work was thus carried out day and night without breaks.During the operation, 85,157 metric tonnes of waste materials was collected, involving around 17,836 truck trips to the city landfill site at Achan, Srinagar. 11.90 lakh

litres of disinfectants and 29,500 kgs of anti-odour formulation -Sanitreet was used to achieve a reasonable level of cleanliness, odour control and liveability. 1686 animal carcasses were carefully picked up (with hugely swollen bodies) and disposed, as per standard protocol. The strategic location of landfill site at dry elevated area added great advantage to these operations, as it was free of any inundation. The problems would have multiplied had this landfill site got affected with flood. The SMC landfill site at Achan, Saidapora has been developed by Jammu and Kashmir Economic Reconstruction Agency (J &K ERA) under the financial support of Asian Development Bank.

During normal days SMC lifts daily 200 to 300 MT of garbage, but during post-flood operations, the quantity of garbage and waste collected increased from 48MT on September 11, 2014, to 2422 MT by October 3, 2014. An average of 1051 MT's of waste was lifted daily which was almost 5 times more than the usual quantity. On a normal day, the usual trucks carrying garbage make 7,542 trips to the landfill site but after the flood 17,836 trips of trucks to landfill sites were recorded which is almost three times more than usual (Refer Figures 21). The team also lifted 320 dead cows from Bemina Dairy Farm (Refer Figure 15) within 48 hours by working round the clock, using robotic arms, JCBs, highly specialised loaders and hydraulic tippers (Refer Figure 16). Little more than a month was taken to collect and dispose of most of the garbage.

A total of 1685 animal carcasses (687 small and 998 large) were removed and disposed-off from the city (Refer figure 14, 15). These animal carcasses were buried and to augment decomposition process, chemicals like lime and Bioculum were used. Within a week, most of the animal carcasses were disposed. Awareness related to the disposal of small dead animals at household level was disseminated. Many notable officials, public representatives, trade unions and media representatives also visited the city to witness post flood cleaning operations and rehabilitation works.



Figure 14 Floating Animal Carcasses and accumulate garbage

Source: SMC, 2014

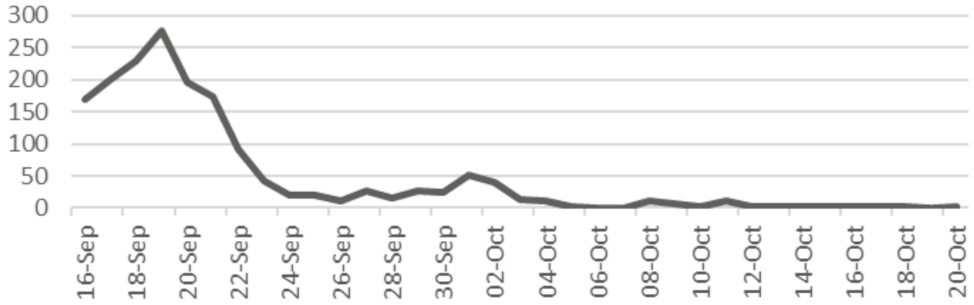


Figure 15 Number of animal carcasses lifted in two months

Source: SMC, 2014



Figure 16: Fleet of trucks and JCBs to lift the waste

Source: SMC, 2014



Figure 17. Thorough washing

Source: SMC, 2014

d) Thorough cleaning to remove accumulated soil

As garbage and animal carcasses were removed, mud and sludge still remained which could become a breeding ground for all sorts of harmful microorganisms. After disposing the garbage and animal carcasses to landfill site, the next task was to remove the thick layer of accumulated soil, by thorough washing and cleaning which if left unattended would cause respiratory tract disorder and other unwanted diseases. (Refer Figure 17).

e) Fogging and Spraying of disinfectants

Removing the accumulated soil and muck was followed by fogging and spraying of disinfectants covering the 100 percent households in the flooded areas. The city was disinfected using liberal quantities of disinfectant chemicals and phenyl. Fogging was done using Corporation's battery fogging machines. SMC widely used various other insecticides and antibacterial sprays including anti-odour formulation - sanitreat, lime powder, and Methanol while cleaning of Hospitals, Government Offices, Colleges and Schools, Civil Secretariat, High Court Complex, roads and lanes, in order to ensure a full disinfectant cover and high-quality cleaning.

To disinfect individual houses, people were provided a liberal supply of black phenyl and anti-odour formulation.

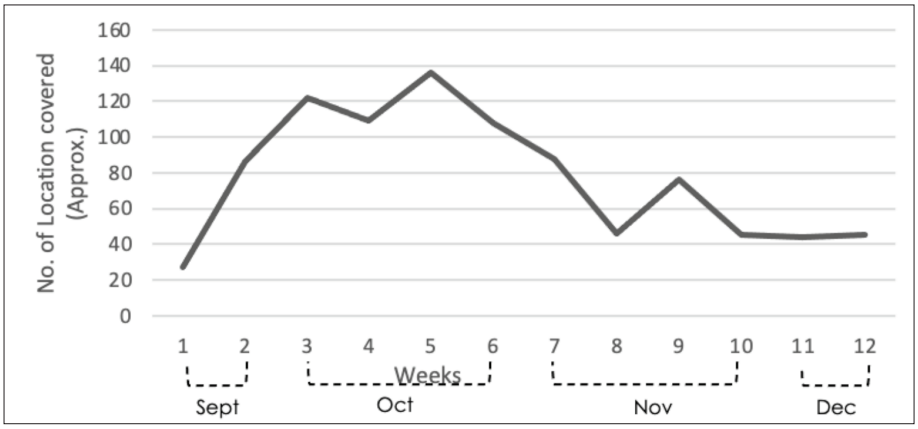


Figure 18 Weekly progresses in spraying of disinfectants during Sept-Dec 2014

Source: SMC, 2014

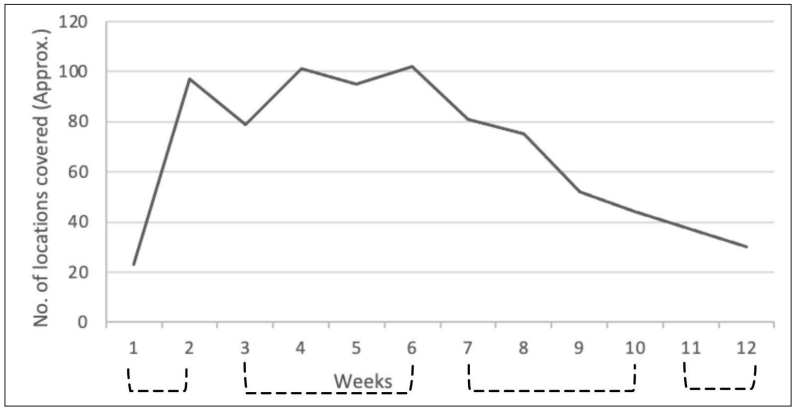


Figure 19 Weekly progresses in fogging the areas during Sept-Dec 2014

Source: SMC, 2014

Above graphs (Refer Figure 18, 19) show that most parts of Srinagar city were covered with fogging and spraying disinfectant in the month of October (Refer figure 20). Daily basis spraying of disinfectant and fogging in flood affected areas started picking up by the first week of October. For safe drinking water, State Health Department further distributed Chlorine tablets from their central offices to the workers and the public.



Figure 20 Fogging and Spraying Disinfectant

Source: SMC, 2014

As cleaning and sanitisation progressed, SMC team worked round-the-clock without any pause and in a short span of time, getting the city life back to normalcy, an effort that was highly appreciated by the public. Figure 21 shows the graph of Garbage collected and daily truck trips to the landfill site. Table 2 enlists the achievements of SMC during sanitation drive.

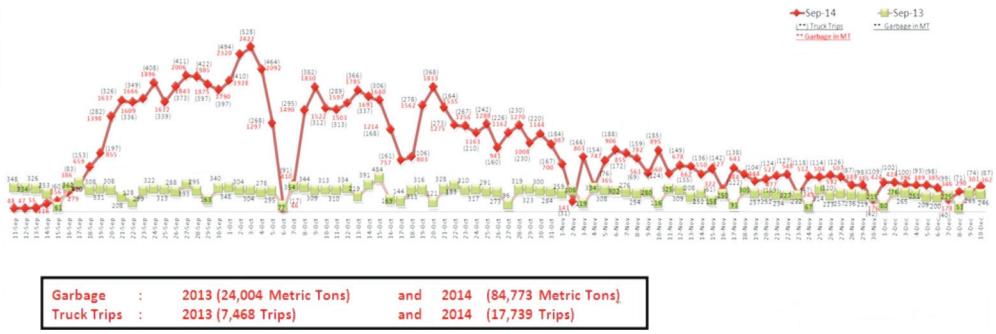


Figure 21 Garbage collected and Truck trips

Source: SMC, 2014

Post Flood Waste Management initiatives from 11 September- 12th September- 10th December 2014	
Garbage collected and Disposed off	84773 Metric Tons
Truck trips to land fill site (Achan)	17739

Disinfectants and other chemicals used	59540 liters
Anti-Odour Formulation (Sanitreat) used	29500 kgs
Animal Carcasses disposed	1686 (Small- 687, large 999)
Source: SMC, 2014	

Table 2 Achievements of SMC sanitation drive during September 2014, Srinagar flood

f) Outcome of the Operation- a Full stop to Epidemic Outbreak

The biggest outcome of the operation "Clean Srinagar" was the prevention of disease and epidemic. No case related to chest infection or water borne disease was recorded, as reported by the Director of Sher-e-Kashmir Institute of Medical Science, Soura. The director appreciated the commendable work done by the SMC and stated that the efficient removal and disposal of garbage and dead animals helped in achieving this. The process was so quick and efficient that senior military officers, notable citizens of society and tourism operators from flood affected areas acknowledged and praised these efforts. The operation "Clean Srinagar" was thus the biggest ever sanitation and cleanliness drive in Srinagar city.

The India Today report published on December 1st, 2014, ranked Srinagar city at ninth spot for cleanliness. Efficient port-flood management practice enabled the city to secure its place in the list of top 10 cleanest cities in the country.

5. CONCLUSION

Despite limited resources, the success of the "Operation Clean Srinagar" can be accounted to the following factors.

- Strategic location of landfill site: A well-constructed Scientific Landfill Site, strategically located at Achan, Saidpora, Srinagar was away from any risk of inundation due to flood. It is equipped with a computerised weighing bridge, keeping a full record of waste and movements of the garbage trucks. It comfortably accommodated over 85,000 kg of post flood waste in less than two months.
- Availability of Right Equipment: As the flooding had caused heavy damage to the infrastructure, the heavy capacity dewatering pumps, fogging machines and disinfectants/anti-odour formulations were organised by the state Government Authorities from Delhi and in support from other states and Industrial houses.

- Community engagement through social media: Immediately after the mobile telephones and internet was restored, use of Facebook (social media) was encouraged and SMC kept the public and outside world updated about the progress on handling the sanitation and cleanliness crisis. An interactive exchange was taking place on Facebook where people were posting alerts, grievances and suggestions on SMC Commissioner's Facebook page and steps to tackle individual problems were also being suggested.
- Leadership and management: The team SMC was well trained and motivated. The team worked under the leadership of experienced persons and efficiently handled the post flood crisis of sanitation and cleanliness operations.
- Liberal use of Chemicals: Liberal use of Baygon, phenyl (including black phenyl) and an anti-odour/deodorising formulation Sanitreet were used to fight the odour and to disinfect the affected areas.
- Proactive Planning: As part of the planning strategy, 15,000 litres of diesel was already stored to prepare for this calamity. It was because of this that initial rescue, relief and SMC operations were facilitated.

Acknowledgement

The operation "Mission Clean Srinagar" was made possible by the efforts of the selfless staff of the SMC, who contributed immensely beyond call of duty, particularly the officers, officials, Engineers, Technicians, drivers, and Fieldworkers. The success story of this mission shall be elaborated further in the voluminous body of written work to come. We extend our sincere thanks to Dr. Jyoti K Parikh, Executive Director, IRADe and Dr. Kirit Parikh, Chairman, IRADe, their guidance and support throughout the course of this study.

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Chapter 4

NATURAL DISASTERS AND VULNERABILITIES: A CASE STUDY OF BIHAR FLOODS 2019

Nahia Hussain

ABSTRACT

Climate change will be the harbinger of uncertainties. There have been unpredictable changes in local weather conditions across the globe. Temperature has soared, rainfall has become erratic and frequency of natural disaster has increased enormously. The recent ill-timed rainfall in Bihar wreaked devastation of an alarming level. This case study attempts to explore the intricacies of the havoc caused by the sudden advent of floods in a State grappling with a poor health care system, feeble disaster management architecture and endemic poverty. Urbanization, agriculture and population growth of the state have not accounted for the flood-prone topography of the region. Bihar has been reeling in the spate of floods since time immemorial however the change in precipitation patterns, owing to climate change, will require an overhaul of the existing notion of flood preparedness. A dimension of sustainability and retarding climate change will have to be included in the disaster management policies. Hence, while floods cannot be prevented, the fury of the disaster can certainly be managed by a multisectoral approach.

Keywords: *Climate Change, Flood resilience, Poverty, Sustainability.*

Nahia Hussain
Consultant, Centre for Development Policy and Practice, Hyderabad, Telangana, India
nahiahussain@nls.ac.in

1. INTRODUCTION

Hydrological and precipitation cycles have undergone unprecedented changes as a result of global warming. The global temperatures increased by 0.85% during the period 1880-2012. Global Warming has impacted the Indian subcontinent as well and 0% increase has been recorded in the temperature during the period 1901-2010 (IPCC, 2018). Climate Change has evidences in. heat waves felt across Andhra and Telangana, cold wave in Kashmir and heavy rainfalls in Mumbai and Uttarakhand (Guleria & Gupta, 2016).

Summer monsoons play a pivotal role in an agricultural economy like India. The food security as well as the economy of India is dependent on agriculture. Thus, variability in precipitation can be extremely catastrophic. Climate change is resulting in erratic precipitation patterns. Seasonal rainfall being concentrated in short span of time leads to flooding. Several parts of India are grappling with unusually heavy rainfalls, leading to severe loss of human life and property. Studies have shown that the warming of the Arabian Sea has resulted in increase in extreme rainfalls over Central India and rainstorms in North India have become 50% more common and 80% longer (M.K et al., 2017). World Bank prediction warns that India's summer monsoons are going to get even more unpredictable. Rainfalls during monsoon have been deficit, but rains outside monsoons are increasing.

The combination of flood proneness, geography, poverty, and unpreparedness increase the vulnerability of a region several times over. Bihar has a multi-hazard profile. 28 out of 38 districts are prone to floods. About 13 districts in the South are prone to droughts. 21 districts lie in zone IV and 7 districts lie in zone V of seismic activity. Cyclonic storms affect 27 districts. Additionally, heat waves, cold waves as well health emergencies are common in the State (Government of Bihar, 2016).

Floods are a consequence of climate changes, hydrological movements, and land-use pattern. Bihar is divided by Ganga flowing eastward; Kosi and Gandak drain the northern half of the state. Other Rivers include the Bagmati, the Bhutahi Balan, the Burhi Gandak, the Ghaghara, the Kamala, and the Mahananda. Bihar is thus constantly subject to shifting courses of these rivers.

2. BACKGROUND

The geography and flat topography of the State of Bihar increase the incidence of floods. Located at the point where rivers from Nepal flow into India, Bihar faces fury of these rivers. The shift from sharp bed slopes in Nepal to flatlands in Bihar, deposits silt which produces recurring floods in the region. Flood prone area in Bihar amounts to 68.80 lakh hectare. About 73% of the total geographical area in Bihar is under flood threats, which accounts for 17.2% of the country's total area (Kumar, Sahdeo, & Guleria, 2013). Heavy Siltation of the Ganga as a result of Farakka Barrage has also faced much criticism in the recent floods. The reduced carrying capacity of the Ganges has made the region susceptible to floods. As per records, the flood affected area of Bihar

has increased from 2.5 million hectares in 1954 to 7.3 million hectares in 2016 (Bandyopadhay, 2017).

As per a study that analyzed rainstorms over North India which lead to large-scale floods, it was found that the frequency of these rainstorms increased at 6% per decade between 1901-2009 and the duration of rainstorms increased by 15 days over the period 1951-2015 (Guhathakurta & Pai, 2017). Between September 28 to October 1, Patna received about 400 mm of rainfall.

Global temperatures have increased by 1%, warmer air has the capacity to hold more water vapor and thus the torrential downpour. From the period of 1950-2010, Bihar has seen average annual temperatures rise by 0.5 to 1 degree Celsius. The State has witnessed severe extremities in weather conditions over the year. The year began with 25 of the 38 districts reeling under severe droughts. Monsoons saw the districts in North Bihar bordering Nepal, reeling under floods, the Southern districts, on the other side of Ganga, facing droughts (Kumar S., 2019). The monsoon rainfall in Bihar is generally 1013.3mm. According to the MET centre, there has been 1017.4 mm rainfall till September 30, which is about 4% more than normal.

An IPCC report titled "The Ocean and Cryosphere in a Changing Climate" investigates how climate change impacts oceans and frozen bodies. India will face the brunt from melting of the ice in the Hindu Kush region, which holds largest reserves of water in the region. Floods are likely to become fairly routine in the downstream regions of Indus, Ganges and Brahmaputra river basins, as a result of extremities in precipitation (Prakash, 2019).

India witnessed a sharp rise in the number of floods decade-on-decade, India's flood mortality has severely increased, with 90 floods claiming 15,860 lives in 2006-2015, up from 13,660 lives lost in 67 floods the previous decade (United Nations Office for Disaster Risk Reduction, 2017). Accounting for last three years, rain-related deaths have been the highest in Bihar, a total of 970 or 15% of such deaths. Table 1 presents the period the flood casualties during 2016, 2017 and 2019.

Table 1: Damages reported in floods during 2016-19

Time-Year	Deaths	Population Affected	No. of Districts Affected
2016-17	243	8.823 million	12
2017-18	649	17 million	21
August 2019	130	8.84 million	13
October 2019	166	22 million	24

Source: (Government of India, 2019); (Press Trust of India, 2016); (Press Trust of India, 2019) (Davis, 2017); (Situation Report-1: Bihar Flood 2017, 2017)

The population affected by floods has been increasing in the wake of inadequate disaster management. In State of Bihar, the population at risk of facing floods will increase from 1.8 Million in 1971-2004 to 9.2 Million in 2035-44 (Bahri, 2018).

3. EVALUATION OF PRE, DURING AND POST-FLOOD SCENARIOS

3.1 Status of Existing Machinery

The Comptroller and Auditor General's performance audit on flood forecasting system revealed glaring gaps in the architecture of flood management. There exists an inadequacy in flood forecasting and post-flood management. The report highlights the incompetence and delays in flood management projects as well the glaring gaps in funds promised by the center and the actual funds received (Goswami, 2017).

The CAGs report also states that telemetry stations remained non-functional and reliance on manual stations continues. The River Management Activities and Works related to Border Areas were also inordinately delayed. Only a few Dams claimed to have an Emergency Action Plan in place. The Kosi High Dam Project even in its 26th year is incomplete.

In 2015 Central Water Commission was awarded with the task of undertaking morphological studies of 15 rivers in 11 Ganga Basin States. However, only 8 were taken up. The report states that in the absence of such studies, "planning, building, renovating and maintaining revetments, spurs and embankments to prevent loss of land due to erosion, could not be ensured" (Report of the CAG, 2017).

3.2 Status in Bihar

3.2.1 Policy Framework

Bihar Government has developed a framework for disaster management in the form of 'Roadmap for disaster risk reduction 2015-2030'. The States' water policy also boasts of an outline on management of floods. Water Resources Department as well State Disaster Management Department includes standard operating procedure, clearly defining the course of action pre, during and post floods. Rules mandate that District Magistrates must assess flood control preparedness in the month of May in their respective districts.

National disaster Management act was adopted in 2005 followed by establishment of institutions like Bihar State Disaster management authority, District Disaster Management Authorities, State Executive Committee and State Disaster Response Forcewith the larger goal of managing disaster and building resilience. One Battalion of NDRF has been allocated to Bihar.

Several Risk assessments tools like Flood Hazard Atlas and Flood Management and Information System has been created with the intent of moving towards disaster preparedness and management of flood prone areas in Bihar.

'Surakashit Bihar ka Lakshya', is an initiative of Disaster Management Department of Government of Bihar. The online portal deals with knowledge on Disaster Risk Reduction with regards to Bihar. It collates and disseminates policy reports, training modules, Standard Operating Procedures etc. to relevant stakeholders.

Bihar Inter Agency Group was set up in the Aftermath of 2004 floods to strengthen coordinated responses to disasters. Standard Operating Procedures were developed by the State on Flood and their control as well other disasters. Civil Society was mobilized to give impetus to community-based disaster risk reduction.

Several Schemes were developed to ease distress post disasters. These include Schemes such as Bihar Shatabdi Anna Kalash Yojana, Kosi Flood Recovery Project and the Bihar Scheme for Assistance to Farmers in Farm Distress.

Bihar Action Plan for climate change was initiated to deal with issues of climate change and disasters plaguing the State. Several steps have been taken to spread awareness as well as build capacity of institutions (Government of Bihar, 2016).

Use it like a form and just fill in your information in the appropriate places.

3.2.2 Current Status.

The State Disaster Response Fund released rupees 417 crores in 2018-19.

- In the State rivers like the Kosi, Mahananda, Gandak, Bagmati and Ganga are running rash and have also breached embankments (Down to Earth, 2017).
- An expert committee reviewed two dams in December 2015 and suggested remedial measure. None of which were addressed (Report of the CAG, 2017).
- Under 'Namami Gange' sewer lines being laid down have disrupted the previous drainage system. Broken pipelines, created manholes, ditches and puddles have aggravated the floods by accumulating water.
- Indian Meteorological Department had alerted the State Authorities 72 hours prior to rains.
- Drains also were not de-silted despite a budget of rupees 6 Crores being allocated for the purpose (Rohini & Singh, 2019).

4. IMPACT OF DISASTER IN BIHAR

4.1 Food Security and Agrarian Incomes

Natural Disasters such as floods deepen the malaise of poverty. Destruction caused to livelihoods and assets perpetuates inequality. According to the census of 2011, Bihar is the third most populous state in India, with around 40% of its population below the poverty line. Floods and ill-timed rains destroy crops, making sustenance for poor farmers extremely difficult. In 2017-18, a crop area amounting to 8.100 lakh hectare was damaged due to natural disasters in Bihar (Ministry of Home Affairs, 2018). Farm areas become uncultivable because of silt deposition. Small farmers are often most vulnerable to such disasters, given that they lack crop insurance and agricultural investments. Around 78% of the population is involved in agriculture and 91% of the farmers in Bihar are marginal farmers with small landholdings. Economic Survey 2017-18 highlights that with climate change an average reduction of 15-18% in annual agricultural income, and between 20-25% in unirrigated areas.

4.2 Infrastructure and Livelihood

The structures built inside an embankment like schools, huts, health centers lack a flood-proof architecture, hence every year people living in these areas lose all their belongings. This pushes back development by 5 years at least. Disruption of livelihoods poses serious concerns for the poor as they are pushed into the poverty cycle. The poor in the state lack savings as well as disaster resilient housing. Once floods strike, absence of food security, leaves them on the streets awaiting relief. Industrial and manufacturing sector also suffer during flood as they depend heavily on power supply, water supply, communication etc.

4.3 Health

Floods bring with it a plethora of diseases. Stagnant waters provide ample breeding ground for vectors of diseases like Chikungunya, Malaria and Dengue. Several water-borne diseases like typhoid, cholera etc. also see a spurt during floods. In Bihar, 900 people have been tested positive for dengue post the floods. Patna alone registered 640 cases (Firstpost, 2019). In the aftermath of the floods, about 110 cases of chikungunya were reported and more than a hundred children were treated for diarrhea (News18, 2019).

In the wake of floods, hospitals were waterlogged. Nalanda Medical College and Hospital was flooded knee-deep even in the Emergency and ICU, thus patients had to be shifted (Singh R. K., 2019). Amidst the stench, filth and floating animal carcass people suffering from fever found it extremely difficult to go get tested for dengue.

Bihar's health infrastructure is already inept in dealing with the health issues of the state. Indicators like maternal mortality, infant mortality and total fertility

rate are worse off than all-India averages. The state is in need 1,210 sub-centers, 131 primary health centers (PHCs), and 389 community health centers (CHCs) to cater to its large population. During crisis, the machinery operated with several lags.

Table 2: Existing PHCs and CHCs in Bihar

Institutions	Present	Required	Shortfall	Percentage Shortfall
PHCs	3099	1899	1200	39
CHCs	744	150	624	81

Source: 2011 Census

Bihar did not use Rs 88.5 crore given by the Centre in 2018-19 to upgrade its existing Primary Health Centres and sub-centres. The center provides cashless insurance benefit under its Ayushman Bharat scheme. Out of 10.8 million eligible families, 50,369 hospital admissions were made worth claims of rupees 51 crores only (Sharma, 2019).

5. ANALYSIS

The intensity of rainfall has increased while the numbers of the rainy days have declined. This changes the entire discourse of a predominantly agrarian country and a State like Bihar. Bihar faced its worst flood in the same year as it had a monsoon deficit. It clearly drives home the point of building resilience against the changing climate.

The state has an extremely high population density and is a victim of haphazard development. Roads and buildings have been built illegally and without clearance, across riverbeds. The proliferation of unauthorized construction subsuming public lands and water bodies has resulted in the present distress (Singh & Upmanyu, 2019). The lack of coordination between Urban Development Ministry, Bihar Infrastructure Development Corporation and Patna Municipal corporation became evident as chaos ensued during the floods. The situational mismanagement by the top-level to ground-level functionaries led to unprecedented damage during these floods.

While the State boasts of a roadmap with a framework of policies, laws, schemes, and rules in place to mitigate and reduce disaster-related risks and tragedies on paper, in implementation several gaps exist. Also, so far, most institutions or guidelines that have come into place have been in the aftermath of floods or other disasters. These points to more of a post-disaster role rather than developing a pre-emptive approach. So far, the strategy of the Government in dealing with floods, has been largely post-flood aid rather than pre-disaster preparedness. Given the rising uncertainty of rains, the enormity of these floods will increase several times over and a band-aid approach may not help.

The bulging human footprint has put undue pressure on open lands and water bodies. Human density has become demanding of infrastructure like housing, schools, roads, and workspaces leading to concretization of open spaces. Poverty intensifies the severity of disasters and vice-versa. The endemic poverty of Bihar puts daily wage earners and farm earners in extreme distress. Post-flood control tactics fails to alleviate their state.

6. RECOMMENDATIONS

The strategy to prevent, mitigate and reduce flood-related damages and casualties must include prior, during and post flood remedial measures. A framework that investigates minimizing losses and reducing the risks prior to a catastrophe is the need of the hour. Climate Change induced disasters may become a norm, a policy that enforces holistic rehabilitation rather than hand-outs and damage control post floods will need to be incorporated into the traditional approach.

6.1 Pre-Flood Measures

- Develop a robust data monitoring network that combines both hydrological and meteorological data, whilst strengthening trans-boundary exchange of similar data.
- Measures like flood plain zoning, flood proofing, flood forecasting and warning, watershed management may be adopted to ease distress.
- Information communication must be designed to reach the remotest areas in the region.
- Investments in groundwater recharge, irrigation, and reservoirs.
- Diversification of farm and non-farm activities as well encouraging insurance schemes for crop, livestock, and housing.
- Mainstreaming the discourse on climate-induced floods into sustainable development paradigms.
- Capacity building of institutions and actors.

6.2 During Floods

- Cash transfer to help the poor and vulnerable groups to help them get back to normal lives.
- Accessible Community kitchens for the affected populations.
- Setting up shelter and distribution of materials like tarpaulin, ground sheet, bed sheet, mosquito net and blanket.

- Improved access of drinking water via tanks and chlorination of water resources.
- Install mobile toilets and temporary rest rooms to minimize open defecation.
- Distribution of medical necessities like ORS, sanitary napkins, Soaps etc. via community volunteers.
- Search and Rescue Team comprising local volunteers.
- Steps to control Vector-borne diseases.

6.3 Post Floods

- Restoration of houses, schools, electricity and communication lines, health services disrupted by floods.
- Repatriation of all the displaced people, economic rehabilitation via restoring traditional and alternative livelihoods along with development of community-based infrastructure and institutions.
- Documenting and Dissemination lesson learned.
- Restoring mental and physical health of the victim affected by floods.
- Socio-economic and environment impact assessment.
- Global Climate Change will bring unexpected changes in precipitation, temperatures, sea levels and water bodies. Increasing urbanization coupled with the radical changes in the climate will intensify the impact floods have on local community and resources. Infrastructure and civic works like drains, sewer lines, houses and schools will all be at mercy of such floods given the absence of flood resilience.
- Climate Change may render the current flood management structures and policies inadequate and insufficient to deal with erratic rainfall. Flood risk assessment thus must account for climate-change induced floods. Floods cannot be prevented, but only managed to minimize the impact on the population and resources. Structural and Regulatory architecture should be strengthened by mechanisms such as early warning systems, insurance, and reliable communication systems.
- While disasters like floods are inevitable, it is important to incorporate sustainable practices in the development debate. This is essential to decelerate the rate of change of climate. India being a developing country is also bearing the brunt of rapid industrialization of the West. It is crucial to mobilize international community to investigate concerns of the developing world regarding climate change.

7. CONCLUSION

Global Climate Change will bring unexpected changes in precipitation, temperatures, sea levels and water bodies. Increasing urbanization coupled with the radical changes in the climate will intensify the impact floods have on local community and resources. Infrastructure and civic works like drains, sewer lines, houses and schools will all be at mercy of such floods given the absence of flood resilience.

Climate Change may render the current flood management structures and policies inadequate and insufficient to deal with erratic rainfall. Flood risk assessment thus must account for climate-change induced floods. Floods cannot be prevented, but only managed to minimize the impact on the population and resources. Structural and Regulatory architecture should be strengthened by mechanisms such as early warning systems, insurance, and reliable communication systems.

While disasters like floods are inevitable, it is important to incorporate sustainable practices in the development debate. This is essential to decelerate the rate of change of climate. India being a developing country is also bearing the brunt of rapid industrialization of the West. It is crucial to mobilize international community to investigate concerns of the developing world regarding climate change.

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Chapter 5

FLOODS IN HILLY AREAS REQUIRE A DIFFERENT APPROACH

(Case Study - Uttarakhand Cloud Burst of June 2013)

Ramachandra Kamath and Edmond Fernandes

ABSTRACT

The multi-day cloudburst over the Himalayan state of Uttarakhand caused havoc and huge loss of life, property and infrastructure loss within a short span of a few days. The rainfall between 16th and 20th of June 2013 was 375% above normal for the period. Four hilly districts of Uttarkashi, Rudraprayag, Chamoli and Pithoragarh were completely cut-off for days together. Weather conditions like heavy rainfall, very cold temperatures and fog further hindered the rescue and relief activities that were essential in the initial days of such disasters. Post-traumatic stress disorders, rrespiratory infections, diarrhoea, skin infections, fever, vomiting were common among flood victims. New innovative flood management guidelines to manage floods in hilly areas should be prepared.

Keywords: *Cloudburst, Floods in hilly areas, Post flood situation, Challenges.*

Ramachandra Kamath✉
Professor and Head, Department of Community Medicine, Kodagu Institute of Medical Sciences Madikeri, Karnataka, India
ramymarne@gmail.com

Edmond Fernandes
CEO, CHD Group, Mangalore & Senior Fellow, Atlantic Council, Washington DC

1. INTRODUCTION

Uttarakhand state has a composition of metamorphic rocks and tectonically active making the state vulnerable to repeated disasters and climatic risk. Socio-economic, geopolitical, environmental and ecological make up of the state makes it highly vulnerable to natural disasters, cloudburst being one among them. The average annual rainfall in Uttarakhand is about 1229 mm with the state having cold weather with snow for many months, besides receiving moderately high rainfall and mild summers given the terrain.

In terms of vulnerability profile, the state is prone to landslides, earthquakes, floods, hailstorms, lightening, road accidents and also epidemics. The state remains in the Zone IV and V for earthquake and other multi-hazard risk like avalanche, cloud bursts and forest fires. (SDMP-UK).

Historically, the earthquakes of 1991 at Uttarkashi and the 1999 earthquake at Chamoli have been of lesser magnitude, but seismic events of greater magnitude can be anticipated in the days to come, driving the agenda to prepare a composite risk index to climate change driven risks. The landslides of 1998 at Malpa killed over 300 people while the one that occurred in 2009 at La Jhakela in Munisyari Tehsil claimed 43 lives, besides large number of loss of livelihood. Similarly cloud bursts have had historical relation with the state where 43 people lost their lives in the 2009 cloudburst at Pithoragarh and the 2010 cloudburst at Kapkot saw 18 children buried alive with 36 lives lost.

As per the Vulnerability Atlas of India, in Uttarakhand approximate 56% percent houses are made of mud, un-burnt brick and stone wall. This is a sign of 27 very high vulnerability, considering probability of Earth quake, Landslides, Flash flood and Cloud burst etc. (SDMP-UK)

The multi-day cloudburst over the Himalayan state of Uttarakhand caused havoc and huge loss of life, property and infrastructure loss (Houses, Hospitals, Hotels, temples, townships) within a short span of a few days. Uttarakhand is a well-known tourist place and religious place. The birth place of rivers became watery graveyard in few hours of cloudburst and the state witnessed one of its worst monsoons in June 2013.

The rainfall between 16th and 20th of June 2013 was 375% above normal for the period. (Aggarwal, 2018). Official figures documented a loss of around 6,000 lives Over 2000 houses were destroyed, 147 bridges were destroyed and 1,307 km of roads were damaged. Buildings which were constructed along the path of the rivers without following any construction norms were washed away along with several vehicles that were parked. Large number of dams on the Himalayan rivers and large hydropower projects aggravated the situation.

Four hilly districts of Uttarkashi, Rudraprayag, Chamoli and Pithoragarh were completely cut-off for days together. The complex phenomenon of high intensity rainfall (cloudbursts) leading to massive landslides, debris flows and flash floods became etched in public consciousness during this disaster. This phenomenon was not clearly predicted by any agency national or international. Along with the unprecedented nature of the calamity, the unpreparedness of the national, state and local authorities made it difficult to manage the mitigation, rescue, and relief efforts that followed.

The Himalayan mountainous terrain with its unstable soil led to multiple landslides and debris flows thus destroying the road network which cut off the access to evacuation of victims and supply of relief materials. Weather conditions like heavy rainfall, very cold temperatures and fog further hindered the rescue and relief activities that were essential in the initial days of such disasters. Dropping of relief material by air (helicopters) which is normally done in plains (such as Bihar) was not possible due to the presence of trees and isolated homesteads.

2. RAINFALL RECEIVED DURING THE PERIOD OF JUNE 2013

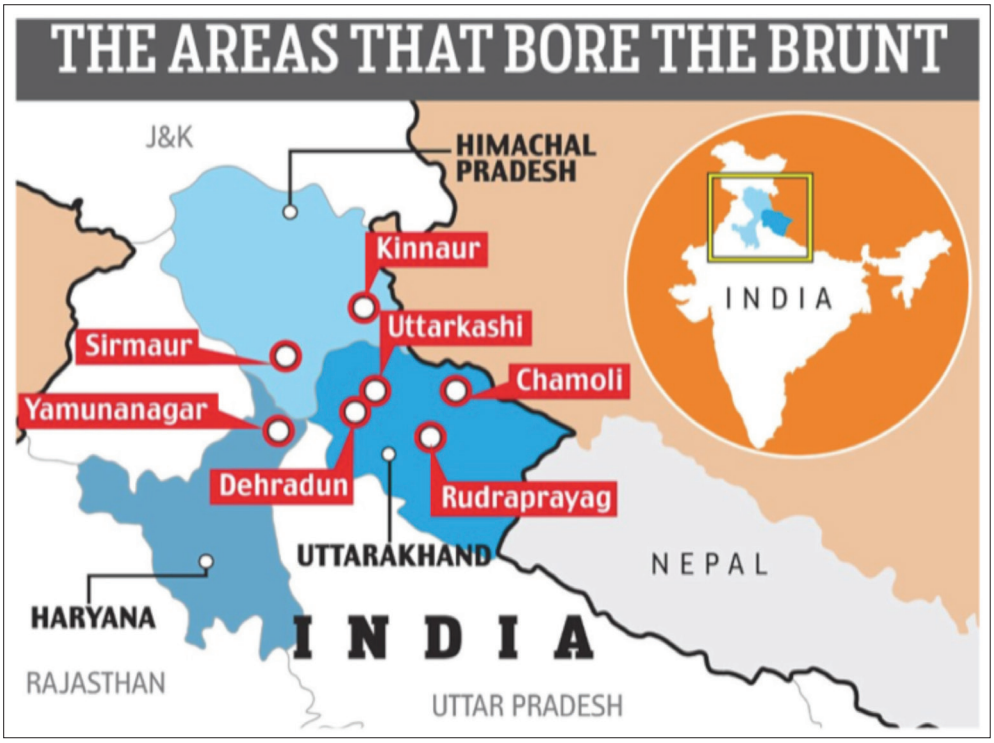
On 17th June 2013 the state of Uttarakhand in India (Latitude 28.72°N to 31.45°N and Longitude 77.57°E–81.03°E) received more than 340 mm of rainfall, which is 375% more than the daily normal (65.9 mm) rainfall during monsoon.

Rainfall Data of the districts

Districts	Average in the month of August Rain Fall of the district in mm	Max Monthly Rainfall in last 100 years in mm	Min Monthly Rainfall in last 100 years in mm	Rainfall on August 2013 in mm
Dehradun	673.9	1271 August 1943	20.4 June 1965	676.7
Uttarkashi	405.2	800.8 (August (1963)	36.88 (June 1987)	529.9
Teheri Gorwal	366.7	1097 (Sept 1995)	0 (Sept 1977)	453.4
Haridwar	367	848.2 (Sept 1924)	0 (Sept 1971)	426
RudraPrayag	639.4	914.6 (Aug 1925)	0 (Sept 1971)	664
Pithoragarh	538.9	1057(Aug 2000)	22 (June 1901)	471.9
Chamoli	452.4	860.7 (Sept 1924)	0 (1998)	537.9

On 17th June alone, the state of Uttarakhand received more than 340 mm of rainfall (37 cm/day in Dehradun [30.32°N, 78.36°E]; as reported in the Climate Diagnostics Bulletin of India, June 2013 (Dube A 2014), which is 375% more than the daily normal (65.9 mm). The India Meteorological Department (IMD) reported a weekly departure of about 847% in the rainfall volume for the week ending on 19th June 2013 in Uttarakhand.

MAP OF AFFECTED AREA 2013:



3. OBSERVATIONS, LESSON LEARNT AND CHALLENGES: GROUND REALITIES

3.1 Post flood situation:

3.1.1 Missing Tourist and Pilgrims

More than 70,000 pilgrims and tourists trapped in the valleys nearly 3 days. About 110,000 people were evacuated by Indian Air Force, Indian Army, Indo-Tibetan Border Police (ITBP), Border Security Force, National Disaster Response Force (NDRF) which was recorded as the most challenging and the largest evacuation in hilly areas.

Pilgrims and tourists were the main victims of the cloudburst. Most of the pilgrims were elderly population. People searching for their family members, relatives and friends was the most common scene in the disaster site. Few survivors were searching their close relatives by showing the photographs of missing people and asking for their whereabouts.

3.1.2 Rescue and relief

58 Helicopters 7,000 soldiers, airlifted a total of 18,424 people, 150 parachute commandos were deputed for the rescue. During the rescue two Helicopters were crashed on 25 June and killed 20 people due to bad weather conditions.

Relief materials supply and distribution were completely hampered due to lack of connectivity both by road and air.During relief work, 3,36,930 kg of relief material were dropped for the survivors. As most of the roads were damaged relief materials could not reach the disaster site. Even distribution of relief materials through helicopters was a big challenge because of the extreme weather conditions and scattered houses in the hilly and forest areas.

3.1.3 Health issues: Even after a week, dead bodies had not been removed from Kedarnath town. Identification and preservation of dead bodies, collection of DNA samples and disposal of dead bodies was the major challenge for the health team.

3.1.4 Emergency medical relief: Immediate requirements were resuscitation, dressing materials, splints, portable X-Ray machine, mobile operation theatre, lifesaving drugs, medical evacuation and trained manpower. Emergency medical relief was provided by Quick Reaction Medical teams, Mobile field teams, Floating hospitals, Army relief mobile vans, Heli-ambulance and Railway Medical vans during mass causalities.

Since, the disaster coincided with peak time for tourists and pilgrims, the casualties and damage. Majority of them had minor and major injuries including fractures. Respiratory infections, diarrhoea, skin infections, fever, vomiting, eye infections, Leptospirosis, Snake bites were common among flood victims.

Post-traumatic stress disorders were the major concern along with large number of deaths among the males. Local survivors were in shock for few days as they lost their near and dear ones. Social worker, Psychologist, Psychiatrist played a crucial role in handling such issues.

4. TRANSPORT

Most of the vehicles carrying relief materials were stranded due to heavy landslides which made it difficult for the timely distribution of relief materials.

5. FOOD AND WATER

Most of the food grains were washed away along the river banks. Hence, there was a shortage of food material. Availability of safe drinking water was the main issue as the most of the surface water was contaminated by the flood water.

6. AGRICULTURAL LOSS

Most of the farmer's lands were washed away due to heavy floods. Whatever they cultivated were lost due to cloudburst. Over 10336 hectares of land has been washed away by rain including crops of rice, wheat, lintels pulse, potatoes and vegetables have been drowned by the floods and derbies of landslides and paddy field, and >500 hectares of top soil has been turned into silt in the flood affected areas.

7. COMMUNICATION

Communication was the biggest barrier for emergency rescue, evacuation and emergency medical relief due to poor or absolutely no connectivity either landline or mobile network.

8. LOSS OF LIVE STOCK

People lost their livestock mainly, Animals like cows, buffaloes, sheep, goats.

9. DAMAGES

Life lines namely roads, bridges, Hospitals, electric poles, telephone poles and property damage was observed along the river banks. Damaged houses were filled with mud and sand up to 4-5 feet level destroying all the household belongings.

10. SPECIAL CHALLENGES

Uttarakhand state receives a large number of tourists throughout the year. During the disaster, a large number of pilgrims and tourists (nearly 3 lakh), many elderly, were stranded in vehicles for 2-3 days with little food. The presence of tourists during such disasters creates special challenges for evacuation.

Even though rescue and relief operations can only be conducted by air in such hilly areas, the presence of thick fog, heavy rainfall, poor visibility, cold weather, forested areas, melting of snow, narrow valleys, inaccessible areas, and lack of designated landing and drop-off sites for helicopters proved to be a challenge.

11. RECOMMENDATIONS

Periodic Flood forecasting and warning system is very essential during the pre-disaster period to prevent damages and save lives

Flood zoning regulations needs to be followed strictly during construction of buildings near the riverbanks

Flood proofing measures namely flood shelters; flood safe buildings are very much required in the flood prone areas.

New innovative flood management guidelines to manage floods in hilly areas should be prepared. Capacity building of human resources should be done at all levels in relation to preparedness, and post-floods stage: Rescue, Relief, Recovery, Reconstruction, Rehabilitation and Research.




Loss of agricultural land and damaged buildings along the river bank




Damaged roads Heavy traffic jam due to landslides and they are staying in vehicles for days with fear



House filled with mud and sand after the calamity

Picture Credit: Dr. Ramachandra Kamath (Author)

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Chapter 6

IMPACTS AND IMPLICATIONS OF EXTREME WEATHER EVENTS: LATUR WATER CRISIS 2016

Anjali Barwal and Anil Kumar Gupta

ABSTRACT

Climate change is a major threat to the health of the people. Rise in greenhouse gas concentrations result in increases in temperature, changes in precipitation, increase in the frequency and intensity of some extreme weather and climate events, and rising sea levels. India is prone to extreme weather events, especially, floods, drought, cyclones and landslides. This study focuses on the drought conditions in Latur, a district in Maharashtra state of India, which has been confronting severe water shortage due to drying up of a major source of water i.e., Manjara dam. The water crisis in this region has been contributing to many infectious diseases and other health related issues. The present study also aims to explore challenges for effective drought management and certain recommendations which can recover such situation. Scientific improvement is needed for breeding more drought-resistant animal and plants varieties will play a key role to balance the ecosystem.

Keywords: *Climate change; Extreme weather events; Public health; Latur Water Crisis; Latur drought.*

Anjali Barwal
Research Associate, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi, India
anjali.barwal@gmail.com

Anil Kumar Gupta
Professor & Head, ECDRM Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi, India

1. INTRODUCTION

In the last four decades, the frequency of natural disasters recorded in the Emergency Events Database (EM-DAT) has increased almost three-fold. Over the last decade, intense climatic disasters like floods, storms, heat-waves and droughts have been on the rise globally (Thomas & López, 2015). Change in climatic profile and rapid growth of urbanisation leads to loss of vegetation, topography, over concretisation, affecting natural drainage and intensive use of hydrocarbons. Unplanned development and encroachment on water bodies such as canals, lakes, streams, and wetlands are further deteriorating the sustainable ecosystems.

Water is the most essential element for human survival. All living beings and the communities, in which they live, cannot do without water since it corresponds to their primary needs and constitutes a basic condition of their existence and survival (Dixit, 2016). Access to safe water and sanitation is indispensable for the life and full development of all human beings and communities in the world. The adverse health effects that can arise by drinking contaminated water range from acute health effects such as acute gastrointestinal diseases to long-term outcomes such as cancer and physical and neurological developmental delays in children (Forde et. al., 2019).

Disasters directly or indirectly threaten the living environment of human beings and the health of the people, such as the deterioration of the ecological environment, the loss of huge property, death and related diseases, psychological trauma, and other immediate and delayed adverse effects (Ma & Jiang, 2019). Among the extreme meteorological events, intense drought events have been observed all around the world with high economic and social costs (Gupta et. al., 2011). It differs from other natural hazards due to its slow occurrence and its indefinite start and end. It often fails to draw attention of the world community and its impact persists even after the event is over (Bhuiyan, 2004). During the drought period, water sources are more likely to be contaminated by feces and pathogens, causing outbreaks of digestive tract diseases. Drought can also increase risk of non-communicable diseases such as gynecologic diseases, esophageal cancer, renal damage, etc. (Ma & Jiang, 2019). This study focuses on the health impacts and lessons learned from the drought conditions in Latur, a district in Maharashtra state of India, which has been confronting severe water shortage due to drying up of a major source of water.

1.1 Study Area: Latur city

Maharashtra is well developed and industrialized state of India. It is the third largest state with geographical area occupying 307713 sq km, holding 112.3 million populations (Census of India, 2011). Latur is a district in Maharashtra state of India. It is the 16th largest cities in Maharashtra with district headquarter

located in the city. The district comes under Marathwada region of Maharashtra, geographically located between 17°52′ North to 18°50′ North and 76°18′ East to 79°12′ East in the Deccan plateau. It has an average elevation of 631 meters (2,070 ft) above mean sea level. The entire district is on the Balaghat plateau, 540 to 638 meters from the mean sea level. Total area of Latur city is 970.71 sq. km. having population of 683666 (CGWB Report 2016). A map of Marathwada region is shown in the Figure 1.



Figure 1 Map of Marathawada region

Marathwada region is extremely prone to drought conditions and this region is experiencing it regularly after every three years. Drought impacts are long lasting, at times lingering for many years (Osmani & Patil, 2019). Latur district of Marathwada is the worst drought-affected region in Maharashtra. Unlike other disasters, drought gives sufficient warning and it was building for the past four to five years.

1.2 Rainfall pattern of Latur city

In 2015, Latur received less than 50% of its average monsoon rainfall, 361 mm as against monsoon average 723 mm. Water stress in Latur has been intensifying

over the last years. In July 2015, Latur received an unbelievably low rainfall of 28 mm as against the July average of 192.7 mm and had mere 2 rainy days. In 2014 too, monsoon rain was just above the 50% mark (SANDRP, 2016). About 80-85% of the annual rainfall is concentrated in the month of June-September. The district has an average of 42 rainy days per annum (Osmani & Patil, 2019). In Maharashtra state, the percentage to normal rainfall is gradually decreasing from the year 2011-2016. The rainfall pattern of Latur district is shown below in Figure 2.

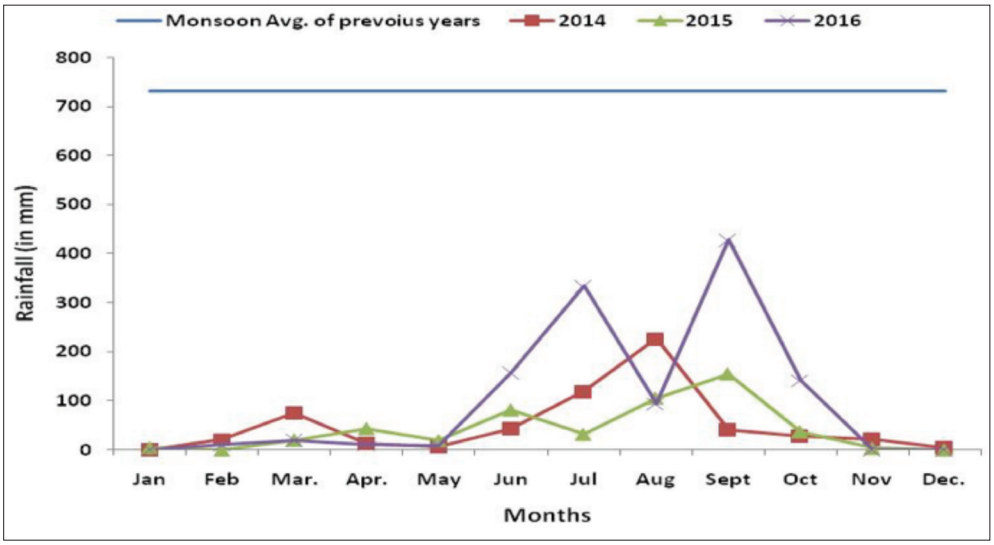


Figure 2 Rainfall in Latur region

Wrong agricultural practices in the Latur region is a major issue of concern and also adversely affect the ground water resources (Dixit, 2016). Of the total 205 sugar factories in Maharashtra, 34% are in Marathwada. Latur alone has 13 sugar factories and 45,000-50,000 ha area under annual sugarcane cultivation. Presence of sugar factories excessively draws ground water. And almost 90% of the total water available for irrigation in the district is used for sugarcane cultivation (Marathwada's dry story, 2016).

Latur city is dependent on three surface water sources i.e. Manjara dam, Sai barrage and Nagzari barrage. Satellite images show how dramatically the Manjara dam is shrinking over the course of past decades, which is shown in Figure 3.

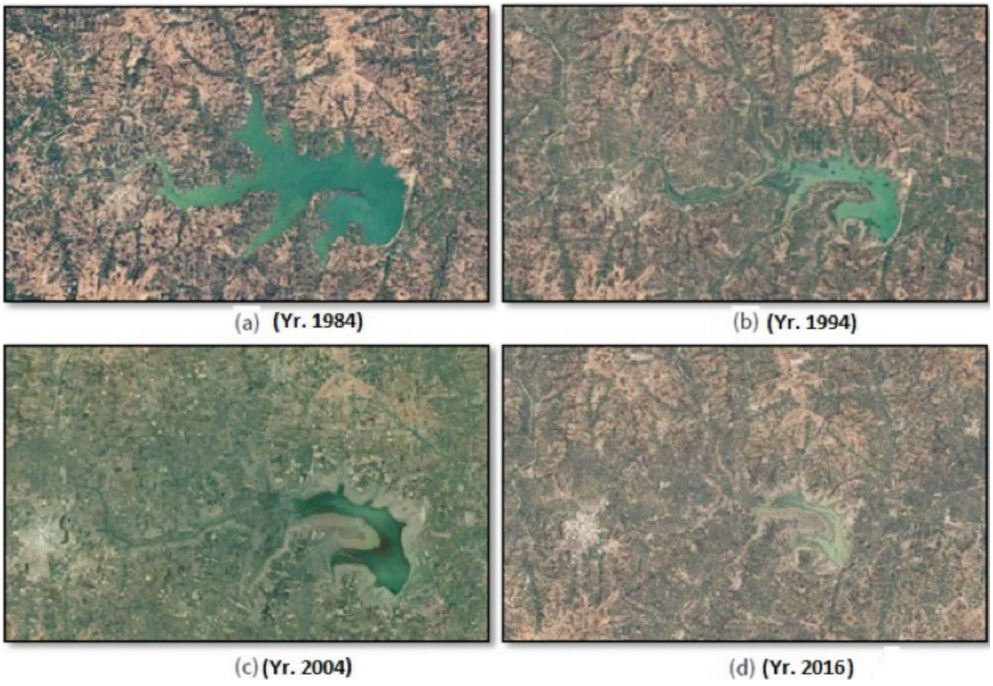


Figure 3 Drying up of Manjara dam over the past years
(Source: Google Earth pro time series satellite data)

2. HEALTH IMPLICATIONS OF DROUGHT

Drought poses many health implications which can be directly observed and measured and having indirect health effects that are not that easy to observe and monitor. The indirect health effects are usually long-term public health problems which include drinking water shortage, unpotable drinking water, impacts on sanitation, hygiene, food and nutritional security and other infectious disease (CDC, 2020). The health implications related to drought can be classified as follows:

2.1 Poor water quality

Reduced precipitation and increased evaporation of surface water increases the concentration of pollutants and cause stagnation. Increased water temperatures in lakes and reservoirs also lead to reduction of dissolved oxygen level in water bodies, which further deteriorates the water quality and affects the fish and other aquatic life. Untreated surface water poses a health threat in drought conditions.

2.2 Food and nutritional insecurity

Unfavorable conditions during the drought stress limit the crop production and growing season. Low crop yields results in rising food prices and shortages, potentially leading to malnutrition. Not only human beings, drought also affects the health of livestock animals. Livestock and other animals also become malnourished, diseased, and sometimes die (Eslamian & Eslamian, 2017).

2.3 Infectious diseases related to poor water quality

The risk of infectious diseases increases during the drought period due to shortage of water. Microorganisms pollute both groundwater and surface water when rainfall pattern decreases. e.g., E. coli and Salmonella Typhi are bacteria that contaminate food and cause infectious diseases. People who get their drinking water from private wells are at higher risk for infectious disease. Acute respiratory and gastrointestinal illnesses spread more easily from person to person when hand washing and hygiene is not maintained due to lack of available fresh and clean water. (Eslamian & Eslamian, 2017).

Food also serves as a vehicle for disease transmission during a drought because water shortages can cause farmers to use recycled water to irrigate their fields and process the food they grow. When used to grow crops, improperly treated water can cause a host of infectious diseases, which can be life-threatening for people in high-risk groups.

2.4 Zoonotic and vector-borne diseases

During drought, the likelihood of zoonotic and vector-borne disease transmission and infection increases. For instance, during dry periods, wild animals are more likely to seek water in areas where humans live. These behaviors increase the likelihood of human contact with wildlife, the insects they host, and the diseases they carry. Drought reduces the size of surface water bodies and causes them to become stagnant, which provides additional breeding areas for certain types of mosquitoes.

3. CITY'S ACTION PLAN & EFFORTS

Acute water shortage in Latur city in year 2016 was a result of previous two consecutive year's drought. All necessary water requirement and distribution planning for the city was done in very short duration. State government approved the proposals on priority basis. To avoid disturbances and unfair practices in water distribution, the District Magistrate imposed section 144 of IPC (unlawful assembly) at tanker filling points. For doorstep water distribution Global Positioning System (GPS) enabled water tankers were used in the city. Following actions and efforts were also undertaken by the Government to overcome the drought situation in the city:

- Changes in agricultural practices: Changes in agricultural practices and farming pattern in the semi-arid Marathwada region have been adapted in the past few decades. Marathwada receives an annual average rainfall of 844 mm, while sugarcane ideally needs 2,100-2,500 mm of rainfall. Several farmers have ditched drought-resistant crops such as jowar (sorghum) and chana (chickpea) for water-intensive cash crops such as sugarcane.

- Jalyukt Shivar Abhiyaan: The state government scheme, the Jalyukt Shivar Abhiyaan was started in 2014 with the promise to drought-proof the state by 2019. It aimed to make 5,000 villages free of water scarcity every year through deepening and widening of streams, construction of cement and earthen stop dams, work on nullahs and digging of farm ponds.

- Widening & deepening of main stream: In Latur, 18 km of Manjara river was widened and deepened between Sai and Nagzari barrages. At Harangul village on the outskirts of Latur city, local irrigation officials and farmers widened and deepened 27 km of main stream and its mini-streams that flow through the 160-ha cultivable land of the village. At some places the river was dredged to more than five metres depth.

- Ridge-to-valley approach: Administration in Bhadegaon village in Khuldabad tehsil of Aurangabad district has been successful in keeping drought at bay by adopting the ridge-to-valley approach of watershed management. In 2015, village residents, along with the forest department and agriculture officers, carried out deep continuous contour trench on the entire ridge around Bhadegaon on an area of 75 ha. Cemented nullah bandhs were constructed and compartment bunding was carried out in each farmland covering 60 ha. A number of farmers also adopted drip-irrigation.

- Water train (Jaldoot): Jaldoot, commissioned by the railway ministry in collaboration with the Maharashtra government, was one of the key measures to alleviate the situation, transporting half a million litres of water on each of its trips from Miraj in Sangli district. Miraj gets its water from the Warna dam, downstream of river Krishna. In April 2016, Maharashtra operated the water train to supply drinking water to drought-affected Latur.

- Water rationing: The municipal corporation started rationing water and even stopped supplying it through taps. Every household was supplied 200 litres of water free of cost once a week against the daily need of 85 litres of water per person.

- War room: Alarmed by the situation, Maharashtra Chief Minister interacted with 21 collectors on March 25 in Mumbai via video conferencing to take stock of the situation. He directed them to take the help of the Groundwater Surveys and Development Agency to find locations suitable for water conservation. He gave all powers to collectors to ensure compliances are

met. A war room was set up and a 24x7 toll-free helpline was made available for citizens to connect with the administration from March to September 2016. They had been asked to concentrate on water supply and take strictest action on those engaged in illegal selling of water (Latur: The great thirst, 2016). All tanker filling points were monitored from the war room by CCTV cameras for 24 hours. Information related to water intake and distribution was regularly updated on Collector office website and communicated to press and electronic media.

- Wagon service: Indian Railways and local government authorities in Latur made arrangements to run a 50-wagon service soon, with each wagon carrying at least 50,000 litres.

4. CONCLUSION

Disasters directly or indirectly threaten the living environment of human beings and the health of the people. Drought increases the risk of many infectious diseases. This study discussed about the various health implication of drought. The present study leads to certain recommendations which can recover the drought situation. In Latur city, all necessary water requirement and distribution planning for the city was done in very short duration. State government also approved the proposals on priority basis. Such prompt actions are required by the Government to restore balance in the society.

Government, NGOs, civil society groups and community itself will have to foresee the challenges and develop sustainable models of water harvesting and conservation as soon as possible. Sensitization of communities, affected or non-affected, on the issue, using all means of communication be it public or private, be it mass media or social media should be ensured. The development of watershed will increase surface and groundwater resources. The drought management should be carried out through public participation and awareness to cope up with possible future droughts. Scientific improvement in breeding more drought-resistant animal and plants varieties will play a key role to balance the ecosystem. The water budgeting at all level is also very essential.

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Chapter 7

THE FANI: A CASE STUDY OF ODISHA DISASTER MANAGEMENT

Pratap Kumar Jena and Jugal Kishore

ABSTRACT

Odisha's date with tropical cyclonic storm is a routine affair. Odisha has witnessed about one hundred major and eventful cyclonic storms during last century and lost around 1.6 lakh people in the ill fated events. The intensity of storms clubbed with geographical and socio-economic vulnerability, and limited coping capacity has converted many storms into disaster. The fatality per million affected population during super cyclone (1999), Phailin (2013) and Fani (2019) cyclones were 779.3, 3.55, and 3.82 respectively. Both Phailin and Fani preparedness had seen a large scale and intense evacuation efforts that shifted more than one million at risk people to safe shelters within 24 hours period in multi-sectoral coordinated efforts. Odisha has effectively used technology for early and timely warning, mobilized resources, community preparedness, relief and rescue operation to minimize the impact of Fani. It appears that the disaster management in Odisha has changed from relief & rescue to a proactive disaster readiness state. Despite of such readiness level, Odisha was able to minimize loss of life only, but not the material, economical and environmental loss, making Fani a mixture of success and failure story in disaster management. A further hazard reduction strategy in tune with the international framework to built disaster resilience community, infrastructure and environment is the need of the hour.

Keywords: *Fani, Cyclone, Odisha, Community Resources, OSDMA.*

Pratap Kumar Jena✉
Associate Professor, School of Public Health, KIIT Deemed to University, Bhubaneswar, India
drpratapjena@gmail.com

Jugal Kishore
Director Professor & Head, Department of Community medicine, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi, India

1. INTRODUCTION

Compassion towards the victims of crisis is a systematic societal phenomenon. The crisis may involve loss of life, loss of material, economic and environmental loss. Many times, society heals itself using its resources. However at times the crisis results in large scale losses that exceed the community's or society's own capacity to cope up, using its own resources, converting a crisis or hazard into a disaster (Roberts & Brennan, 2015). Epidemiological patterns of global disasters suggest Asian region has the most frequently affected region for natural disasters like floods, cyclones and earthquakes (UN ESCAP, 2017). The intensive natural disasters like earthquakes, tsunamis, cyclones, etc., results in mass casualty. Limited capacity to mitigate among Low-Middle-Income-Countries like India is a challenge. Since 1960, India has witnessed 84 tropical cyclones that killed 48,748 people and caused damage about 21.2 billion USDs (Table 1). Within India, Odisha (formerly Orissa) is the most vulnerable coastal state that witness four to six tropical cyclones annually, floods and droughts seasonally (Sahoo & Bhaskaran, 2018). Most (74%) of coastline of Odisha is moderate to highly vulnerable to disasters (Mani, Ankita & Vethamony, 2018). The tropical cyclones usually accompanied with storm surges, high winds, extreme rainfall, and resultant riverine flooding (Govt. of Odisha, 2002). Odisha with its half of the population under the two USD a day poverty line, agriculture and natural resource dependent economy, higher population density in the coastline, weaker socio-economic profiles (World Bank, n.d.), and sub-tropical littoral location (OSDMA, 2016), makes it highly vulnerable to natural disasters. This vulnerability killed 9,843 people during the 1999 Super cyclone (Table 2). This has led the complete transformation of disaster management in India from relief and rescue to pro-active disaster readiness (Thomalla & Schmuck, 2004). The traumatic shock of 1999 super cyclone and commitment at the political leadership level, made to rethink governance to avoid the 1999 mistakes (Colin, 2019) and it has made the Odisha State Disaster Management Authority (OSDMA) as the global example of disaster risk reduction (DRR) and disaster risk management (DRM) best practices (Jha, Basu & Basu, 2016). The recent cyclone Fani, a Category four Hurricane, in May 2019, was deadliest because of high wind speed during landing i.e. 180 Kmph, but death toll was far less than the comparable wind speed as was in Super Cyclone, 1999 (Table 2). About 1.5 million people were shifted within 24 hours to a place of safety before the landfall of Fani on 3rd May 2019 in Odisha (Govt. of Odisha, 2019). The success of this mammoth rescue operation was possible due to the early warning system, coordinated communication, an integrated approach at all levels of administration, involvement of reliable non-governmental organizations and community leaders, and community participation. In this context this essay explores the Odisha Disaster Management practice citing example of Fani cyclone preparedness.

Years	Frequency	Total deaths	Total affected	Total damage ('000 US$)
1916-50	11	108,544	1,042,010	NA
1950-60	4	2,400	2,375,000	NA
1960-70	7	2,437	425,000	12,530
1970-80	10	24,736	23,010,672	541,335
1980-90	21	3,749	21,363,793	2,325,163
1990-2000	18	15,802	28,216,101	5,126,700
2000-10	15	709	5,827,550	328,416
2010-20	13	1,315	16,742,174	12,876,096

Table 1: Tropical cyclone induced damage in India in the past century

Source: EM-DAT Disaster Database available at https://www.emdat.be/emdat_db/

Name of Tropical Cyclone	Year	No. of Deaths	No. Affected (million)	Damages (million USD)	Fatality per million affected
Super Cyclone	1999	9843	12.63	2500	779.33
Phailin	2013	47	13.23	633.5	3.55
Fani*	2019	64	16.5	2352	3.82

Table 2: Select tropical cyclones in Odisha and its impact during last two decades

*Source: EM-DAT Disaster Database available at https://www.emdat.be/emdat_db/&*Govt of Odisha, Fani Report (May 2019)*

2. THE FANI EVENT - THE EXCERPT FROM THE REPORT ON FANI (GOVT. OF ODISHA, 2019)

Fani Impact: The rare summer storm Fani with a surface wind speed of 175-180 Kmph hit the Odisha coast at Satapada of Puri District on 3rd May 2019 in the morning hours (between 8-10 AM). Cyclone Fani left 64 dead, 16.5 million exposed people and 2352 million USD damages. The Fani has badly affected the lifeline of modern society like power supply, telecommunication, and road services and the capital city was not spared. About 3.62 lakh dwellings were damaged and 21.9 lakh trees were uprooted or damaged due to high winds.

Before the fateful event: Odisha State plan of action for all the hazards (like flood/cyclone/epidemics/heat waves etc.) is an annual events of multiple government departments including health, education, agriculture, revenue etc., during start of every financial year in April, which is incidentally happens before the monsoon sets in. It prepared the state actors to have a standard Operating Procedure in the event of natural disaster such as Fani.

Fani Preparedness: Indian Meteorological Department (IMD) was following a low pressure area over the east Equatorial Indian Ocean and adjoining southeast Bay of Bengal in the early morning of 25th April. The low pressure became deep pressure on next day and took the shape of cycloning storm by noon of the 27th April. In the mean time, times of India has flashed the news on 26th April that "Possible cyclone Fani may skip Odisha". However the IMD closely followed up the event and issued warning bulletin on the night of 27th April. This has triggered the national and state actors to implement the Standard Operating Procedures (SOP) as per the OSDMA guidelines. Not only Odisha other states were also kept on high alert and financial assistance of Rs 340.87 crore was released by 30th April to deal with the impending disaster. Early Warning Dissemination System (EWDS) of OSDMA made a fool-proof communication system to reach the last person in the communication channel covering 1205 villages in the six coastal districts of Odisha. The EWDS used digital mobile radio, location based alert systems, remotely operated siren systems and universal gateways to generate and disseminate repeating early warnings at the same time from the block, district and state levels using mobile messages & voices in local languages, hourly sirens, etc. The other platform used by the OSDMA for early warning was a web and mobile application based platform called as "SATARK" (System for Assessing, Tracking and Alerting Disaster Risk Information based on Dynamic Risk Knowledge). It provided the real time watch, alert and warning information for multiple hazards. The SATARK used "machine learning algorithm" and provided actionable advisories in both the local Odia and English languages.

The repeated warning followed a coordinated evacuation from 1st May, and about 1.5 million people shifted to 9,177 shelters in a record time of 24 hours. The shelters included 879 multipurpose cyclone/flood shelters and schools and public buildings. Authorities used special 23 trains and 18 buses to evacuate 25,000 tourists from impact sites. In parallel, the massive Information Education Communication (IEC) activities were carried out informing the do's and don'ts for the inevitable Fani. Disaster responders like local government officials, special rescuers firemen, disaster rapid action forces from the State and Centre were deployed in the coastal districts for search and rescue operations. Additionally, NGOs and volunteers were mobilized to support pre-empt evacuation, distribution of relief, and shelter management. Disaster responders were made available 24x7 and relief materials were kept ready for distribution. Most vulnerable like pregnant women and coastal dwellers were shifted to delivery points and shelters before the landfall. Post impact food

security was taken care through targeted public distribution system (TPDS). For food distribution during cyclone, food supplies were pre-positioned in child care institutions (CCIs), shelter homes, cyclone shelters, and schools. Anganwadi also distributed the take-home ration and eggs two days before the Fani Landfall to the pregnant women, lactating mothers, and children less than three years.

Relief and Rescue Operations:The relief and rescue operations were started immediately following the landfall involving 60 NDRF teams, 18 units of ODRAF, 585 fire teams, Navy and about 45,000 volunteers. Food was provided through airdropping of 10,000 food packets, and more than 6,000 free kitchens through the involvement of local governments and volunteers.

The major roads were made operational within 48 hours. The power and telecommunication restored within two weeks in the major towns of Puri and Bhubaneswar with the help of technical staffs from Andhra Pradesh and West Bengal. A special package was announced by the government on 5th May for food security, housing, livelihood and environment management. Multi-sectoral impact assessment was carried out side by side of the relief operations by the state government in coordination with the local, national and international agencies and report was submitted to the stakeholders.

3. THE FANI WISDOM

Components of Emergency Risk Management (ERM) and Fani: The standard components of ERM are (i) Prevention, risk reduction & mitigation, (ii) Disaster Risk Assessment, (iii) Strategies and programmes, (iv) Preparedness, (v) Response and (vi) Recovery (Roberts & Brennan, 2015). The OSDMA has addressed each of these components. Mitigation, preparedness, and response to the Fani disaster was commendable. Odisha has done remarkably well during Fani to minimize the loss of life but failed to minimize the loss of infrastructure, economy and the environment. The economic damage was comparable to that of 1999 super cyclone. Risk reduction through structural re-enforcement, building a disaster resilient housing infrastructure, a resource intensive and time-consuming affair yet to be implemented in the risk prone areas. This could further minimize the loss of life and structural damage induced economic impact. Additionally, lack of underground power supply, underground transports, and satellite communications makes the Odisha coast vulnerable during frequent tropical storms and makes the suffering extreme. The climate change has increased the frequency of disasters over time (Thomas & Lopez, 2015), which may intensify in future. The loss of environment was severe during Fani. Therefore, OSDMA should have DRR plan ready with a climate resilience component. The quantum, timeliness, adequacy and quality of work before, during and after Fani impact is praiseworthy. Odisha was able to evacuate a record one and half million people to shelter houses in 24 hours is also exemplify the effective

SOPs in place for risk minimizing efforts such as evacuation. The management and maintenance of shelters though officials, committees, community leaders and volunteers make the affected people a feeling of safety, security and homeliness. Availability and access to Early Warning System in Odisha which minimizes hazard impacts (Kumar, 2012), is a critical element in DRR and it has played a key role in minimizing the Fani Impact. The bureaucratic drive and resource provision to the DRR programme through able political leadership and commitment has paid off during Fani. In case of Fani the limitation owing to absence of adequate risk pooling mechanisms such as micro-insurance, and micro-financing, weather-index insurance, and limited investment in social capital, had led to government to sick compensation from central government.

The Brennan ERM guiding principle (Brennan, Bradt & Abraham, 2009) & Fani: The Fani cyclone preparedness was a part of all-hazard preparedness of OSDMA and not hazard specific disaster preparedness. Making the disaster Fani preparedness as efficient and effective one as assessment, communication, logistics are common for all the natural hazards. Multi-sectoral coordinated effort during Fani preparedness and response and community preparedness were other factors that had limited the devastating impact of Fani. The vulnerable pregnant women and children were kept in the appropriate safe shelters with medical facilities. This effort of OSDMA is suggestive of comprehensiveness, multi-sectoral coordination, sensitiveness for the vulnerable among the vulnerable during the Fani relief and rescue operations.

International Framework and Fani: Disaster risk reduction is at the heart of sustainable development goal (SDG). The Sendai Framework for Disaster Risk Reduction 2015–2030, that replaced the Hyogo Framework for Action (2005-2015), along with SDG-2030 mandate to 'leave no one behind', Paris Agreement on Climate change, New Urban Agenda, etc., are directed towards developing a disaster ready and disaster resilient community across the globe. The Hyogo Framework for Action (HFA) has set the goal for substantial reduction in social, economic, and environmental losses by 2015 (UNDRR, 2015). The review of progress report (Table 3) for India (2011) and 14 local areas of Odisha (2013) using the Hyogo Framework indicators suggest multiple actions need to be taken care at local level. Still Odisha managed well the Phailin cyclone in 2013. It may be the fact that decentralization in DRR strategy is yet to reach the last mile and futuristic climate change induced disaster resilience is yet to be started. The current Sendai Framework for DRR has seven global targets and thirty-eight global indicators that will compare the progress considering 2015 figures as the baseline. It basically aims to (a) substantially reduce the disaster induced mortality, at risk population, economic loss and structural and service disruption; and (b) substantially increase the number of countries with DRR strategy, international cooperation and availability and access to the early warning system & DRR information. The Global Assessment Report on

DRR - 2019 (UNDRR, 2019) suggest, India has made explicit reference to Sendai Framework in its Nationally Determined Contributions (NDCs) under the Paris Agreement (UNFCC, 2017). It means India is making progress towards building resilience against future climate change induced disaster.

Public Health & Fani: Public Health system preparedness for Fani was started as a part of Ministry of Health's annual plan for all disasters in April and it was also part of all hazard preparedness of OSDMA. The leave of doctors and paramedical staffs were cancelled and there presence at headquarter was made compulsory during 1st to 15th May 2019. Quick assessment of vulnerable expectant mothers, lactating mothers and malnourished children were carried out with the help of Anganwadi Workers. Infrastructural safety audit of health centers and Anganwadi centers were carried out. This input was used to evacuate expectant mothers and children to safe shelters with medical and nutrition facility during 1st and 2nd May 2019. That ensured the safety of vulnerable mothers and children. The discharge of malnourished children and other vulnerable patients were prevented. The evacuation was part of the coordinated massive evacuation for other at risk people. About 1,031 health facilities were affected mostly due to damage to buildings, supply of water & electricity, air-conditioning and communication system. Boundary walls, iron grills, window & door panels, false ceilings, non-pukka roofs of multiple health centers were damaged indicating infrastructures are not disaster resilient and model building codes and designs were not followed for public health facilities. Fani impact had disrupted the power supply dependent equipment functioning and larger medical equipment like X-Ray machines that could not be run for 1-2 weeks. Routine out-patient, inpatient and emergency deliveries, surgeries, dialysis, etc. were given priority for operationalization. Routine universal immunization programme was made operational through alternate vaccine delivery mechanism. A team of pediatricians were deputed to examine infants at sick new born care units and follow up discharged newborns at blocks. Overhead Water was restored in a record time at all affected health centers. With the help of grass root level health functionaries 2.69 million ORS Sachets, 4.05 million chlorine tablets, 0.13 million kg bleaching powder, 2.4 million Sanitarynapkins were made available at the community level for utilization. Around 83 unsafe water bodies were barred for the public. Massive IEC & BCC campaigns were carried out through 265 TV spots, 244 radio spots, 82 newspaper advertisements and 0.6 million leaflets through health functionaries. Coordination between United Nation agencies, Govt. of India and other research institutes for disease surveillance and outbreak were established. response was chalked out. Vector control measures, food and water testing trough mobile squads in the community and relief camp was carried out. Mental health staffs in eightteams were deputed for psychological counselling to the victims in the affected areas. All these public health interventions were monitored through daily review meetings and field supportive visits.

Despite of this, Fani has caused a great damage to public health system in the tune of 972 crore considering damage to health & nutrition sector, environment, an water resources & WASH infrastructure alone. It would require 1677 crore for recovery. We believe such damage is going to be repeatedly inflicted owing to Odisha's vulnerability to tropical storms and other natural disasters. Therefore investing in disaster resilient infrastructure and service would be of paramount importance.

Table 3:Level of progress achieved using Hyogo Framework for Actions

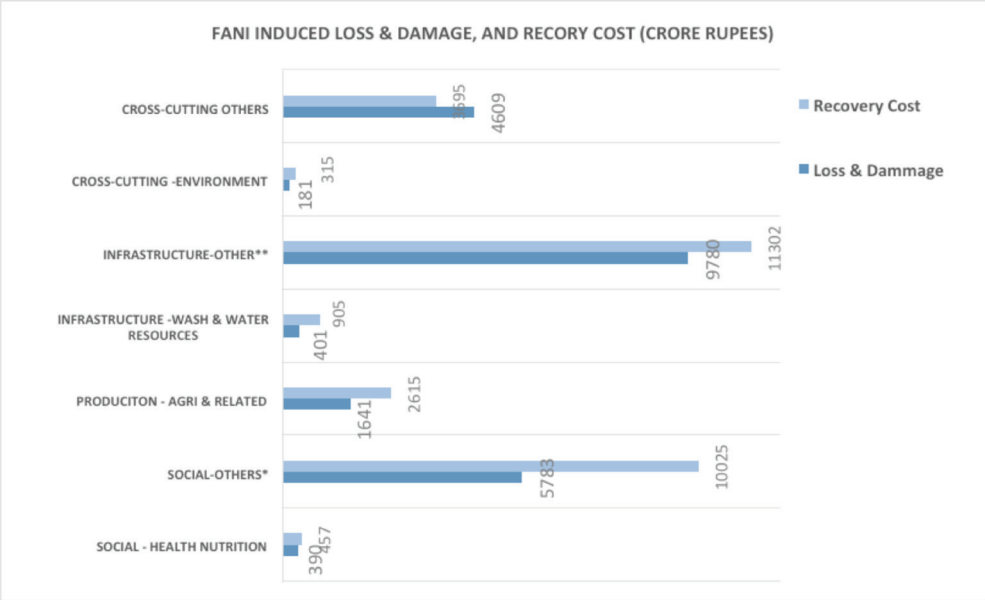
Hyogo Framework for Action (HFA) Priorities and Indicators	India (2011)	Odisha (2013) Local Level Progress														
		Gunupur	Bhubaneswar	Konark	Jharsuguda	Basudevpur	Dhenkanal	Hirakud	Khariar	Sundargarh	Sunabeda	Banki	Berhampur	Bhuguda	Khariar Road
Priority 1: Making disaster risk reduction a policy priority, institutional strengthening															
1.1: National policy and legal framework for DRR exists with decentralised responsibilities and capacities at all levels	4	1	3	1	2	2	2	2	1	1	1	1	1	1	1
1.2: Dedicated and adequate resources are available to implement DRR plans and activities at all administrative levels	3	1	3	1	2	1	2	1	1	1	1	1	1	1	1
1.3: Community Participation & decentralisation is ensured through the delegation of authority and resources to local levels	3	1	3	1	1	1	2	1	1	1	1	1	1	1	1
1.4: A national multi sectoral platform for disaster risk reduction is functioning	3	1	1	1	2	1	1	1	1	1	1	1	1	3	1
Priority 2: Risk assessment and early warning systems															
2.1: National and local RAs based on hazard data and vulnerability information are available & include RAs for key sectors	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2.2: Systems are in place to monitor, archive and disseminate data on key hazards and vulnerabilities	4														
2.3: Early warning systems are in place for all major hazards, with outreach to communities	4	1	2	2	2	3	3	2	1	2	1	2	2	2	1
2.4: National and local RAs take account of regional/trans boundary risks, with a view to regional cooperation	3	1	3	1	1	1	2	1	1	1	1	2	1	1	1
Priority 3: Education, information and public awareness															
3.1: Relevant information on disasters is available and accessible at all levels, to all stakeholders	4	1	2	4	1	2	1	1	1	2	1	1	3	4	1
3.2: School curricula , education material and relevant training include DRR and recovery concepts and practices.	4	1	4	2	3	4	4	4	3	3	3	4	3	4	3
3.3: Research methods and tools for multi-risk assessments and cost benefit analysis are developed and strengthened.	2														
3.4: Countrywide public awareness strategy exists to stimulate a culture of disaster resilience, with outreach to communities.	4														
Priority 4: Reducing underlying risk factors															
4.1: DRR is an integral objective of environment related policies and plans (land use, climate change etc)	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1
4.2 : Social development policies and plans are being implemented to reduce the vulnerability of populations most at risk	3	1	3	1	2	1	2	2	1	1	2	2	3	1	1
4.3: Economic and productive sectorial policies and plans have been implemented to reduce the livelihood vulnerability	4	1	2	1	1	1	2	1	1	1	1	1	2	1	1
4.4: Planning and management of human settlements incorporate DRR elements, including enforcement of building codes	3	1	4	1	1	2	1	3	1	1	1	2	2	1	1
4.5: Disaster risk reduction measures are integrated into post disaster recovery and rehabilitation processes	4	1	3	1	4	3	3	3	1	2	3	3	3	1	1
4.6: Procedures are in place to assess the disaster risk impacts of major development projects, especially infrastructure	3	1	3	1	2	3	2	2	1	2	3	3	2	5	1
Priority 5: Preparedness for effective response															
5.1: Strong policy, technical and institutional capacities and mechanisms for DRM, with a DRR perspective are in place.	4														
5.2: Disaster preparedness plans and contingency plans are in place at all administrative levels, and regular training drills and rehearsals are held to test and develop disaster response programmes.	4	1	2	1	1	1	1	1	1	1	1	1	2	1	1
5.3: Financial reserves and contingency mechanisms are in place to support effective response and recovery when required.	4	1	3	1	2	2	2	2	1	1	1	1	1	3	1
5.4: Procedures are in place to exchange relevant information during hazard events and disasters, and to undertake post-event reviews	4														

DRR-Disaster Risk Reduction, RAs - Risk Assessments, DRM - Disaster Risk Management. For local progress the lowest value for sub-indicators are provided

Level 1 - Minor progress with few signs of forward action in plans or policy
Level 2 - Some progress, but without systematic policy and/ or institutional commitment
Level 3 - Institutional commitment attained, but achievements are neither comprehensive nor substantial
Level 4 - Substantial achievement attained but with recognized limitations in key aspects, such as financial resources and/ or operational capacities
Level 5 - Comprehensive achievement with sustained commitment and capacities at all levels

Table 3: Level of progress achieved using Hyogo Framework for Action in Odisha & India

Source: HFA India Progress Report (2011) and HFA Local Progress Report (2013)



**Education, Housing, Culture, **Public Buildings, Roads, Energy & Telecommunication*

Figure 1: A comparative sector wise loss-damage cost and recovery cost due to Fani

Source: Odisha Government Fani Assessment Report (May 2019)

International framework requires national government to empower the sub-national governments or functionaries with resource, technology and training. Govt of India is providing financial and technical resources, operational guidelines and tools to the OSDMA in timely manner that benefited Odisha to have a state specific local strategies which is linked to the national disaster risk reduction and development policy priorities (UNDRR, 2019). This good practice of decentralized capacity building effort is helping to build contextual disaster resilience in Odisha. This is also a factor that helped Odisha for efficient and effective response to Fani cyclone.

4. CONCLUSION

The Fani experience implies political commitment, availability, access to EWS and its outreach, community preparedness and empowered and effective system of DRR can minimize the impact of disaster. Intensive disaster like tropical cyclone Fani has trapped the Odisha people with half of people lying below poverty line, into the vicious cycle of poverty and hazard over generations. But the extensive' disasters such as small or medium-sized storms is common and routine phenomenon in Odisha and other parts of country, that deliver low-intensity but recurrent shocks usually remain out of government support system and need to be given attention. The disaster resilient society should protect its people from the impact of both the intensive and extensive

disasters. Else, the SDG 2030 aim to reach everyone to leave no one behind, may be derailed.

Investing in disaster resilient housing programme to protect the economic loss and loss of life; disaster resilient agriculture to absorb economic shock, improving livelihoods, food security, nutrition and poverty reduction are critical. Improving upon traditional hazard analysis by including the climate change impact on frequency and severity of cyclone is of paramount importance.

Odisha can experiment with crowd sourcing for disaster mitigation as was done during Kerala flooding, and use Artificial Intelligent (AI) enabled drones to get vital information on people trapped in disaster-hit areas for rescue operations.

Further, Odisha government need to assess social strata (gender, caste, age, income etc.) stratified risks in disaster risk reduction to capture the risk generation and accumulation process over time with multi-stakeholder involvement. Health sector should be central in all such assessments, planning and resilient development. Hospital buildings should be resilient to such disasters and more so in areas where they are frequently striking on. A review of Indian Public Health Standards for public health facilities to ensure disaster resilience also need to be given priority.

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Chapter 8

EMERGENCIES AND CRISIS MANAGEMENT FOR THE CONTAMINATION OF WATER BODIES

Kanika Garg, Anjali Barwal and Anil Kumar Gupta

ABSTRACT

Contaminants can reach environmental water bodies through natural and accidental incidents. This problem of water contamination is increasing day by day which causes ecological damage, public health issues, and diverse environmental risks. Water contamination can result in severe crisis- disrupting water supply, sanitation facilities, health hazards and mass extinction of aquatic life. This study is based on water crisis cases of India that occurred intentionally or unintentionally in India. Drawing from a wide range of contemporary crisis including cloudburst in Leh, molasses leakage from a sugar mill in Punjab, and mercury contamination of Kodaikanal lake by Hindustan Unilever, this paper addresses the causes and long term impacts of crisis on public health and the environment. The study also helps in understanding the action plan and efforts taken to address these crises and the scope of improvement. It is concluded that more effective crisis management plans are required for these incidents. For an appropriate response to a warning or incident, decision-makers need to rely on proper preparation and skilled evaluation of available information resilience community, infrastructure and environment is the need of the hour.

Keywords: *Crisis, Water Contamination, Public Health, Water Scarcity, Water Pollution.*

Kanika Garg
Intern, National Institute of Disaster Management, New Delhi

Anjali Barwal✉
Research Associate, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi
anjali.barwal@gmail.com

Anil Kumar Gupta
Professor & Head, ECDRM Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi

1. INTRODUCTION

Nowadays, problems such as water scarcity, water contamination, severe water ecological damage, and diverse environmental risks are a matter of concern and baleful to the environment at many places all over the world (USEPA, 2018). The water crisis can be through intentional or unintentional contamination of a water system that can degrade public health, economic well-being, and the environment. Such incidences of water contamination could also cut off water needed for other vital uses such as food preparation, sanitation, fire fighting, agriculture, and industry. Water crisis can also be used as a threat to society; for example, terrorists can introduce a broad range of contaminants into the water supply from widely available industrial chemicals to exotic, engineered microorganisms (Magnuson, 2005). Drinking water is a critical component of the nation's infrastructure. Water crisis due to contamination should be dealt with scientifically and by intensifying action plans which have been developed to control water pollution and ensure water safety for the nation (USEPA, 2011). The Water (Prevention and Control of Pollution) Act, 1974 and subsidiary Rules; The Water (Prevention and Control of Pollution) Cess Act, 1977 and subsidiary Rules; The Environment (Protection) Act, 1986 and subsidiary Rules are the regulation laws and policies set by environment legislations to control contamination in water bodies in India. National environmental protection policy, 2011 and national water policy 1987; which was reviewed and updated in 2002 and later in 2012 also set by the government to maintain water environment. The objective of the National Water Policy is to take cognizance of the existing situation, to propose a framework for the creation of a system of laws and institutions and for a plan of action with a unified national perspective. Water quality standards and public nuisance actions are provided by the Indian legal system for addressing the water contamination issues. It aims to enhance water environment quality, conserve water bodies, develop or adapt environmental technology, whether for prevention, remediation, control, analysis, or other goals. Executing the strategy featuring safety, cleanliness, and health, improve source control, take scientific management methods in different drainage areas and regions and promote water pollution control, water ecological protection, and water resource management in a systematic way (Magnuson, 2005). Water contamination raises many crises and is a major cause of water scarcity amid the stressed situation.

The major causes of contamination of water bodies are mentioned below (Refer figure 1):

- In water bodies, disposal of solid waste and litter causes a huge problem and badly affects the aquatic ecosystem as well, which includes glass, plastic, aluminum, extruded polystyrene foam, etc. Degradation in water takes different time as waste varies.

- Terrorists could also introduce a broad range of contaminants into the water bodies, which could be hazardous for humans as well as for living beings (Williams, 2019).
- Natural disasters like Earthquakes can damage sources and distribution systems, storms can disrupt power supplies for an extended period and floods can cause widespread microbial contamination of water bodies.
- Sudden discharge of municipal sewage having bacteria, blue-green algae, protozoa, E.coli, pharmaceutical residues, poisonous gases etc. pollutes the sewage systems, thus contaminating surface water and groundwater respectively. And these contaminated water bodies adversely affects aquatic life, human beings and the ecosystem.
- Industrial wastewater having pollutants like crystallite amphibole, lead, mercury, and petrochemicals are extremely hazardous to both individuals and the environment. All these chemical effluents are released directly into water bodies making it toxic and contaminated.
- During transportation, oil spilling occurs from the tankers, which forms a thick sludge layer on water surface and contaminates water bodies in many ways.
- Failure or degradation of the water and wastewater treatment system due to earthquake and pollution (USEPA, 2011).

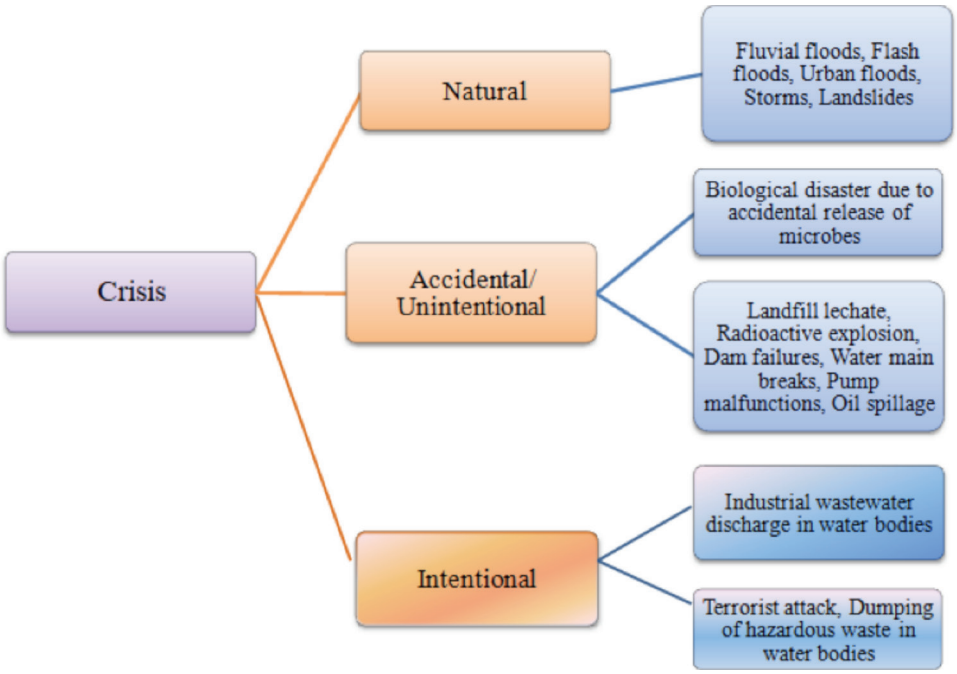


Figure 1. Flow chart showing the causes of contamination of water bodies

2. CASE STUDIES

2.1 Case 1: Sugar mill molasses leak incident in Gurdaspur district of Punjab, 2018.

The sugar mill molasses leak incident happened in May 2018 in the Gurdaspur district of Punjab and has done huge damage to aquatic life and public health in the Beas river. Molasses leaked from storage tanks into the storm water drain. Molasses black treacle is a byproduct of processed sugar, which is viscous and majorly produced in sugar mills. The sugar mill management failed to stop the leakage which continued for the at least 30 hours (SANDRP, 2018). As per the report of the Punjab Pollution Control Board (PPCB), an estimated ten thousand kiloliters or one crore liters of molasses flushed out in a nearby drain which adjoins the Beas river about 1km downstream. The mill was storing the molasses and waste products in storage tanks during the sugar manufacturing process. Mill had two tanks of 1.35 lakh kilo-litres capacity to store effluent and these tanks were full (Brar, 2018). Extra molasses produced was not stored properly, it started boiling over. Around 10,000 kilolitre molasses was over spilled in a single day.

On the next day of spillage, the contaminated water reached Harike wetland, which is listed under the Ramsar international wetland convention. It is located at the confluence of Satluj and Beas rivers around 110 kilometers downstream from the sugar mill. Harike wetland and surrounded area of about 40 sq. Km was found contaminated with molasses, thus affecting the natural habitat of the critically endangered species like dolphins and gharial, which are found only in India and Pakistan.

Consequences - This incident was a massive ecological disaster affecting the 110 km area of the river (SANDRP, 2018). The river watercolor changed into dark brown following the leak and smelled like brewing liquor. It had a fatal impact on aquatic life and contamination reached the bottom of the river which caused depletion of dissolved oxygen resulting into death of may fishes (Figure 2) including common crap, Catla, mrigal, rohu, catfish, gosh, bam, singari, chital, and sol. The impact of the molasses leak had reached the Sirhind feeder and Rajasthan feeder close to Harike headworks in Ferozepur district leaving many fishes and snakes dead. The fish seeds were the yield of the future but their death also hit future generations of fish in the river. The magnitude of habitat loss was huge (Singh, 2018). According to the forest team of Harike district and WWF India, no dolphins were sighted in Beas river after the molasses leakage incident.



Figure 2. Locals taking out dead fishes from Beas river after its water was effected due to molasses leakage from a Gurdaspur based sugar mill near Amritsar on May 17 (Source: Hindustan Times Photo: Molasses leak: 'Recovery of ecosystem of Beas river will take few years')

2.2 Case 2: Cloud burst in Leh, Ladakh in 2010.

In August 2010, Leh district in the Ladakh region of north-western India received a heavy downpour. Cloud burst caused a flash flood in the northwestern region of India, which resulted in overflowing of waterways, the Indus River and its tributaries.

Consequences- Cloud burst resulted in the generation of debris flows, loss of lives, destruction of houses and hospitals, loss of communication, and flooding of bus stands and railway station. Approximately, 234 people died, 800 were injured, and many went missing, perhaps washed away with the flooded rivers and waterways (Gupta et al., 2012). The civil hospital in Leh was badly damaged, Leh airport was flooded and the runway was covered with debris and became dysfunctional. People became homeless and were forced to live in temporary homes, which again put great stress on water sanitation. The pumping stations were washed away which meddled water supply in Leh. In this vast destruction over 1000 houses collapsed. People were buried under the debris. The local communication networks and transport services were severely affected.

The risk of contamination in water through sediments or dead bodies buried in the debris made water non-potable. The water remained stagnant and further deteriorated drinking water quality in the region. Human beings and animal bodies were washed away and suspected to have poisoned water bodies that caused many water borne and vector borne diseases. Simultaneously, the economy of the region was also critically affected as tourism was the main source of income for locals (Gupta et al., 2012).

2.3 Case 3: Mercury contamination in Kodaikanal, India, 2001.

In Kodaikanal, Hindustan Unilever was manufacturing 100,000 to 150,000 thermometers per month. In 2001, the thermometer factory was responsible for 7-ton elemental mercury spill in the soil of Kodaikanal (Lin, 2016). This occurred because of the factory's improper storage and disposal of mercury in soil. Kodaikanal lake is a man-made star shaped lake located in Kodaikanal, Tamil Nadu. Kodaikanal lake and Gymkhana marshland are situated within 1km from the Hindustan Unilever thermometer factory. The factory was discharging 25 mg/kg of mercury in the soil, which was around 25 times higher than the permissible levels (<1 mg/kg) (Karunasagar et al. 2006). Such a high-level exposure distressed the environment and the densely forested Kodaikanal Wildlife Sanctuary (Agnihotri, 2016). This improper way and disposal of hazardous mercury endured a crisis in the environmental health of the Kodaikanal shola forest. The presence of mercury contaminants in the lake was a major concern as it impacted many areas inside or outside the lake (Lin, 2016).

Consequences- Exposure to mercury is a major concern to public health issues. Elemental mercury can bio-accumulate in different organs and tissues that later cause cytotoxicity (UNEP/ISWA 2015). Many families were affected because of exposure to mercury. Factory workers suffered from illnesses due to exposure to mercury. The elemental form of mercury became a critical health and the environment issue. Elemental mercury is the only form of mercury, which is in a liquid state at room temperature (Park & Zheng, 2012). However, due to its high vapor pressure, it can be easily released into the atmosphere (Baum, 2012). Kodai Lake remains to be one of many areas in Kodaikanal polluted by the 2001 mercury spill. In the previous hydrological studies and initial laboratory assessment done on Kodai lake provided insight of the level of total mercury concentration including inorganic and organic forms of the metal, which was found less than 0.3 µg/L (Karunasagar et al., 2006). However, it was determined that the concentration of mercury has increased between 10-30% from 2002 to 2006 (Lin, 2016). This excessive exposure of mercury caused brain damage, blockage of nerves, damage to kidneys, and lungs. Sensory impairment (vision, hearing, and speech), disturbed sensation and an absence of coordination are symptoms of the upcoming issues that can occur due to acute exposure. Kodai Lake was once a beautiful and pristine lake but is now home to the cascade of human waste, rags, plastics, and other debris.

3. ACTION AND EFFORTS

The water background is linked with the interests of the global populace; it is critical to developing a well-off society and achieving a great dream of renews the nation. At present, problems like low water quality, serious water ecological damage and environmental risks are severe in some regions, which are harmful to public health and sustainability of economic and social development. The

action plan is implemented to control the contamination of water and to ensure water safety for the nation. Some actions and efforts taken by the regulatory authorities at the time of the crisis are mentioned below in Table 1.

Case studies	Action and efforts
Case I (In 2018, Sugar mill molasses leaked incident in Gurdaspur, Punjab)	• The authorities asked to stop drinking water supplied from the canal as a precautionary measure. • Water samples were collected and sent to the Guru Angad Dev Veterinary and Animal Sciences University in Ludhiana for testing and analysis (Singh, 2018). • 11000 cusec water was released from pong dam and 2000 cusec from Ranjit Nagar dam to dilute the Beas river water (SANDRP, 2018). • Ban was imposed on selling dead fishes. • Punjab pollution control board (PPCB) fined the mill management Rupees 5 crores & shut down the unit. • The wildlife department filed a petition in the Batala court under the relevant provisions of the wildlife act, seeking necessary actions.
Case II (In 2010, Flash flood in Leh, Ladakh)	• Temporary arrangements of deep trench latrines were constructed where the military engineers made field flush latrines for use by the troops. • Installation and establishment of water purification units at the site. • The National Disaster Response Force airlifted a water storage system (Emergency Rescue Unit), which could provide 11,000 L of pure water (Gupta et al., 2012). • Super-chlorination was done at all the water points in the army establishments. • To deal with the fly menace in the entire area, anti-fly measures were adopted intensively.
Case III (In 2001, mercury contamination in Kodaikanal lake)	• Hindustan Unilever (HUL) declared they were ready to sustain all the essential responsibilities for exporting the mercury to the USA for mercury recovery. HUL also concluded plans with Tamilnadu Pollution Control Board to remediate and recycle the accumulated scrap bearing mercury, decontaminate the tools and dispose of it as trash and undertake site remediation where high levels of mercury in the soil had been identified.

	• Soil washing and thermal desorption processes have done to remediate mercury poisoning. • After 14 years, Unilever compensates its workers and their family. • After determining the total concentration of mercury in water samples of Kodaikanal lake and Gymkhana marshland, the results suggest that Gymkhana marshland may play a role in the filtration of surface water contaminants before entering in a lake (Lin, 2016).

Table 1 Action and efforts taken up after water contamination incidents

In these cases, several shortcomings have been observed in response such as delayed response, absence of early warning system and inadequate coordination among government. Action needs to be taken to limit the direct negative impacts which alter to decline in water quality. Prompt activation of a disaster management plan with proper command and coordination structure is critical. There are some more actions possibly be taken by the authorities to reduce the impacts on the water systems. Authorities should ensure a fair probe into the issues and take strong actions to avoid reoccurrence of such cases. Also, authorities should not approve projects and location nearby water bodies. Proper treatment plant and management are required to limit the number of toxic substances that normally end up in water systems such as lakes, rivers, and oceans.

To minimize the impacts of the water contamination on public health and ecological damage, it is important to have a water policy that recognizes and addresses the challenges we are facing at the time of the water crisis or in the future. The more effective disaster management strategies and approaches would have either eliminated or at least mitigated the impact of the water contamination disaster on public health issues and ecological degradation. In sugar mill molasses leak incident, there was a delayed response. As response time is a critical attribute in effective crisis management. The authorities could have started within one hour after leakage or complaint registered. Increased public awareness is important to ensure an organized and calm approach to disaster management.

4. CONCLUSION

Water crisis not only causes a large scale ecological loss, but also impact on the economy of the nation. Contamination of water bodies significantly affects public health and aquatic life in the short and long term. For an appropriate response to a warning or incident, decision-makers need to rely

on proper preparation and skilled evaluation of the available information. Natural disasters like cloud burst, it is impossible to anticipate but the disaster preparedness strategies and protocols in public health are very effective in rescue and relief and minimize the adverse impact of the disaster on human life and socio-economic conditions. Emergency medical services immediately after the disaster are crucial to minimize the deaths and disabilities. Effective communication is important for effective coordination for rescue and relief actions. For intentional and man-made causes, industry should strictly follow the rules and regulations for dumping any hazardous and radioactive waste and scarps. Environment and social impact assessment and Cost-Benefit Analysis open for public scrutiny should be done before the approval of any such big projects. An alarm system should be introduced when any contamination occurs in drinking water or cut off the water supply as soon as possible. However, in India, there is a lack of research and development concerning water contamination crisis and disaster management and more effective crisis management plans are required for such incidents.

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TEMPERATURE RELATED DISASTERS

(HEAT & COLD WAVE)

Chapter 9

CLIMATE ADAPTIVE HEAT ACTION PLANS TO MANAGE HEAT STRESS IN RAJKOT CITY

Rohit Magotra, Ajit Tyagi, Mohit Kumar, Asha Kaushik, Moumita Shaw, Ananya Bhatia, Yashi Sharma, Dileep Mavalankar and Mahaveer Jain Golechha

ABSTRACT

Heat wave events are rising across the globe and India is no exception. Heat waves cause highest number of deaths compared to deaths caused by any other natural hazard in Indian cities. It is critical for the cities to adapt to the rising heat stress given cities have high concentration of vulnerable urban poor. Increase in heat stress due to climate change is affecting the health, livelihoods and productivity of the vulnerable population in Rajkot city. Integrated Research & Action for Development (IRADe) with support from International Development Research Centre, Canada (IDRC) and in collaboration with Indian Institute of Public Health (IIPH), Gandhinagar and Rajkot Municipal Corporation (RMC), did action research and developed Climate Adaptive Heat Stress Action Plan (HSAP) for Rajkot city. HSAP identifies ward level heat hotspots, vulnerability assessment of the urban poor and provides framework for implementation, coordination and evaluation of extreme heat response in Rajkot. This paper provides insights about the research approach and analysis to evolve Heat Action Plan at ward level for the city of Rajkot. The Heat Stress Action Plan developed through this initiative supports Rajkot city in prioritizing targeted action through understanding adaptive deficits and strategies to evolve adaptation strategies.

Keywords: *Heat Stress Action Plans, Heat Hotspots, Heat waves, Vulnerability Mapping, Climate Adaptation, Climate Change.*

Rohit Magotra✉ : *Deputy Director, Integrated Research & Action for Development (IRADe) r.magotra@irade.org*
Ajit Tyagi : *Senior Advisor, Integrated Research & Action for Development (IRADe)*
Mohit Kumar : *Research Analyst, Integrated Research & Action for Development (IRADe)*
Asha Kaushik : *Senior Research Associate, Integrated Research & Action for Development (IRADe)*
Moumita Shawn : *Research Analyst, Integrated Research & Action for Development (IRADe)*
Ananya Bhatia : *Research Associate, Integrated Research & Action for Development (IRADe)*
Yashi Sharma : *Research Assistant, Integrated Research & Action for Development (IRADe)*
Dileep Mavalankar : *Director, Indian Institute of Public Health, Gandhinagar, Gujarat, India*
Mahaveer Jain Golechha : *Associate Professor and Project Lead-Climate Change and Health, Centre of Excellence for Climate Change (Heat Health), Indian Institute of Public Health-Gandhinagar, Gujarat, India*

1. INTRODUCTION

The last 50 years have witnessed a hike in the frequency of hot days, nights and heatwaves in the world (IPCC, 2014).Higher daily peak temperatures of longer duration and more intense heatwaves are becoming increasingly frequent globally due to climate change. The duration of heatwaves is expected to increase 92 to 200-fold under 1.5 and 2°C scenarios. Coupled with poverty in South Asia, the impact can be severe. Future projectionsof temperature indicate a steady increase across the three periods (the 2030s, 2050s, 2080s), with anomalies reaching 4-5°C for high emission scenarios by 2080. India has experienced a number of heatwave incidences, since 2006, and average temperature during 2018 was significantly above normal (above +0.41°C). The year 2019 was the seventh warmest year on record since nation-wide meteorological records commenced in 1901. June and July 2019 have been the hottest months recorded globally, with National Oceanic and Atmospheric Administration (NOAA) confirming June 2019 being hottest on records, + 0.95°C above normal average temperature.

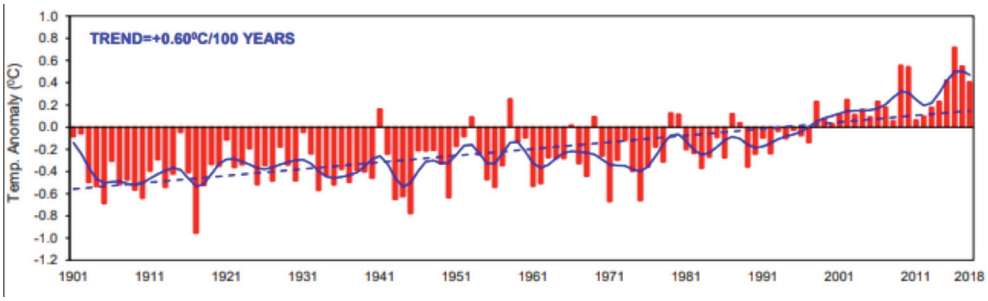


Figure 1: Annual mean land surface air temperatures anomalies 1901- 2018.IMD, 2019

Fig.1 indicates the rise in the annual mean land surface air temperatures anomalies in India between 1901 and 2018. It shows a very sharp temperature increase since 2001. Under the 2°C warming scenario, the frequency of heatwaves in India is projected to increase by 30 times the current frequency by the end of the century.

Heatwaves cause the highest number of deaths compared to deaths caused by any other natural hazard in Indian cities. Extreme temperatures are one of the most dangerous natural hazards but rarely received adequate attention. The Heatwave is a “silent disaster” and adversely affects the health, livelihood and productivity of people. Health impacts of heat are more severe in urban areas, where residents are exposed to higher and nocturnally sustained temperatures due to the Urban Heat Island (UHI) effect (Climate Council of Australia, 2016). Vulnerable population and city authorities lack the resources to adapt to heatwaves. Heatwaves caused over 24,223 deaths recorded over the period of 1992-2015.

Year	Death Record due to Heat Wave
2010	1274
2011	798
2012	1247
2013	1216
2014	1677
2015	2422
2016	1111
2017	220
2018	25
2019	94 (till 16.6.19) 210 (30.6.19)-MHFW
Source: NDMA, Ministry of Home Affairs, GoI, 2019	

Table 1: Heat Wave Mortality Records

Fig.2 indicates the regional distribution of the wave incidences across India and the corresponding heatstroke deaths recorded (2000-2014), which killed 25,716 people from 1992 to 2016 in various states (National Disaster Management Authority, 2016). Refer to Table 1 for the heat-related Mortality Records (2020-2019).The baseline death rate due to heat-induced climate change in the early 2000s in India was 550 per 100,000 of the population. India is projected to see a 10% increase in death rates due to climate change (Climate Impact Lab, 2019). In 2010 May, the city of Ahmedabad had high frequency and severity of heatwaves, registering 1,344 additional deaths in the city with an excess of 800 deaths recorded in the week of 20th-27th May. This served as a wake-up call for the city authorities for intergovernmental agency action, preparedness and community outreach for heat-related awareness and adaptation actions.

Guidelines for Heat wave Action Plans: National Disaster Management Authority (NDMA) noticed the severity of the impact of heatwaves and worked towards heat risk reduction and formulated the 'Guidelines for Preparation of Action Plan – Prevention and Management of Heat-Wave' in 2016, to help the states take a pro-active approach to manage the heat stress. These guidelines have been revised in the year 2017 and in 2019 incorporating new experiences, lessons learnt by state stakeholders, long term mitigation measures and future course of action to mitigate heat stress impact (NDMA, 2019). As per the guidelines, the Heat Action Plans underline measures like the capacity building of healthcare professionals, updating records to track emergency cases, running specialized dispensaries during peak summer, collecting real-time information and regulating the timing of construction and outdoor workers concerned.

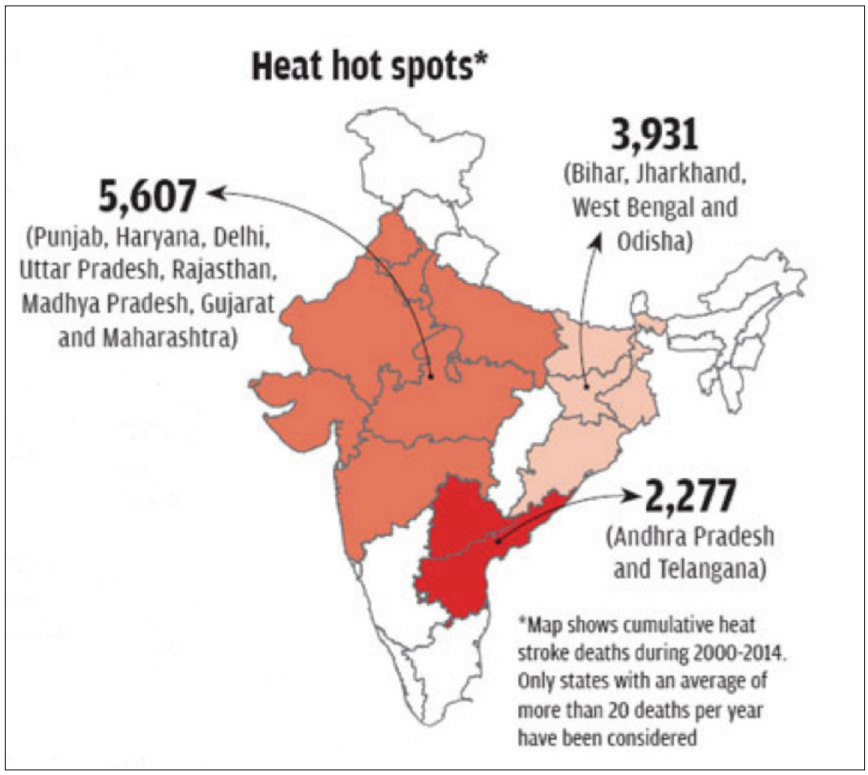


Figure 2:Regional Heat Hot Spots – 2000-2014

Source: National Crime Records Bureau, Ministry of Home Affairs and Ministry of Statistics and Programme Implementation, GoI, 2014

1.1 Heat Stress Thresholds

The threshold temperature for an increase in heat-related mortality depends on the local climate and is higher in warmer locations. Table 2 refers to the temperature thresholds for heat alerts issued by NDMA for Rajkot city. However, there are no thresholds computed for Indian cities specific to region, group (gender, age and other vulnerabilities) exposure, occupation.

Alert Category	Alert Name	Temperature threshold (celsius)
Red Alert	Extreme heat alert day	Greater than or equal to 45
Orange Alert	Heat alert day	43.1-44.9
Yellow Alert	Hot day advisory	41.1-43
White Alert	No alert	40
Source : NDMA guidelines		

Table 2: Heat Alerts Categories (Source: NDMA)

Indian Meteorological Department IMD defines Heatwave conditions if the maximum temperature of a station reaches at least 40°C or more for plains, 37°C or more for coastal stations and at least 30°C or more for Hilly regions.

1.3 Heatwave Action Plans

Cities being the engines of economic growth need to be climate resilient and should have appropriate mitigation and adaptive strategies at a place to combat the impact of heatwaves on public health. To increase people's resilience to heat stress and to reduce the adverse impacts on public health, it is important to have climate-adaptive heat stress action plans at the city level. By 2018, 30 cities and 12 states across India had prepared Heat Action Plans (Figure 4). The Action plans have been beneficial in checking the death rates in the cities, with a decrease in mortality rate recorded in cities of Ahmedabad, Orissa, Surat and other cities.

For Ahmedabad, mortality has come down 20-25% with the implementation of the Heat Action Plan, Ahmedabad, 2010 (IIPH-G – the Hindu, 2017), (Langa, 2017). Mortality related to heatwave has decreased in Telangana from 489 deaths (2015) to 108 deaths (2017) (Telangana Heat Wave Action Plan, 2018). In Andhra Pradesh, the death toll of 2017 shows a fall to 87, after the implementation of the Andhra Pradesh Heat Action Plan, 2016.In the past two years, the numbers dying from heat-related illnesses has fallen sharply in Surat, from 2,040 in 2015 to a little over 200 in 2017, according to government data. The number of people known to have fallen ill because of extreme temperatures has come down from almost 40,000 cases in 2017 to a little over 1,000 in 2018 (Heat and Health Action Plan- Surat, 2016). But existing Plans are generic and do not address action required at regions, wards, vulnerable groups, climatological and spatial variation of the cityscapes in planning appropriate adaption and mitigation actions. Along with the identification of vulnerable groups, the particular city level thresholds needs to be calculated as well in order to develop a comprehensive Heat Action Plan.

2. STUDY AREA: RAJKOT, GUJARAT

Rajkot is the largest city in the Saurashtra region of Western India. It is fourth-largest city in the state of Gujarat with a population of 1.39 Million (2011 census of India). The city is spread across an area of 170 sq.km with 18 wards and population density of 12,275 Persons per Sq. Km. The city population growth rate had shown a significant rise from 1991-2001 (79.12%). Rajkot is urbanizing fast and the population is projected to cross 2.4 million by 2030 (UN Population Report, 2018).

The city has emerged as a major Industrial Hub in Saurashtra region with more than 43000 industrial units This has lead to rapid urbanization, triggering a pull-effect form the adjacent urban and rural areas. This has also resulted in the increase in the slum pockets and scattered settlements across the city from 118 slums in 2012 (SFPoA, Rajkot, 2012) to 145 slums as of 2017 (Gujarat Government Gazette, 2017). The city is characterized by a semi-arid climate. May is the hottest month of the year with an average maximum temperature of 40.5°C. Heatwaves are a major climate hazard which affects the city. It has been noted that the frequency of heatwaves in Rajkot has increased substantially during the decade of 2001-10, as compared to earlier decades (Ray, Chincholikar, & Mohanty, 2013). The decadal frequency of moderate heatwave days oscillated from 2 days during 1971-80 to 33 days during 2001-10. This is a substantial rise and with climate change, the heat events are bound to rise and also increase the number of heat extreme events. The years subsequent to 2010, have been hotter than before. Therefore, the risk associated with human life due to heat stress in the city cannot be under estimated. Refer to Figure 5 for the heatwave condition in Saurashtra and Rajkot.

3. NEED FOR CLIMATE ADAPTIVE ACTION PLAN IN RAJKOT

The trend of heatwave occurrence in the Rajkot city indicates a gradual increase in the heatwave days in the past decade (IMD), with severe heat days ranging from 2 to 13 days in the summer months (March – June). If we look into the number of heatwave days in Rajkot over the past decade (2011-2017), there has been a sharp increase from 2 days to over 12 days (Refer to Fig.3). The Disease Surveillance System and Death Record System of the city do not record heatwave/heat stress deaths. However, due to the rise in temperature in the last few years in the city of Rajkot the cases related to heat stress has been increasing during summer months (Refer to Fig.4).

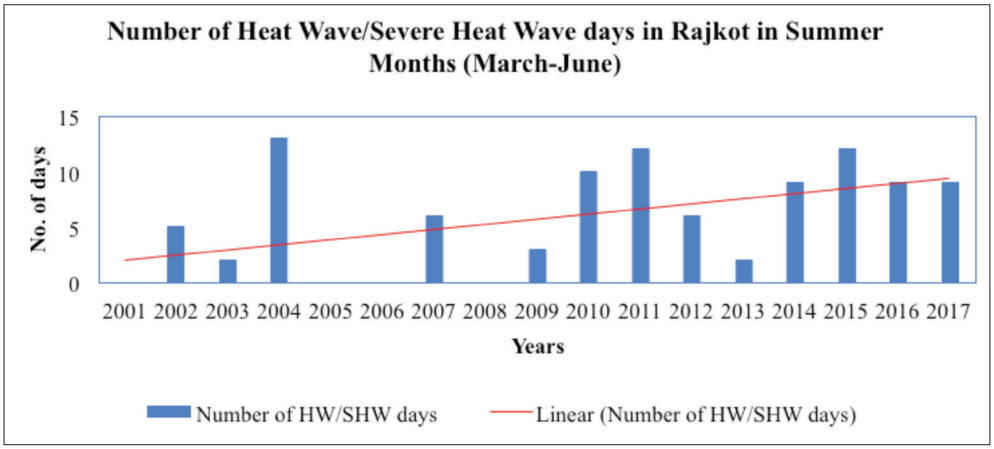


Figure 3:Trend in Heat Wave Days, Rajkot, Source: IMD

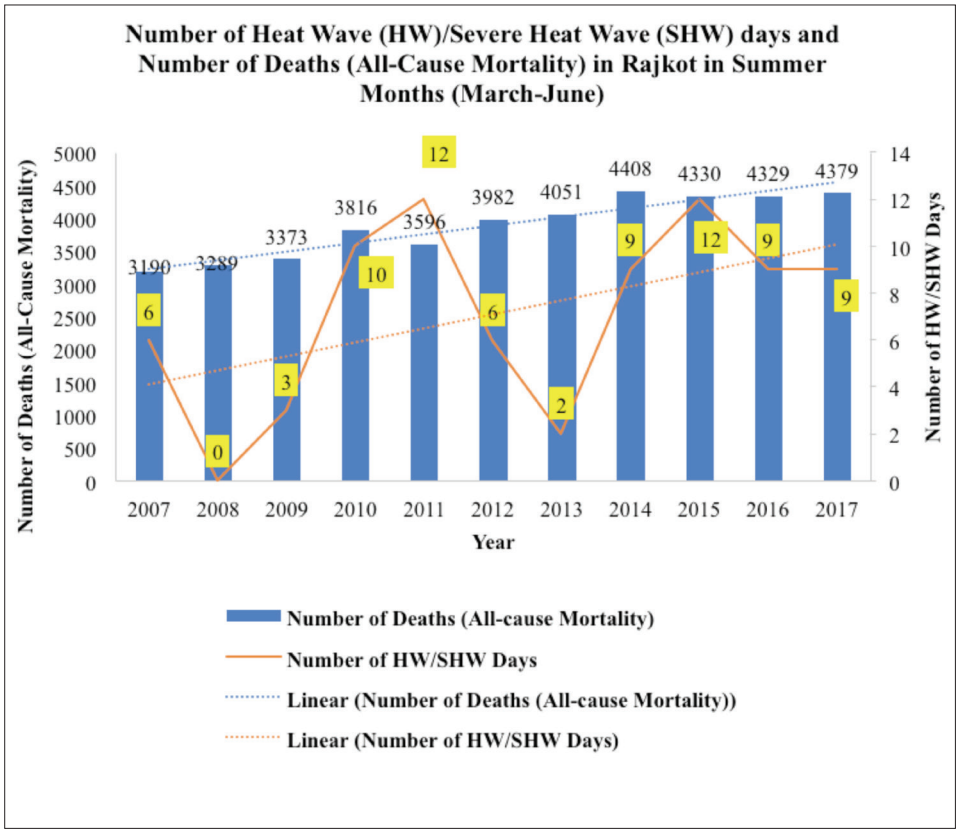


Figure 4: Co-relation between Heat Wave Days and Mortality Rate (2007- 2017)

Source: IMD & Heath Dept. Rajkot Municipal Corporation

3.1 Climate observations of Heat Waves in Rajkot

In order to analyze the changing climate patterns in Rajkot, IRADe conducted a study of Rajkot climatology for the summer season (March, April, May and June) from years 2001 to 2017. The study revealed a significant increase in the city's temperature and decline in its humidity levels indicating that the city is getting drier and hotter over time. Based on data from Indian Meteorological Department (IMD) for temperature and the regional IMD centre, Rajkot, for relative humidity, IRADe analysed the city's temperature data from 2001 to 2017 to determine its trends in maximum temperature (T_{max}) and minimum temperature (T_{min}) for the summer months (March, April, May, and June) and compared it against the city's long-term climatological mean T_{max} and T_{min} (mean of 1905 to 2000) for the corresponding months to determine the deviation in the city's temperature trends. Similarly, it analyzed trends in the morning (08:30) and evening (17:30) relative humidity for the summer months (March, April, May, and June) from 2004-2017 against the long-term climatological

mean relative humidity. Refer to Figure 5i, 5ii, 6i and 6ii for variation of T_{max}, T_{min} and RH at 8:30 hrs and 17.30 hrs, for the entire summer season in Rajkot.

Month 2001-2017)	T_{max} (°C)	Average Mean T_{max} (°C)	Deviation from Mean T_{max} (°C)	T_{min} (°C)	Average Mean T_{min} (°C)	Deviation from Mean T_{min} (°C)
March	+35.2	+37.92	+1.09	+18	+22.65	+1.7
April	+38.6		+1.2	+21.7		+1.6
May	+40.3		+0.84	+24.8		+0.7
June	+37.6		+0.36	+26.1		+1.2
T_{max}- Maximum Temperature, T_{min} - Minimum Temperature, Source: IMD						

Table 3: Mean monthly Temperature value and Deviation, Rajkot, 2001-18

The average monthly T_{max} value in Rajkot has increased for all the summer months, though the increase is relatively more in March and April. This in addition to the significant deviation in May, indicates shorter winters and prolonged summers for the city. The average deviation for the entire summer period over the decade is 1.095°C, with mean temperatures recorded above 38°C. There is a visible shift in the baseline T_{max} values, indicating increasingly hotter summer daytime temperatures.

In terms of the T_{min} value, the average deviation for the entire summer season over the 17 year period was 1.43°C, with maximum deviation in seasonal T_{min} value observed in 2009 (2.46°C). Refer to Table 3. A Significant deviation in T_{min} resulted in higher daily mean temperatures during summer, increasing the frequency of hot days.

The average deviation for RH (morning) and RH (evening) over the 14-year study period was -0.23% and -0.17% respectively, which is negligible. This suggests average morning humidity remained stable over the entire summer season during the 14 year duration. However, the last four summers (2014-17) were, in particular, drier in the morning, recording the RH values consistently below the climatological mean. Refer to table 4.

Month 2004-2017)	RH (8:30) (%)	Average Mean RH (8:30) (%)	Deviation from Mean RH (8:30) (%)	RH (17:30) (%)	Average Mean RH (17:30) (%)	Deviation from Mean RH (17:30) (%)
March	+69	+73.705	+1.33	+21.33	+30.66	-1.27
April	+71.33		+1.12	+21		-0.48
May	+75.16		+0.42	+30.16		-1.40
June	+79.33		+0.29	+50.16		+2.46
RH - Relative Humidity Source: IMD						

Table 4: Mean Monthly Relative Humidity Value and Deviation, Rajkot

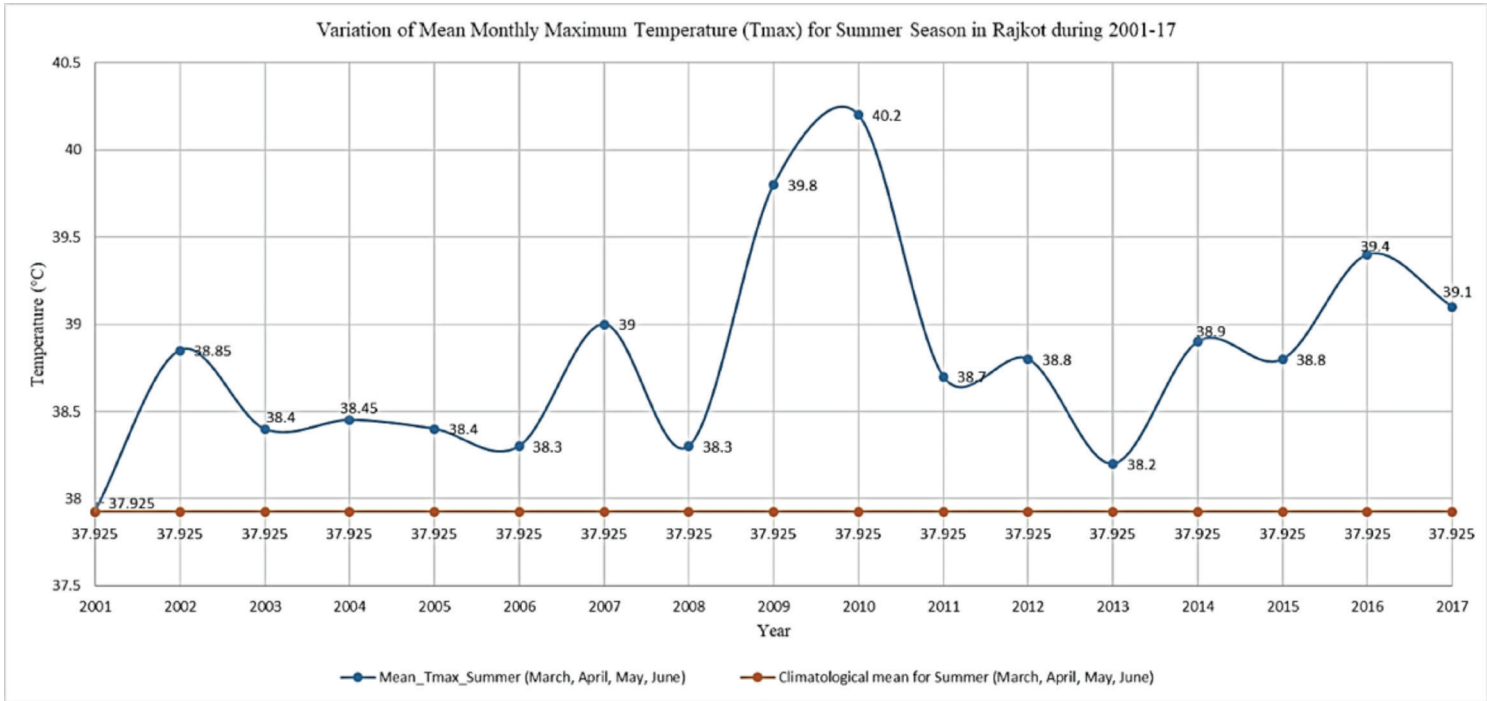


Figure 5i: Variation of T_{max} for summer season in Rajkot during 2001-17

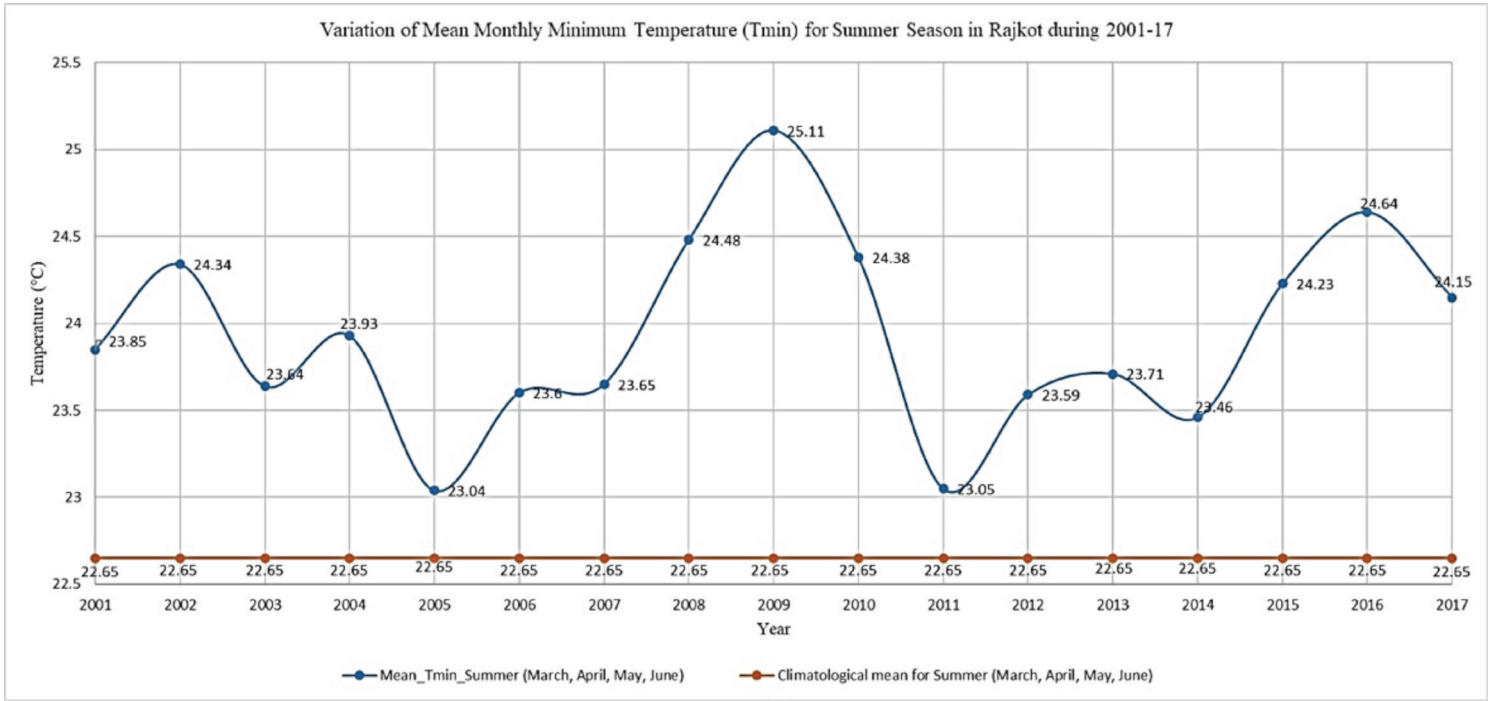


Figure 5ii: Variation of T_{min} for summer season in Rajkot during 2001-17

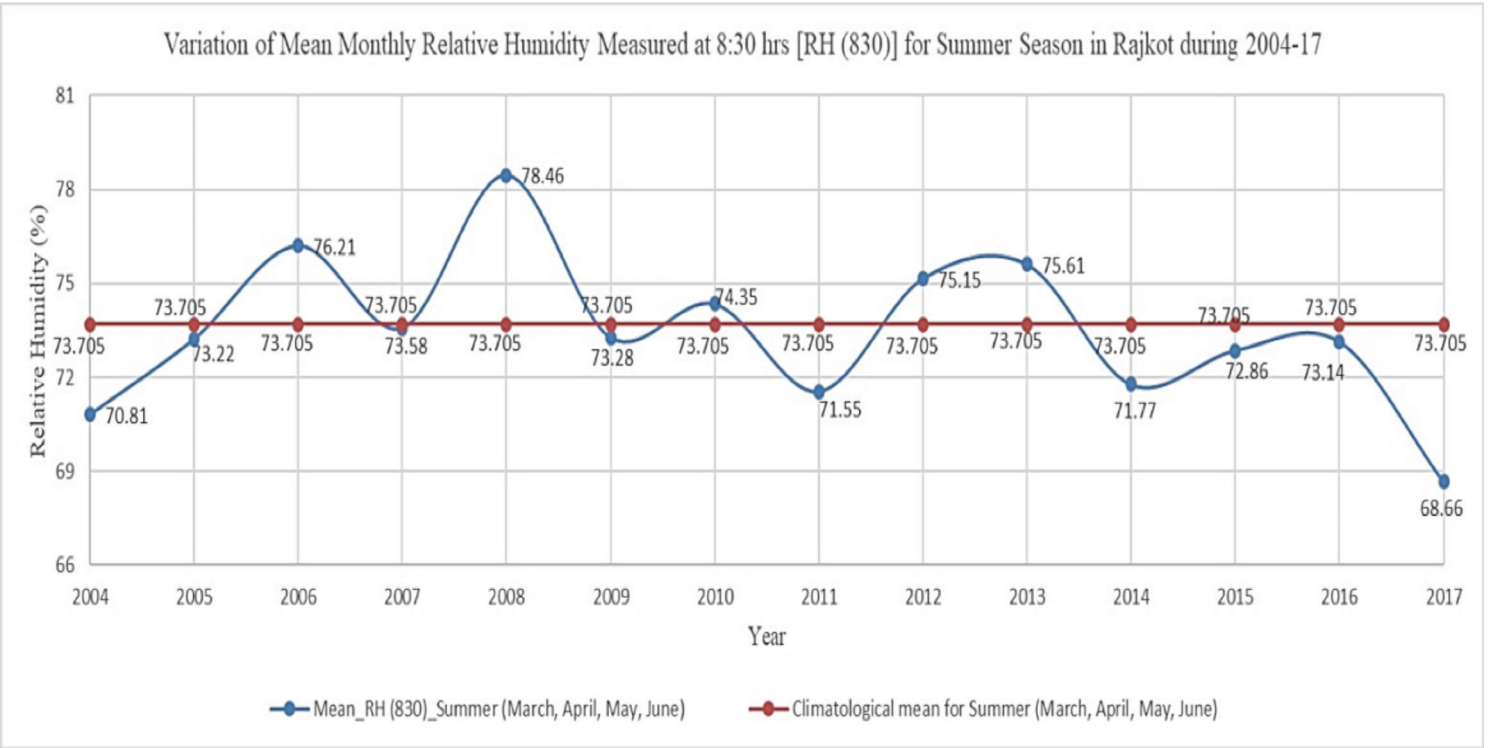


Figure 6i: Variation of RH at 8:30 hrs for the entire summer season in Rajkot during 2001-17

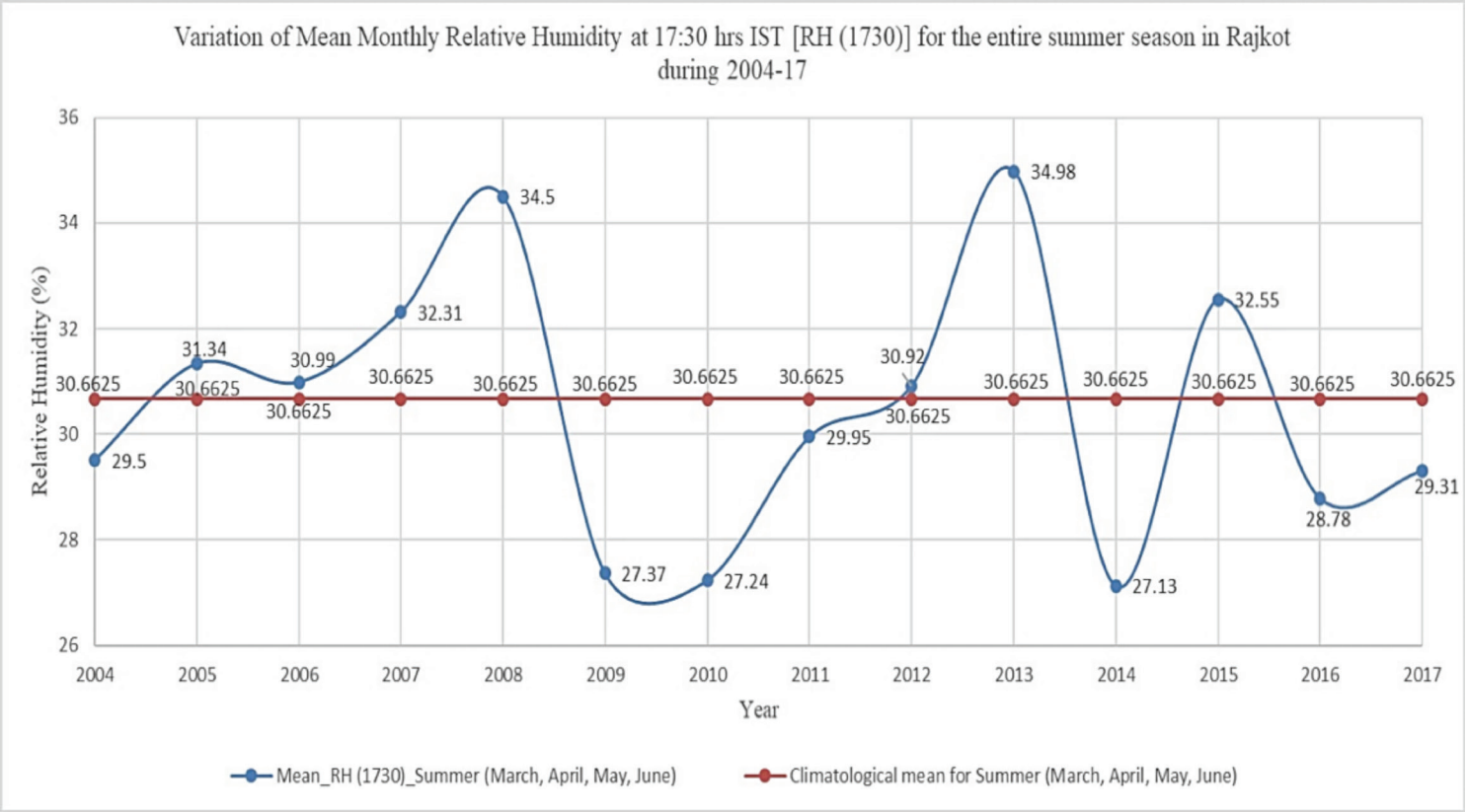


Figure 6ii: Variation of RH at 17.30 hrs, for the entire summer season in Rajkot during 2001-17

4. SPATIAL VARIATION AND MAPPING OF HOTSPOTS, RAJKOT

The thermal hot-spot maps give insight into the differences in hot spot distribution within cities. Identifying hot spots within a city can help focus interventions where they are most needed during heat waves. We consider 'hot-spots' as the areas within the city which experience ambient temperature in excess of the average monthly maximum temperature. Such thermal maps provide information about the areas which have the accumulation of hotspots, and therefore population living there is under high physiological and socio-economic risks due to thermal stress. Thus, specific measures to curb the problem of heat stress for the resident population can be taken using these maps.

Thermal hotspots maps were developed using Landsat 8 data. The Land Surface Temperature (LST) mapped was validated using ambient air temperature (AAT) recorded by 20 AWS (Automatic Weather Stations) installed by RMC and the Indian Meteorological Department (IMD) station. Landsat 8 provided a range of open-source data at a spatial resolution of 30 m and with 11 spectral bands, out of which two are thermal bands. The thermal bands, band 10 and band 11, are mostly employed for the purpose of LST retrieval; however, it has been observed that band 11 has more uncertainty than band 10 (Yu, Guo, & Zhaocong, 2014). Therefore, band 10 of Landsat 8 data was used for retrieval of LST. Data of May and June months of the years 2017 and 2018 were employed to map LST. For 2017, data of 04 May and 14 June were used, whereas, for 2018, data of 07 May and 08 June were used, as these dates provided images without any cloud cover. Hence clear images were derived on the particular dates. Shape file of Rajkot municipal wards and slum distribution data was obtained by RMC. The methodology flow chart is shown in Fig.7.

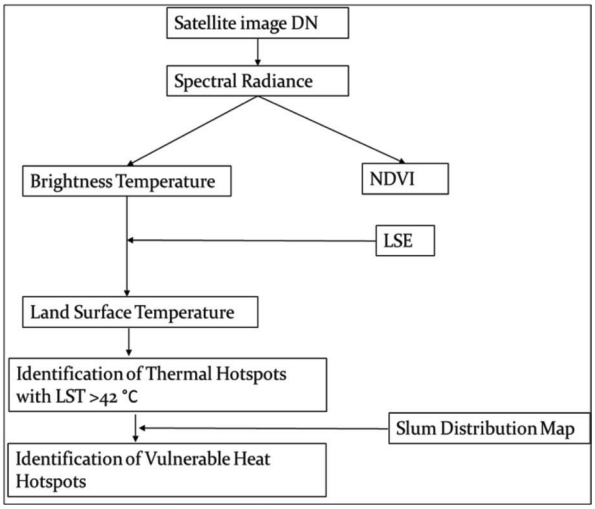


Figure 7: GIS methodology for identification of vulnerable heat hotspots

The LST derived from satellite data (NDVI – Normalized Difference Vegetation Index and LSE–Land Surface Emissivity) was validated with ambient air temperature recorded by IMD station within the city as well as the data received from 20 AWS stations installed within the city by Rajkot Municipal Corporation (RMC).

To mark the high temperature areas within Rajkot city, thermal hotspot maps were prepared to map areas with temperature higher than 42°C, and were marked as thermal hot-spots. Landsat 8 data of May and June months of 2017 and 2018 were employed to map Land Surface Temperature (LST). Refer fig. 8i, 8ii, 9i and 9ii.

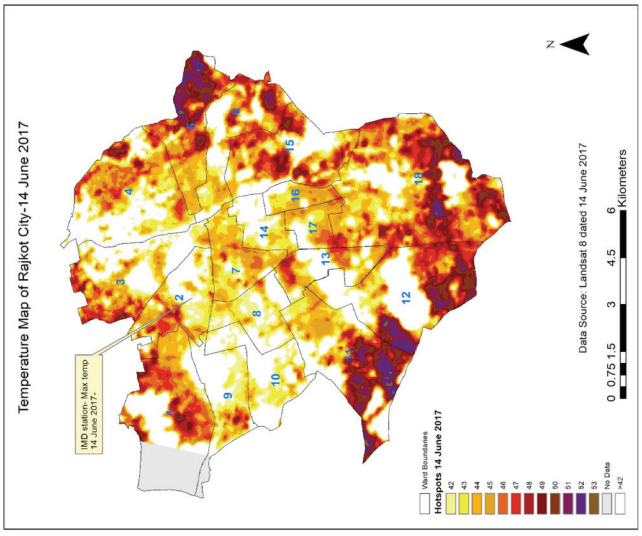


Figure 8ii: Thermal LST distrtution in Rajkot on, 14 June, 2017

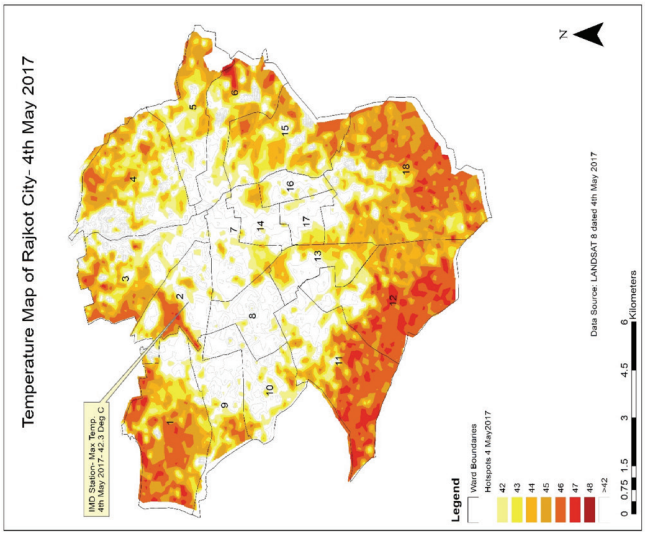


Figure 8i : Thermal LST distrtution in Rajkot on, 04 May, 2017

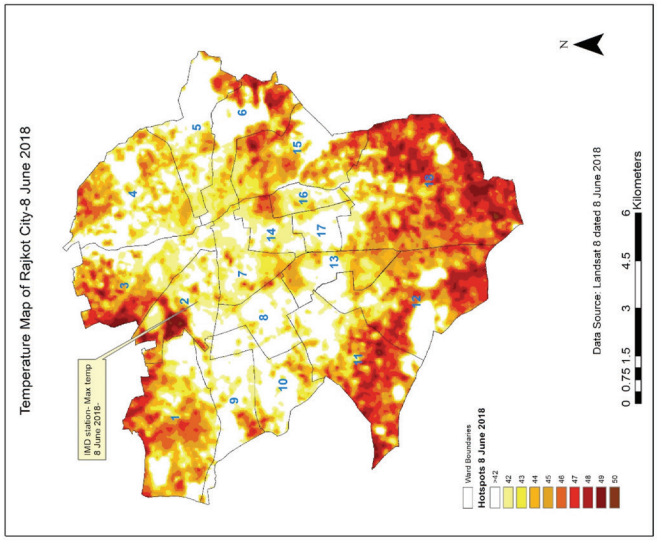


Figure 9ii: Thermal LST distrtution in Rajkot on, 08 June, 2018

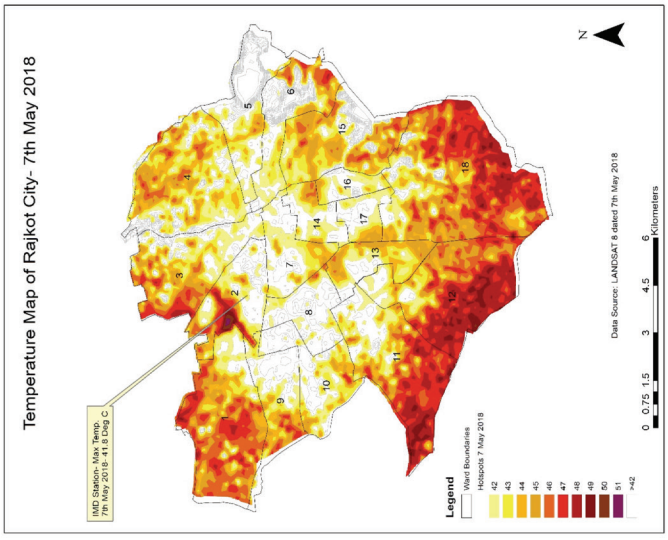


Figure 9i: Thermal LST distrtution in Rajkot on, 07 May, 2018

5. VULNERABLE MAPPING OF HEAT STRESS, RAJKOT

Vulnerability to heat is defined as a function of: the degree of exposure to the heat hazard, sensitivity to changes in weather/climate (the degree to which a person or system will respond to a given change in climate, including beneficial and harmful effects), and adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate) (IPCC, 2001).

Slum distribution in Rajkot was mapped using GIS (Geographic Information System), and slum distribution map was overlaid on LST maps to identify vulnerable thermal hotspots. Satellite images of Rajkot were downloaded from Earth Explorer portal of United States Geological Survey and processed using TRS Tool Box (Thermal Remote Sensing)(Walawender, Hajto, & Iwaniuk, 2012) in ArcGIS software.

The various areas identified as thermal hotspots in Rajkot city include: Ambedkar Nagar, Rashulpura, Bajrangnagar, Rajyadhar, Shitaldhar, Jay Bhim Nagar, Bharat Nagar 1, Pradyuman Park and Laludiwonkdi. Refer Fig.10.

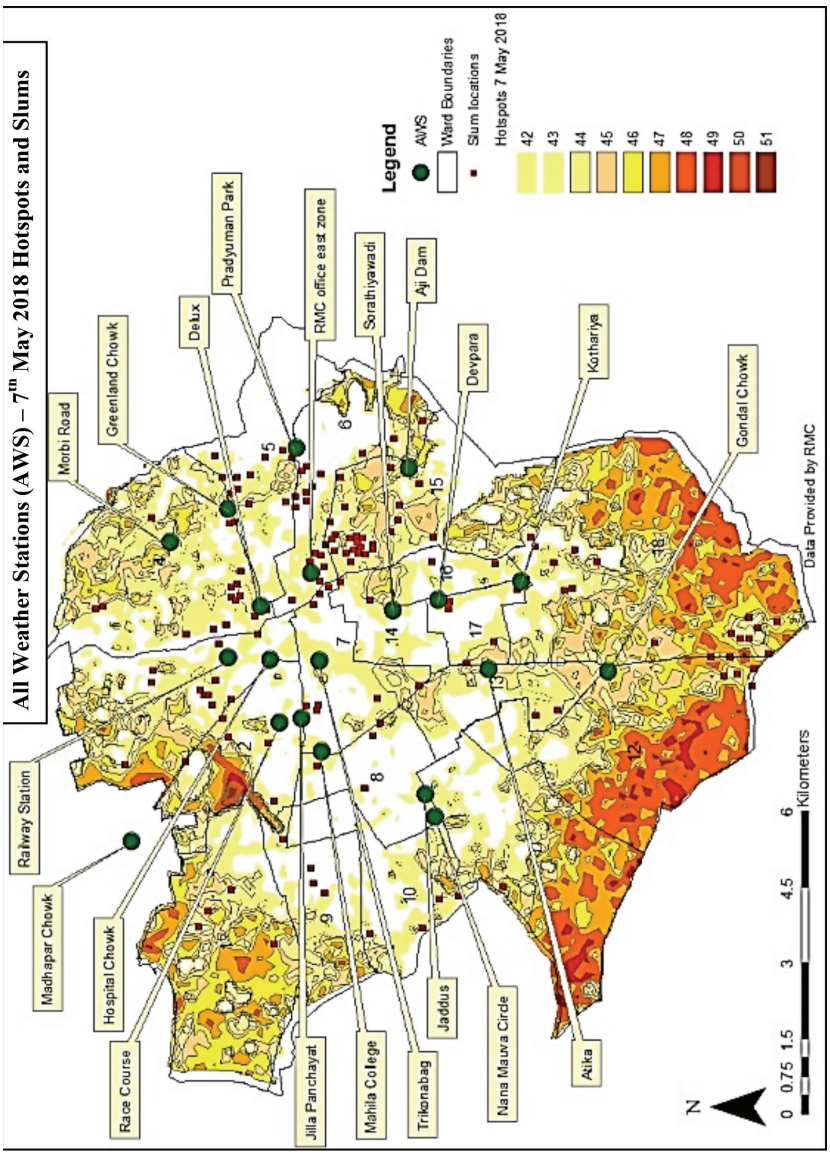


Figure 10: Vulnerability Mapping-Thermal Hotspots and Slum, Rajkot

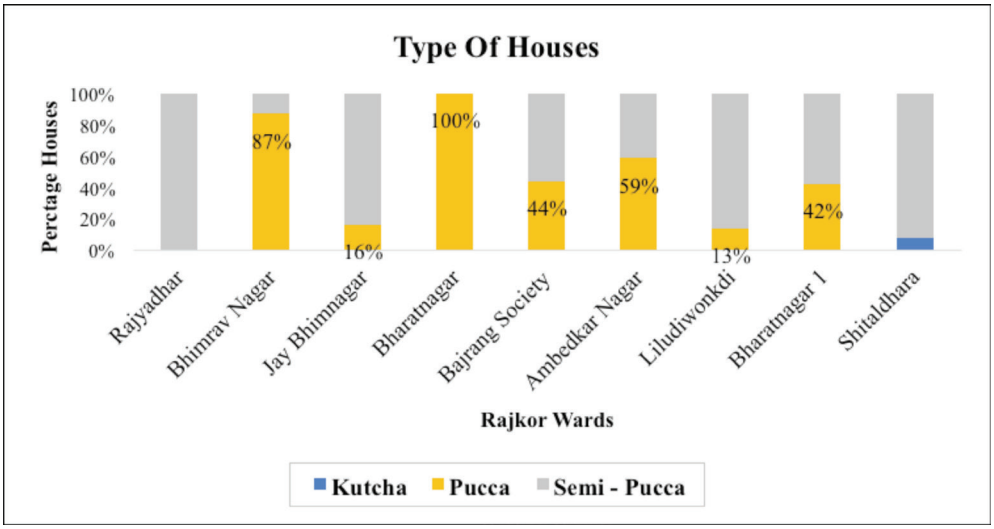
It is usually found that both men and women are affected by heat stress, with children and elderly being more susceptible to heat stress (McGeehin, 2001), (Oudin Åström, 2011), (Lundgren, 2013), (Li, 2015). People with low socio-economic status (Harlan, 2006), i.e. the economically weaker section, are also found to be more susceptible to heat stress.Pregnant women are also susceptible to increasing ambient temperatures and heatwaves since their ability to thermos-regulate is compromised (Wells J.C, 2002) pregnant women working in extreme heat are more prone to dizziness and fainting.

Vulnerable population in Rajkot are those who have to stay outside for work all day long and have limited options to protect themselves, for example, vendors, beggars, shopkeepers, policemen, auto/rickshaw drivers. Lack of adequate measures to combat the effects of heatwave results in health issues such as diarrhea, heat stroke, rashes, dehydration, dizziness.

6. VULNERABILITY ASSESSMENT AND IMPACTS OF HEAT STRESS ON VULNERABLE POOR

After identifying the 9 hotspots in Rajkot city, household surveys were conducted to assess the housing infrastructure including the size of housing units, ventilation, cooking area, water supply, sanitation, and access to clean fuel, electricity as well as their awareness of the health complications from heat stress, and access to medical facilities and the health impacts of high temperature or heatwaves among the residents. The existing state of heat exhaustion and heat stress among the identified wards was assessed to understand the vulnerability. All these factors influence the community's resilience and preparedness for high temperature or heatwaves.

6.1 Type of Housing



Majority of the houses in the city are Pucca and Semi Pucca, the only ward which has the presence of Kutcha houses is Shitaldhara, which indicates that indoor temperatures usually remain higher than outside, especially in roof-top stories. Refer to Fig. 11.

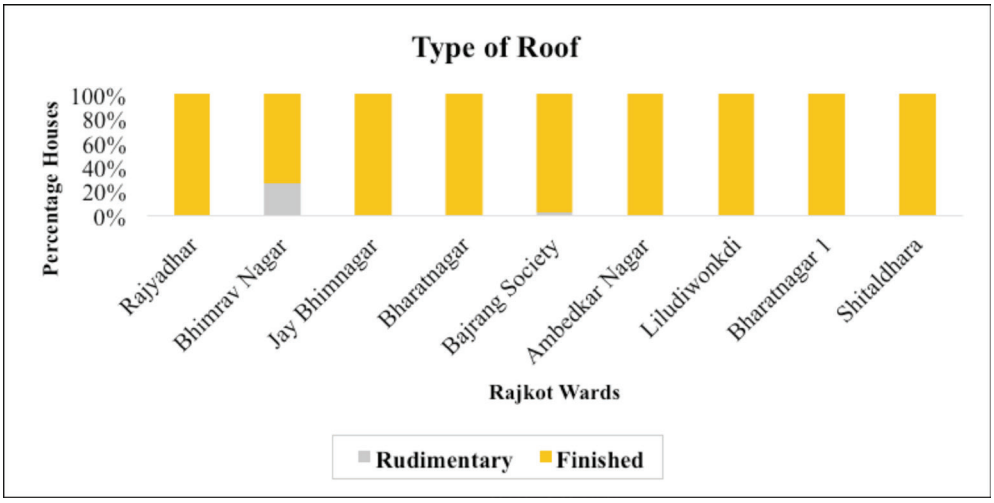


Figure 11: Housing Typology

6.2 Heat Stress Awareness

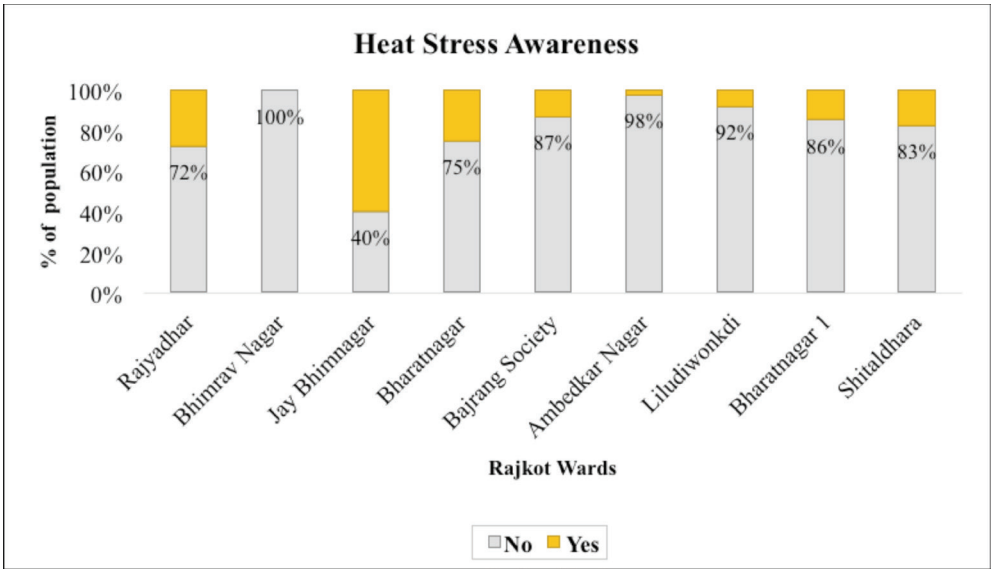


Figure 12: Awareness to Heat Stress

The survey revealed that the majority of the people are unaware of the heat stress phenomenon in the city, refer Fig. 12. The people lacked the awareness

regarding medical facilities for heat and the available adaptive measures taken by Urban Local Bodies (ULB) to mitigate the impact of heat stress.

6.3 Access to Water

Being an arid region, water availability is a major issue in Rajkot with the average frequency of water supply in the city being once a day. The accessible sources of water in the city are piped water and public taps. In Bhimrav Nagar, Bajrang Society, Rajyadhar and Shitaldhara Majority of the people do not have a water source in their own dwelling. Refer to Fig. 13.

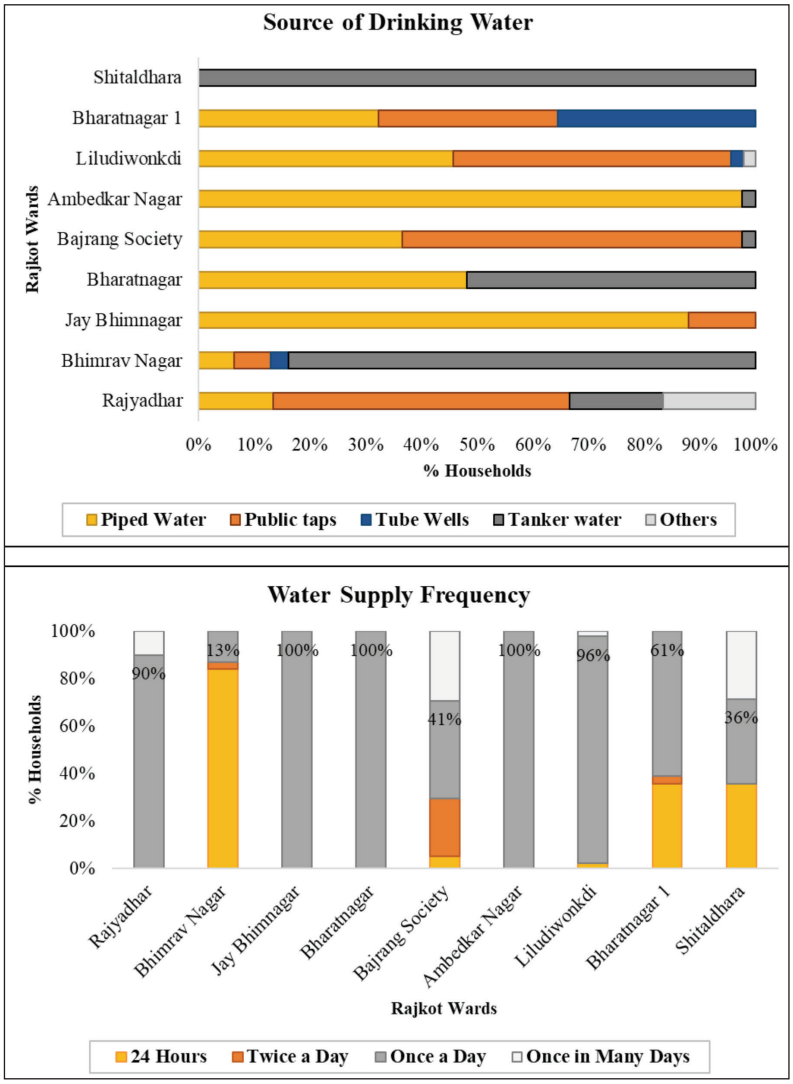


Figure 13: Source of drinking water and water supply frequency

6.4 Health Impacts: Heat Exhaustion and Heat Stroke

As per the household surveys conducted in Rajkot thermal hotspots, it was recorded from the survey participants, that majority of the people suffered from Heat Exhaustion and Heat stroke as a direct impact of heat stress on health. The most affected wards include – Rajyadhar followed by Ambedkar Nagar. Refer to Fig. 14.

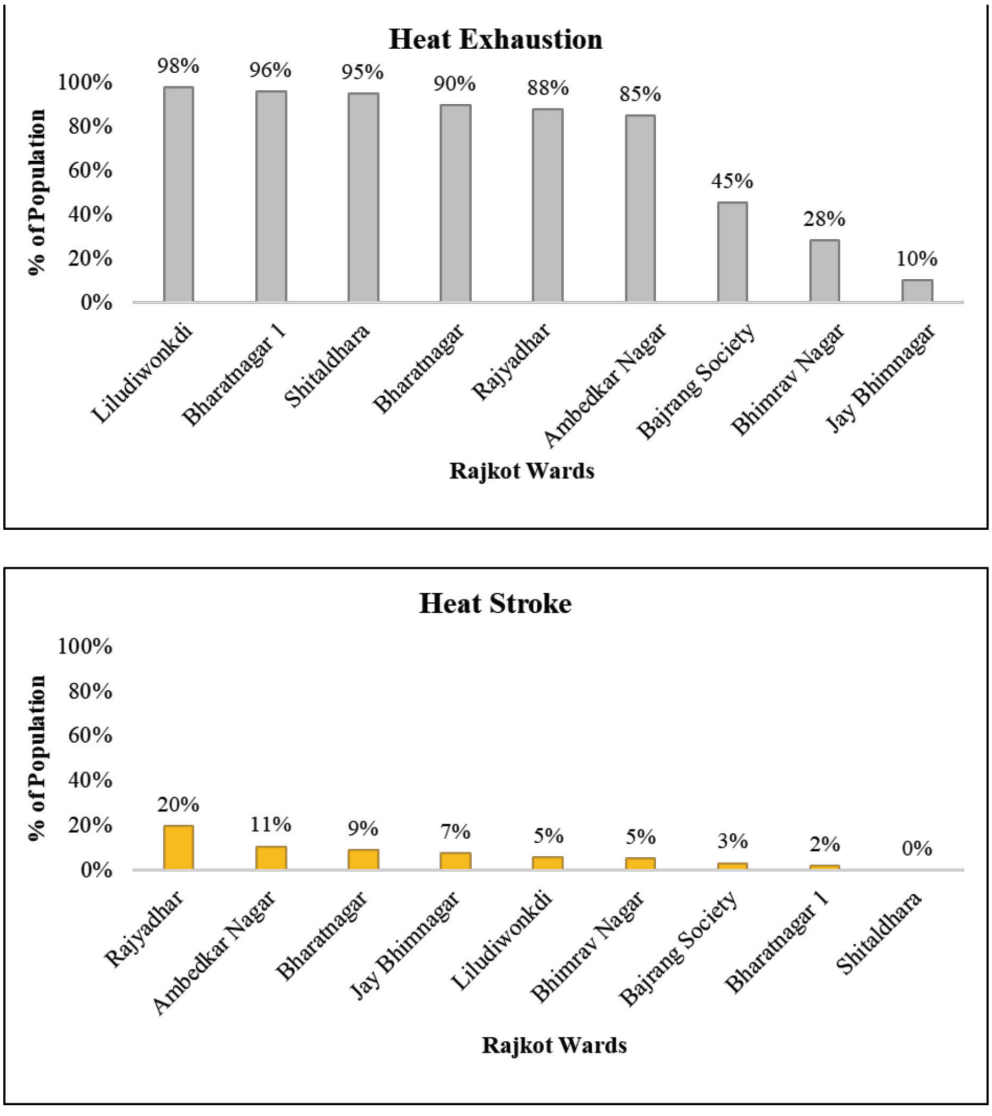


Figure 14: Impact Heat on Health

6.5 Awareness and Access to Health Infrastructure

The survey indicated that in almost all the wards the awareness regarding the available heat-related treatment is low, more than 30% of the people are unaware of the facilities. Refer to Fig. 15.

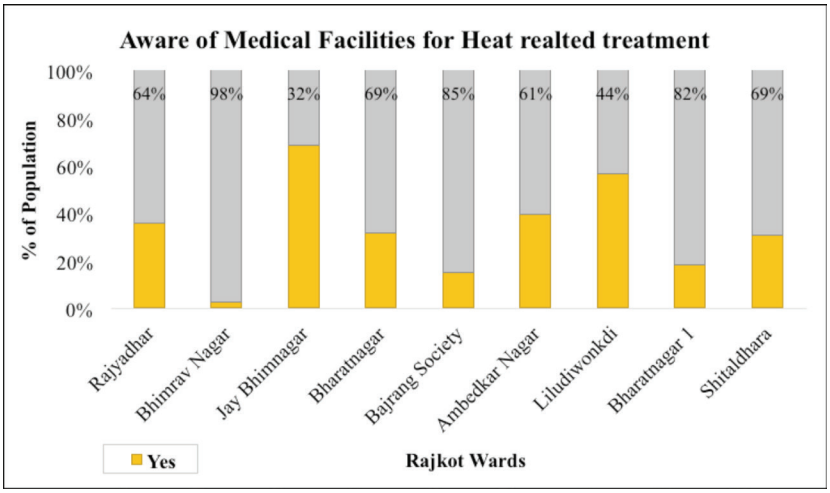


Figure 15: Awareness Regarding availability of Medical Facilities for Heat Stress

The survey also indicated that access to public medical facilities in and around the respective wards, hence they approach private facilities which are expensive and economically weaker sections avoid to approach. Refer to Fig.16. The Distance from the health care centres indicate that majority of the wards require minimum 16-30 minutes to reach the nearby health care 4 (Public / Private), hence at the time of emergency, it becomes difficult to reach the nearest health centres. Refer to Fig.17. All nine wards are highly vulnerable in access to health services.

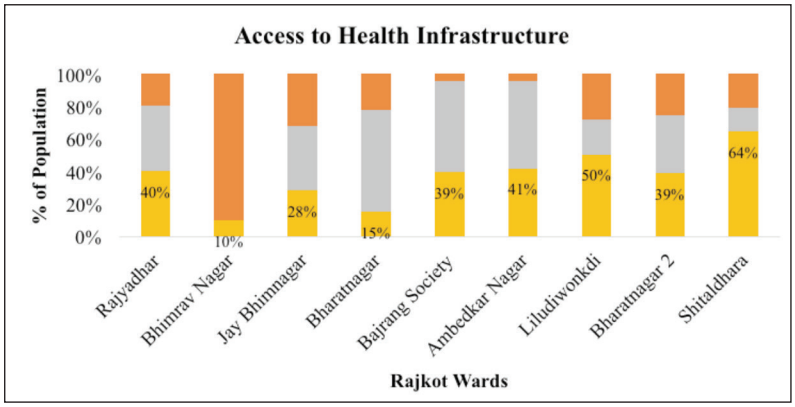


Figure16: Access to Health Infrastructure

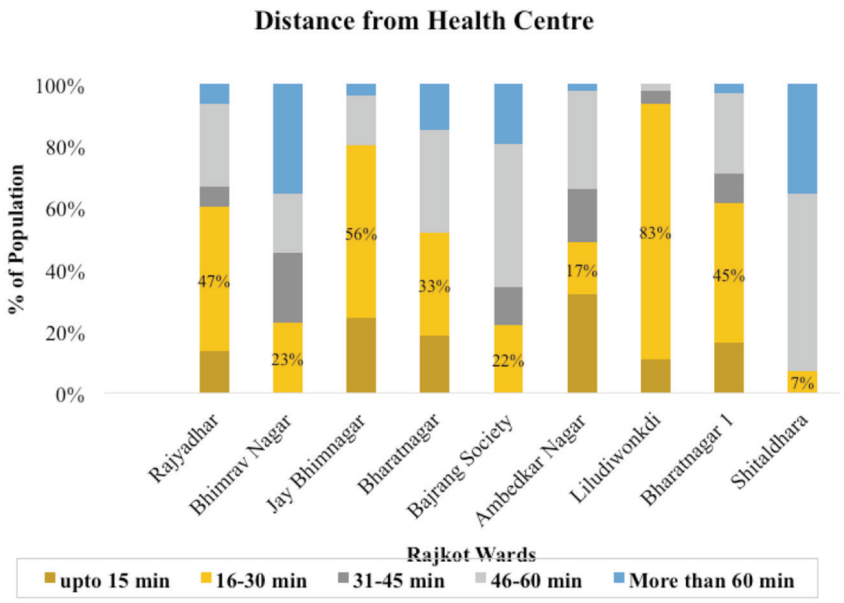


Figure17: Distance from Health Care Centres

6.6 Access to Electricity

Rajkot was found to have a reliable electricity supply to all areas. Of the surveyed households 98% reported uninterrupted access to electricity. Of the remaining 2% of households, 1% did not have an electricity connection and the other 1% reported electricity supply for 15 hours a day. About 7% of the sampled households reported minor outages during summers, refer to Fig.18. This factor, therefore, poses low vulnerability.

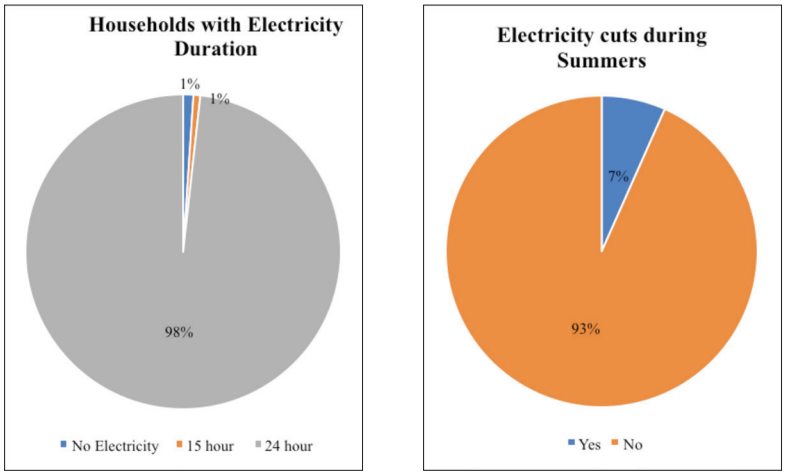


Figure18: Access to Electricity

6.7 Access to Sanitation

The survey showed that only 82% of the households had toilets, either pit latrines or flush toilets. Of these, about 16% of households shared toilets. Members of 14% households either used community toilets or practised open defecation, refer to Fig.19. Access to sanitation and piped water supply for all households is a major step for checking peak summer disease caseloads.

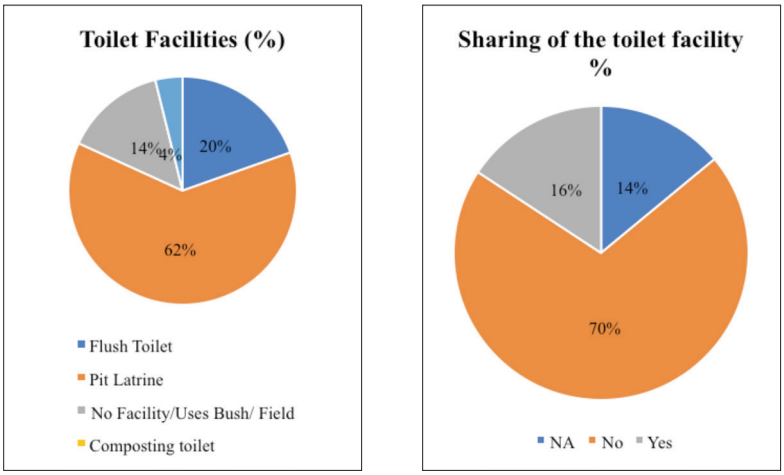


Figure19: Access to Sanitation

6.8 Access to Clean Cooking Facility

All surveyed households use clean fuel 96% of households use LPG, 3% use electricity and 1% biogas. Therefore, the cooking fuels used are not the matter of concern. However, unplanned or improper location and ventilation of cooking area can trap heat in the living area. This is of concern particularly in small housing units.

7. CLIMATE ADAPTIVE HEAT ACTION PLAN, RAJKOT

The Climate Adaptive Heat Stress Action Plan has been developed to improve the management of heat-related risk in Rajkot city. The plan intends upon being more spatially oriented and gender-sensitive while supporting the city's planning especially in prioritizing and integrating adaptive resilience within the agenda towards climate-resilient smart city.

The plan intends to identify impacts of extreme heat events on the health, work productivity and livelihoods of the vulnerable population within the city and mobilize communities and government agencies towards appropriate, innovative and affordable climate adaptation measures for improving health and livelihood resilience for the urban population, with consideration of the associated cost-effectiveness as well as gender-based implications. The plan

also aims to improve the communities' resilience through capacity building of key stakeholders to facilitate the implementation of the Plan. The various components of the heat action plan for Rajkot city are indicated in Fig 20.

The Action Plan divides responsibilities into pre, during and post-event categories, detailing preparation for a heatwave (pre-event responsibilities), steps to be taken to reduce heat stress during a heatwave (during-event responsibilities) and measures to incorporate lessons learned and fill gaps found in the management of heat stress (post-event responsibilities).

Phase-I: – Pre-Heat Season (February to March) Pre-Heat Season is devoted to developing early warning systems, communication plan of alerts to the general public, health care professionals and voluntary groups (caregivers) with emphasis on training and capacity building of these groups.

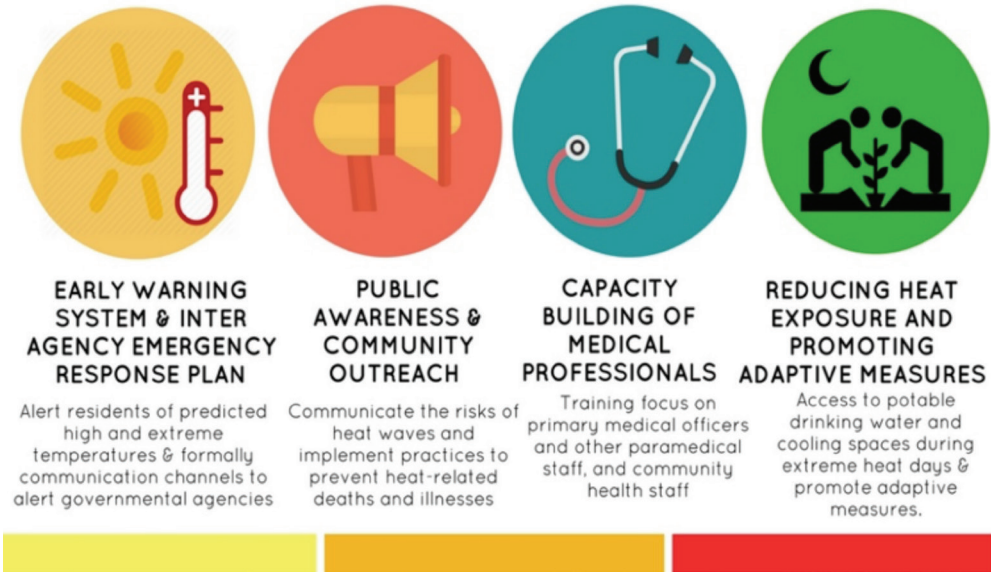


Figure 20: Heat Action Plan Components for Rajkot city

Source: Indian Institute of Public Health, Gandhinagar

Phase-II: - During the Heat Season (April to June) High alert, continuous monitoring of the situation, coordination with all the department's agencies concerned on one hand and general public & media, on the other hand, is the focus of this phase.

Phase-III: – Post - Heat Season (July to October) In Phase – III concentration is on evaluation and updating of the plan. It is important at the end of the summer to evaluate whether the heat-health action plan has worked. Continuous

updation of the plan is a necessity. Global climate change is projected to further increase the frequency, intensity and duration of heat-waves and attributable deaths. Public health preventive measures need to take into consideration the additional threat from climate change and be adjusted over time.

The measures which have been taken by Rajkot Municipal Corporation as part of Rajkot Heat Stress Action Plan can be classified into short term, medium term and long term measures.

7.1 Short and Medium Term Measures

Awareness Campaigns

- Hoardings, posters, to be displayed by smart city LED TVs at various locations, distribution of pamphlets.
- Awareness workshops for occupationally exposed - traffic police, hawkers, street vendors, construction workers and school children.

Mitigation measures

- Keeping gardens, cooling shelters and other possible cooling centres open with water availability.
- Availability of water and sheds at open construction sites.
- Pilot project on roof painting with white colour - cool roof and or distribution of gunny bags for putting on the tin roofs/asbestos in slums.
- Provision of water points and ORS at Construction sites, Bus stands and other Public places during processions and political and other rallies and processions during summer.
- Distribution of cool roof jackets to on-duty traffic police personnel.
- Water tanker campaign- Tankers to be made available on call in slums during orange/red alert days.

Early warning communication

- SMS and WhatsApp messages for early warning to citizens, NGOs, Citizen welfare groups, construction contractors.
- Public announcement through microphones across the city during orange and red alert days a day before and early on the forecasted day.
- Press Releases and campaigns on radio, TV and websites.

Medical Preparedness

- Stocking ORS and cool packs at the health centres & readiness with cooling and rehydration as well as shock management treatments.
- Medical camps on day of red alerts at hotspots.

Monitoring and Analysis

- Recording ward wise heatstroke cases, proper cause of death and monitoring daily mortality as well as daily hospital admission due to all causes and due to heat-related causes.
- Monitoring and analysis of the morning temperatures recorded from AWS sites and issue early warnings.

7.2 Long term Measures

- Heat alerts and emergency response plan needs to target vulnerable groups, high-risk areas and incorporation of the same in the City Development Plan. Planned development of urban areas ensuring appropriate amenities are available to all the residents in every location is required.
- Insulation and building standards need to be increased, improving building bye-laws along with increasing heat tolerance for new infrastructure, retrofitting. Building bye-laws can have components of passive ventilation and cool roof technologies to increase thermal comfort and made mandatory in more vulnerable cities.
- Identifying locations for building shelters and shades in urban areas. Shelter locations for the urban poor and slum dwellers must be identified and constructed.
- Incorporation and documentation of indigenous knowledge to develop protective measures at the regional and community level for sensitization and awareness generation. Local culture and physical exposure of population need to be improvised to reduce the impact of heat stress on health and physical wellbeing.
- Capacity building at the community level, through awareness campaigns and outreach programmes. Communicating risks associated with heat stress and its impact on health, livelihood and productivity and ways to mitigate the same.
- Initiating research on micro-climate and corroborating the need to monitor temperatures in urban areas. Policy level intervention to retrieve natural eco-systems and natural shelters.

- Improvising the urban landscapes through vertical greenery, roof gardens can prove to be good alternate methods to bring down the temperature of the built environment. Greening infrastructure can be an effective method to cope with heat stress. Urban forests are found or have been found to be effective for city heat mitigation. A combination of shading, reduced heat build-up in materials, humidity and wind management can provide heat refuge at street levels.

- Initiating Early warning systems, advisories and alerts against extreme heat for the communities and Urban Local Bodies. Building communication networks through Local bodies, Health officers, Health care centres, hospitals, communities and media.

- Encourage investing in water bodies, fountains in areas of mass presence and promote greeneries in urban areas along with improving green transport and energy systems.

7.3 Capacity Building

Medical Stakeholders Training cum orientation workshop was organized for health care professionals towards managing Heat-Related Illnesses in Rajkot, Gujarat. The training aimed towards orienting healthcare professionals of Rajkot city on Heat Stress Action Plan, enhancing their capacities for proper and inclusive management of heat-related illnesses and health impacts. More than 50 doctors and public health professionals from Rajkot city had been a part of the training, which not only heat stress and protocols for heat-related diagnosis and treatment but towards overall preparedness for prevention and management of heat stress.

8. CONCLUSION

Heat stress action plans are key to city climate adaptation strategies. With the forecast of increased frequency and intensity of heatwaves in the future, a climate-adaptive heat stress action plan will enable Indian cities to efficiently prepare, mitigate and adapt to the heat stress-induced by climate change. Through identification of heat hot spots and vulnerable populations at ward level, heat action plan provides adaptation strategies which are localised and targetaction at ward level.

The spatially differentiated Heat Stress Action Plans (HSAPs) will serve to support Rajkot's medium-term development planning especially in prioritizing and integrating adaptive resilience within the agenda of climate-resilient smart cities.

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Chapter 10

IMPACT OF DUST STORMS ON AIR QUALITY AND HUMAN HEALTH IN DELHI

Pallavi Saxena, Ananya Srivastava and Saurabh Sonwani

ABSTRACT

The impacts of dust storms that originated over the north-western parts of India, are therefore very common in northern part of India, in particular, Delhi. Dust storms affect daily lives of people and also reported severe health impacts. The air quality badly influenced by dust storms events and ultimately creates big threat in the surroundings. The objective of the present study is to evaluate the impact of dust storms on the air quality at selected sites of Delhi by analyzing the nature of particulate matter (PM_{10} and $PM_{2.5}$) concentrations in the year 2018. This study also focus on health risk assessment due to dust storms (PM_{10} and $PM_{2.5}$) particularly in relation with relative risk and cardiopulmonary mortality at the selected sites of Delhi. It was found that particulate matter (PM_{10} and $PM_{2.5}$) concentrations were found to be high during dust storm days at selected sites and were crossing the permissible limits which indicates hazardous for human health. In addition to that, relative risks and cardiopulmonary mortality were found be high in the selected period particularly in case of $PM_{2.5}$ which indicates towards high mortality. Therefore, the present study concludes that dust storm studies are very important for health risk assessment and control measures such as planting of tree species or effective plan for management of water bodies are suggested for them.

Keywords: *Dust storms, particulate matter, air quality, human health and Delhi.*

Pallavi Saxena
Assistant Professor, Department of Environmental Sciences, Hindu College, University of Delhi, Delhi, India

Ananya Srivastava
Student, Department of Economics, Hindu College, University of Delhi, Delhi, India

Saurabh Sonwani✉
Assistant Professor, Department of Environmental Studies, Zakir Husain Delhi College, University of Delhi, New Delhi, India
sonwani.s19@gmail.com

1. INTRODUCTION

Dust storms are one of the significant category among all natural hazards, which have harmful important impacts in day to day life for a short period of time (Sonwani and Maurya, 2018). Atmospheric dusts have mainly terrestrial sources and a significant process of land-atmosphere interaction (Seinfeld et al., 2016; Saxena and Naik, 2018). Dust storms also have influential effects on climate variability, nutrient dynamics, biogeochemical cycles of oceans, ground and air transportation systems and ambient air quality (Kim et al., 2016; Sonwani and Kulshrestha, 2017). Satellite and surface observation studies have also reported that global sources of atmospheric dusts are: arid and semi-arid desert regions contributing to long-range transport of dust particles carried out by strong winds (Prospero et al., 2002; Ginoux et al., 2012; Crosbie et al., 2014; Saxena and Sonwani, 2019). Desert dust consists a major fraction of naturally occurring ground-level aerosols (Cheng et al., 2009). These particles are responsible for cooling effect in the lower layer of troposphere, instead, these particles are responsible for additional warming in the middle and upper troposphere (Sharma et al., 2013; Saxena and Sonwani, 2019). Another source of dust pollution is desertification. Nevertheless, natural weathering has more impact on Asian dust emissions and related dust storm occurrences as compared to desertification processes (Hofzumahaus et al, 2009; Sonwani and Kulshrestha, 2019). With increase in dust pollution, other air pollutants like CO and O^3 also increases in the atmosphere. Actually every dust storm is followed by net radiative cooling at the surface whereas absorption of solar radiation by dust suspended in the atmosphere can result in warming up in the middle to upper troposphere region. Thus, a significant decline in surface temperature has been immediately noticed which increases upper air humidity. This large scale change in radiation balance resulted in greenhouse gases like $O^{\cdot}$ and another air pollutant, CO, in the middle-upper troposphere (Sarkar et al., 2019). Moreover, the concentration of NOx also increases due to dust storm. The mineral dust coming from Sahara and Thar desert are found to be rich in nitrates which convert NOx by "re-noxification" process under the presence of sunlight (Ndour et al., 2009).

Dust storms also have harmful impact on human health, visibility and climate. Many epidemiological studies have reported correlation between particulate matter concentrations and respiratory and cardiovascular diseases risks (Samet et al., 2000; Pope, 2000). Those particles which are having diameter less than 10μm are more harmful for respiratory diseases because they will inhaled deeply inside the lungs (Dockery and Pope, 1994; Kulshrestha and Saxena, 2016). Thus, more finer the particles, more is the risk to human health (Peters et al., 1997; Penttinen et al., 2001). The impacts of dust storm also leads to a number of asthma cases all across the world like Australia (Rutherford et al., 1999), Middle East (Thalib and Al-Taiar, 2012) and those areas which are

affected by frequent long-range transport, including northeast Asia (Lee and Lee, 2013) and southern Europe (Karanasiou et al., 2012).

Dust storm events often occur in the Indo Gangetic Basin (IGB) of Northern India during pre-monsoon (March-June) because of the aerosol mixture with the already suspended pollutants which enhances the aerosol loading (Kumar et al., 2012; Sonwani and Saxena, 2016). MiddleEast, Arabia, Southwest Asia and Thar desert are the main sources for dust which are carried over to IGB on the basis of the intensity of westerly winds and meteorological conditions (Dey et al., 2004; Prasad and Singh, 2007; Prasad et al., 2007; Sharma et al., 2012; Aher et al., 2014), western Himalayan range (Hegde et al, 2007; Guleria et al., 2011; Srivastava et al., 2011a; Kumar et al., 2014), eastern range of Everest and North-eastern region (Duchi et al., 2011; Chatterjee et al., 2012). Some scientists have reported various results on dust storm events in IGB region or in other regions of India (Dey et al., 2004; Singh et al., 2005; Prasad and Singh, 2007; Pandithurai et al., 2008; Sharma et al., 2012; Singh and Beegum, 2013; Hegde et al., 2007; Srivastava et al., (2011a) and Kumar et al., (2014). These dust storms are also a source of silt deposition that are carried through downwind directions as noticed in the quartzite ridges in Delhi region (Adhikary et al., 2007). During summer season, heavy loaded dust (including heavy metals) are carried by winds to the IGB (Yadav and Rajamani, 2003; Saxena and Kulshrestha, 2016), results in degradation of air quality and reduced visibility. It has also been observed that a number of dust events often occurred more times in the western part as compared to the eastern part of IGB, New Delhi which is located in the western part of IGB and highly affected by dust-storm events during the premonsoon season locally known as 'Aandhi' (Joseph et al., 1980; Middleton, 1986). During these events, wind-blown dust is carried from Thar desert in Rajasthan and adjoining regions. Moreover, Central Pollution Control Board (CPCB), India also reported that PM_{10} concentrations are above the permissible limit (>150 µg/m3) in many megacities especially in IGB like Delhi (Mitra and Sharma, 2002). Sharma et al, (2003) and Saxena et al., (2020) also observed that high PM_{10} loading is one of the main factor for sulphate formation on the dust particle boundary, resulting in very high concentration of sulphate aerosols in the atmosphere, that is the case of Delhi region. The dusts carried to the IGB particularly in Delhi region every year during summer season affect the air quality of the region (Sonwani and Kulshrestha, 2018).

To control the dust pollution in Delhi, several steps were carried out by government organizations like Ministry of Environment, Forests and Climate Change (MOEFCC) who launched National Clean Area Programme (NCAP) in the year 2018 and suggested to undertake plantation drive programmes for roads and highways, involve other organizations like Universities like University of Delhi, institutes like Indian Institute of Forest Management (IIFM) and research organizations to evolve this plan. Initiatives were also being taken under United Nations Convention to Combat Desertification (UNCCD) for solving the issue of

transboundary movement of dust to Delhi from adjoining regions. Various other plans like disposal of collected dust from mechanical sweeping, wall to wall paving of roads, control measures for construction works by using enclosures, fogging machines etc. and use of retrofitted emission control equipment in DG sets (MoEFCC, 2019; Patel, 2019). However, inspite of these programmes, the levels of air pollutants particularly particulate matter are still alarmingly high and crossing permissible limits by 3-4 times because these schemes may not be followed properly at larger scale and efforts from public are still not significant enough at ground levels. Therefore, there is still need to work on the problem of air pollutants and their consequent events like dust storm which is very much responsible for deteoriating megacities air quality. Very few studies have been reported in Indian cities considering dust storms and their contribution in health risk assessment studies (Gautam et al., 2009b, 2011; Srivastava et al., 2010; Giles et al., 2011; Das et al., 2013; Dumka et al, 2014). Our present study is the first one which focus to evaluate the impact of dust storms on the air quality and health risk assessment due to dust storms particularly in relation with Relative Risk Function (RR) and Cardiopulmonary mortality (CPM) in Delhi.

2. METHODOLOGY

2.1 Monitoring Sites and Data Sources

Measurements of particulate matter concentrations (PM_{10} and $PM_{2.5}$) during dust storm and non-dust storm days at two selected sites in Delhi were analyzed. The location of the sites are shown in Fig.1. Hourly concentrations of PM_{10} and $PM_{2.5}$ at selected sites were obtained from the Central Pollution Control Board (CPCB) (http://cpcb.nic.in/real-time-air-quality-data/ website. PM_{10} and $PM_{2.5}$ were measured by using tapered element oscillating microbalance(http://cpcb.nic.in/air-quality-standard/). The selected air pollutants were analyzed during the given periods as: (a) Dust storm (DS) days (8th, 14th and 16th May and 1st June 2018) and (b) Non-dust storm (NDS) days (23rd and 29th August and 8th and 25th September 2018). The information about dust storm events was procured from Indian Meteorological Department (IMD) website (www.imd.gov.in).

2.2 Description of Study Sites

2.2.1 Punjabi Bagh (PB) (latitude: 28.6707°N, longitude: 77.1285°E) is one of residential site of Delhi surrounded by commercial complexes and as designated as Site 1. There are around four major market places and 2 major commercial complexes. Punjabi Bagh is divided into two parts, east and west by ring road. It is well connected to different parts of the city and has good bus network and roads. It is also well connected to the Delhi Metro with 3 stations within the main Punjabi Bagh Chowk area. The passenger per unit (PCU) in this area has been registered 3,213 per hour. The vehicle composition consists of two-wheelers, three-wheelers, cars, buses, light commercial vehicles (LCVs) and trucks.

2.2.2 Anand Vihar (AV) (latitude: 28.6502°N, longitude: 77.3027°E) is one of the traffic intersection site of Delhi surrounded by small scale industries and nearby railway station and as designated as Site 2. It is also situated near to metro station, Anand Vihar metro station and having 3 major arterial roads. It is one of the biggest traffic intersections in Delhi which is well connected with ring roads and outer ring roads. The passenger per unit (PCU) in this area has been registered 5,144 per hour. The vehicle composition consists of two-wheelers, three-wheelers, cars, buses, light commercial vehicles (LCVs) and trucks.



Figure 1. Map of Delhi showing study sites

2.3 Human Health Risk Assessment Parameters

In order to identify all-cause of mortality with respect to PM_{10} for selected periods, equation (1) was used to calculate relative risk (RR) as mentioned by Ostro, B. (2004).

$$RR = \exp [\beta (X-X_0)] \quad \ldots\ldots (1)$$

Where, X and Xo are the current and threshold PM^{10} concentration (µg/m3) in ambient atmosphere and ß is the suggested coefficient. The value of ß was taken as 0.0008 in case of all cause of mortality and short term exposure to PM_{10}. While in case of $PM^{2.5}$ cardiopulmonary and lung cancer associated mortality were calculated following the equation 2, is given below-

$$RR = \left[\frac{X_0-1}{(X_0-1)}\right] \beta \quad \ldots\ldots (2)$$

For calculation of cardiopulmonary and lung cancer-related mortality, the ß coefficient values were taken as 0.1551 and 0.2322, respectively (Pope et al., 2002).

3. RESULT AND DISCUSSIONS

3.1 Average Levels of Particulate Matter during Dust Storm and Non-Dust Storm.

The average levels of PM_{10} and $PM_{2.5}$ has shown in the Table 1, while the details of the samples with their daily average of PM_{10} and $PM_{2.5}$ during DS and NDS have been shown in the Table 2.

Table 1. Average ± Standard deviation of PM_{10} and $PM_{2.5}$ at selected sites

PB		PM_{10}(µg m^{-3})	$PM_{2.5}$ (µg m^{-3})
	DS	158±65.2	68.4±45.7
	NDS	75±33.6	35.5±54.6
AV			
	DS	224.7±119.3	71.6±53.9
	NDS	88.4±45.9	34.3±13.8

The present study reported the level distribution of the PM_{10} and $PM_{2.5}$ at selected sites in Delhi region. To find the effects of the dust storms, the samples collected on significant dust storm days in comparison to the non-dust storm particulate samples. The average levels of PM_{10} and $PM_{2.5}$ at both the selected locations are reported in Table 1. The average levels of PM10 during dust storm days were found more than 2 times (158±65.2 µg m−3) as compared to its value during non-dust storm days (75±33.6 µgm−3) at PB site. Moreover, the levels of $PM_{2.5}$ were found around 2 times during DS (68.4±45.7 µgm−3) as compared to NDS (35.5±54.6 µg m−3) at PB site. The average observed PM10 levels were found to be 2.5 times (224.7±119.3 µgm−3) during DS as compared to NDS (88.4±45.9 µgm−3) at AV site. Moreover, the $PM_{2.5}$ levels were found more than 2 times (71.6±53.9 µg m−3) during DS as compared to the NDS (34.3±13.8 µg m−3) at AV site. The result showed a significant difference in the PM_{10} levels concentration at both sites within DS and NDS period, which shows important contribution dust storm events in air quality degradation in Delhi region. The similar observations were also found in case of $PM_{2.5}$ levels at both the sites. The

relatively higher levels of PM_{10} (as compared to $PM_{2.5}$) during dust storm days as compared to the non-dust storm days showed the significant contribution of dust storm event as it contributed a large fraction of coarse particulate matter with dust storm event as compared to the fine mode particulate matter. The average PM_{10} and $PM_{2.5}$ levels were found under NAAQS permissible limits during non-dust storm days at both the sites and hence didn't played any role in the posing health related issues in nearby residing population of Delhi.

3.2 Real-time levels of particulate matter during Dust Storm and Non Dust Storm.

The real-time data of PM_{10} and $PM_{2.5}$ are mentioned in Fig. 2 and Fig. 3 indicating their concentration during dust storm and non-dust storm days respectively. Fig 2 shows the real-time observation of PM_{10} and $PM_{2.5}$ during dust storm days at both the sites. Moreover, Fig.3 represents the real-time observation of PM_{10} and $PM_{2.5}$ during non-dust storm days at PB and AV sites. Both the Figs. compared the real-time observation of particulate concentration with the permissible limit of National Ambient Air Quality Standards (NAAQS) recommended by Central Pollution Control Board (CPCB, India). Fig. 2 and Fig. 3 shows hourly variations in the particulate matter concentration during dust storm and non-dust storm days at PB and AV sites. Fig.2A and 2B shows a time series of PM_{10} variations during dust storm days over PB and AV site, whereas Fig. 2C and Fig. 2D shows the time series of $PM_{2.5}$ during dust storm days at both the sites. On comparison of both the sites, the high level of the PM10 observed at AV site as compared to PB site was may be due to the difference in the nature of the sites. PB (Site 1) is a residential area with less number of light motor vehicles on roads, while AV (Site 2) site is characterised by the highly dense traffic intersection site, with large number of small, medium and large scale industries. The Figure 2B shows high levels of the PM_{10} during late night and early morning hours at AV site and it may be because AV location near the national highway possesses large volume of the heavy duty motor vehicles at late night and early morning (which is used for the transportation of goods and services from one city to another at night) resulting in high emission of particulate matter during that time period. The impact of emissions at night time due to heavy duty motor vehicles on highways is also shown in terms of elevated PM_{10} levels during late night and early morning at PB site. High levels of PM_{10} and $PM_{2.5}$ concentration during dust storm days represents the impact of the dust storm events and may pose health risk impacts on the population residing in selected locations of Delhi. Several studies reported that the $PM_{2.5}$ is very much related to the adverse health impacts after inhalation exposure due to their fine size (Brazel and Hsu, 1981; Chin et al., 2007; Baddock et al., 2013; de Longueville et al., 2013). Thus, they get deposited deep in to the lungs and create hindrance in the

transportation of gases across the cell membrane barrier (Fuzzi et al., 2015). It was also reported that these fine mode particles easily enters into the blood streams and deposited in to several organs of the body and responsible for several type of mortality especially cardiopulmonary and lung cancer-related mortality (Indoitu et al., 2012; Giannadaki et al., 2014; Goudie et al., 2014). This study also shows that both the sites had observed with high $PM_{2.5}$ levels which exceeded the permissible limits. Both the sites are reported with the high hourly $PM_{2.5}$ levels which may be responsible for several cause of mortality in the residing population of Delhi.

The hourly average PM_{10} and $PM_{2.5}$ levels during non-dust storm days are shown in the Fig.3, where Fig.3A and Fig.3B represents hourly PM10 concentration during non-dust storm days at PB and AV site respectively. Fig.3C and Fig.3D represents hourly $PM_{2.5}$ concentration during non-dust storm days at PB and AV site respectively. Interestingly, during non-dust storm days on hourly basis showed relatively higher PM_{10} and $PM_{2.5}$ levels at both the sites at some points during the peak traffic hours from 7:00 to 10:00 and 17:00 to 20:30 hrs where it crossed the NAAQS permissible limits. This may be due to traffic congestion at some period of time. Whereas, daily average concentrations of PM_{10} and $PM_{2.5}$ are under the permissible limits (Table 1). Thus the results found that particulate matter under permissible limits concentration played no role in air quality degradation and hence not responsible for any health risk due to their exposure. Overall, it was observed that the air quality of Delhi degraded due to the presence of the increasing levels of PM_{10} and $PM_{2.5}$ due to dust storm events at both the sites. Since, particulate matter (PM_{10} and $PM_{2.5}$) crossed their permissible limits hence it is very much connected to the adverse health impacts due to their exposure. Whereas the non-dust storm days shows relatively less concentration of particulate matters at both the sites and hence, responsible for their no contribution in air quality degradation in Delhi. Apart from the dust storm to non-dust storm comparison, a clear-cut difference in particulate matter also observed. This difference of particulate matter was may be due to the difference in the site because PB site is residential area with very less volume of traffic activity in nearby area. Whereas AV site was comparatively polluted than PB site as it was dominated by traffic and industrial activities which emitted large amount of particulate matter in the ambient atmosphere resulting air quality degradation.

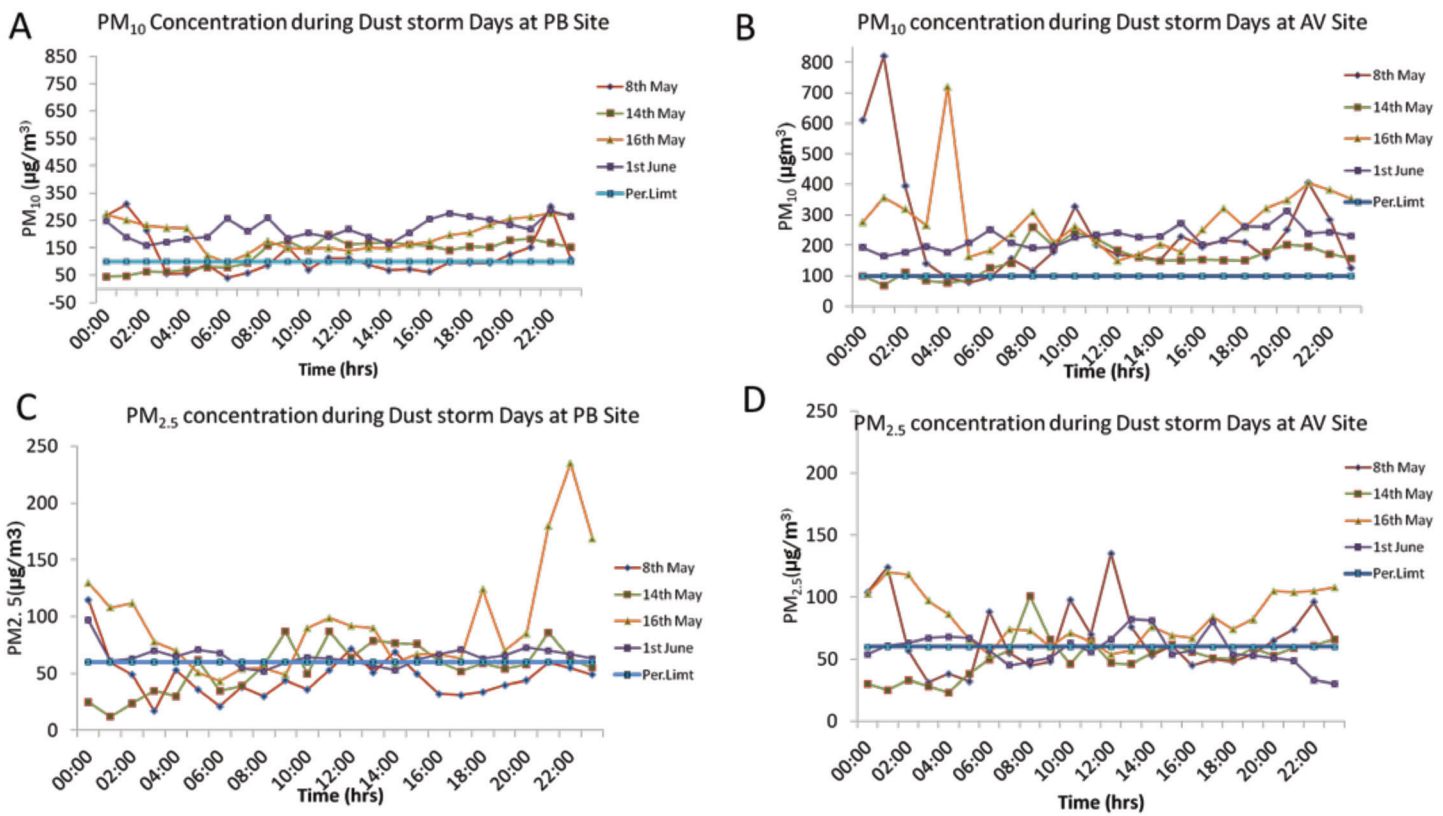


Figure 2: Variation of RH at 17.30 hrs, for the entire summer season in Rajkot during 2001-17

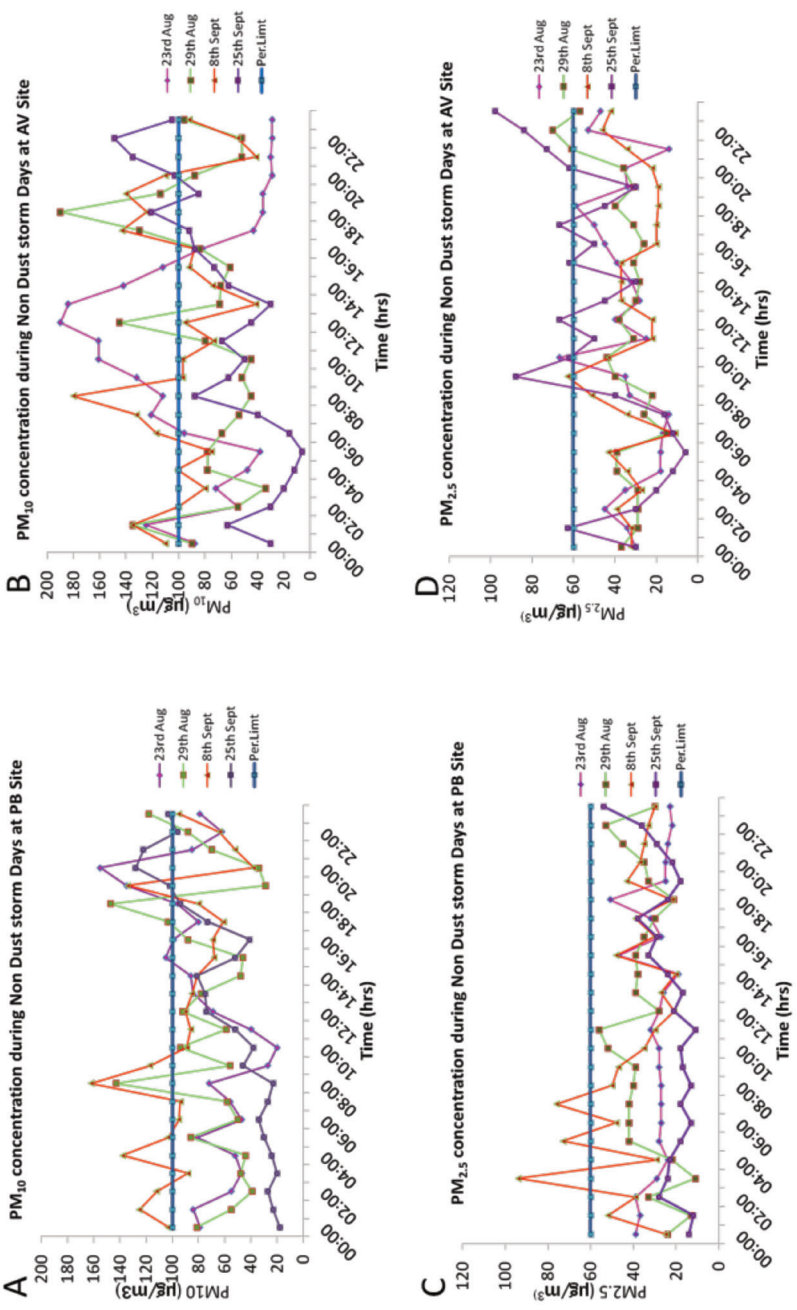


Figure 3. Particulate matter concentration during non-dust storm days at PB and AV sites

3.3 Health Risk Assessment during Dust Storm and Non Dust Storm.

The relative risk with respect to the PM_{10} and $PM_{2.5}$ have been calculated and mentioned in the Table 2. It represents the relative risk during DS and NDS

days at both the sites in Delhi. The calculated daily relative risk at both the sites mentioned in the Table 1S (supplementary material file). For the health impact assessment due to PM_{10} and $PM_{2.5}$ exposure, two health end points were identified and reported i.e. all-cause mortality due to PM10 exposure and cardiopulmonary mortality due to PM2.5 exposure (Ostro, B., 2004; Sonwani and Kulshrestha, 2016; Pope et al., 2002). The relative risk due to the PM10 exposure was found in the range of 1.09 to 1.17 with an average of 1.13 during dust storm period, while it ranges between 1.04 to 1.07 (average of 1.05) during non-dust storm period at PB site (Site 1). The observed RR values were found in the range of 1.12 to 1.25 with an average of 1.19 during dust storm days, while RR ranges between 1.04 to 1.07 with an average of 1.06 during non-dust storm days in AV site (Site 2). The overall average of RR10 for Delhi was found 1.16 during DS days and 1.05 for NDS. Thus the calculated relative risks with respect to the PM10 (RR10) for envisage all cause of mortality due to PM10 exposure. The relatively high RR10 values in the DS days as compared to the NDS represent the high mortality risk due to the presence of the dust storm. The relative risk for $PM_{2.5}$ exposure was calculated for cardiopulmonary mortality (CPM) and represented as RR2.5 CPM. The relative risk due to the $PM_{2.5}$ exposure was found in the range of 1.46 to 1.62 (average of 1.53) during DS period, while it ranges from 1.26 to 1.38 (average of 1.32) during NDS period at PB site. The observed $RR_{2.5}$ values were found in the range of 1.48 to 1.59 (average of 1.54) during dust storm days, while RR ranges from 1.34 to 1.41 (average of 1.38) during non-dust storm days in AV site. The overall average of RR2.5 for Delhi was found 1.54 during DS days and 1.35 for NDS. Thus the calculated relative risk with respect to the $PM_{2.5}$ ($RR_{2.5}$) represents the cardio pulmonary mortality due to $PM_{2.5}$ exposure. Several studies reported this mortality aspect considering high particulate level and found the RR value fall in the similar range and demanding to strengthen the strategies to control the particulate matter pollution in the ambient atmosphere (Pope et al., 2002; Evans et al., 2013; Sonwani and Kulshrestha, 2016).

Sites	#RR_{10}		*$RR_{2.5}$ CPM	
PB	DS	NDS	DS	NDS
Average	1.13	1.05	1.53	1.32
Max	1.17	1.07	1.62	1.38
Min	1.09	1.04	1.46	1.26
AV				
Average	1.19	1.06	1.54	1.38
Max	1.25	1.07	1.59	1.41
Min	1.12	1.04	1.48	1.34

*#RR_{10}: Relative Risk due to PM_{10} exposure, *$RR_{2.5}$ CPM: Relative Risk of Cardio Pulmonary Mortality due to $PM_{2.5}$ exposure*

Table 2. Level distribution of PM_{10} and $PM_{2.5}$ during dust storm days and non-dust storm days at selected sites in Delhi.

It is clearly observed from the table 2 and supplementary material Table 1S that dust storm period had highest RR values for all-cause of mortality and cardiopulmonary mortality as compared to the non-dust storm days in Delhi.

PB (DSD)	Date	#RR_{10}	*$RR_{2.5}$ CPM
	08-05-2018	1.09	1.46
	14-05-2018	1.10	1.49
	16-05-2018	1.16	1.62
	01-06-2018	1.17	1.54
AV (DSD)			
	08-05-2018	1.21	1.56
	14-05-2018	1.12	1.48
	16-05-2018	1.25	1.59
	01-06-2018	1.19	1.54
PB (NDSD)			
	23-08-2018	1.05	1.30
	29-08-2018	1.05	1.26
	08-09-2018	1.07	1.38
	25-09-2018	1.04	1.33
AV (NDSD)	23-08-2018	1.07	1.41
	29-08-2018	1.07	1.39
	08-09-2018	1.07	1.39
	25-09-2018	1.04	1.34

*#RR_{10}: Relative Risk due to PM_{10} exposure, *$RR_{2.5}$ CPM: Relative Risk of Cardio Pulmonary Mortality due to $PM_{2.5}$ exposure*

Table 1S. of Supplementary material: Average relative risks of all cause of mortality due to PM_{10} exposure and cardiopulmonary mortality due to $PM_{2.5}$ exposure during dust storm days and non-dust storm days

Therefore, overall it has been found that relative risk due to PM_{10} represented high mortality risk and relative risk due to $PM_{2.5}$ represented high cardio pulmonary mortality was found to be high during DS as compared to NDS. These results are also showing that mortality rate has been increasing in the year 2018 due to one of the hazardous air pollutant, particulate matter (PM_{10}

and $PM_{2.5}$) and produce deleterious effect on human health. It has also been found from earlier studies that air pollution related problems like respiratory diseases, cardio pulmonary diseases and chronic obstructive pulmonary disease (COPD) showed alarmingly high increase in mortality and disability-adjusted life-years (DALYs) in every state and some of the Union territories of India like Delhi from 1990 to 2016 and considered that one of the main cause of these diseases is particulate air pollution. Moreover, the contribution of COPD to total DALYs in India increased from 4.5% in 1990 to 6.4% in 2016. In particular, Delhi has shown alarmingly high COPD increase from 4.1% in 1990 to 5.6% in 2016 (Salvi et al., 2018). Hence, mortality due to air pollution particularly PM_{10} and $PM_{2.5}$ pollution has alarmingly increased in the last 20-30 years in Delhi as well as overall India.

4. CONCLUSION

The present study link dust storm events to the air quality degradation by comparing the non-dust storm days. This is the first study of its kind that relates the relative risk to the dust storm events especially in South Asian region. The study calculated the relative risk for the all cause of mortality for PM_{10} and cardiopulmonary mortality due to $PM_{2.5}$ exposure considering Delhi as a study area. The overall average of RR_{10} for Delhi was found to be 1.16 during DS days and 1.05 for NDS. Thus, the calculated relative risks with respect to the PM10 (RR_{10}) for envisage all cause of mortality due to PM_{10} exposure. The relatively high RR_{10} values in the DS days as compared to the NDS represent the high mortality risk due to the presence of the dust storm. The overall average of $RR_{2.5}$ for Delhi was found 1.54 during DS days and 1.35 for NDS. Thus the calculated relative risk with respect to the $PM_{2.5}$ ($RR_{2.5}$) represents the cardio pulmonary mortality due to $PM_{2.5}$ exposure. Thus, the present study suggest to strengthen the control measures to reduce PM_{10} and $PM_{2.5}$ levels in the city in order to reduce the health risk and mortality in eastern Delhi. Moreover, the health risk due to dust pollution may be minimized by planting certain tree species like Ficus bengalensis, Ficus religiosa, Mangifera indica, Terminalia arjuna and Morus alba which can be used for dust capturing due to their rough, large surface area and canopy structure as suggested in some of the previous studies. Further advanced research is going on to suggest plant species in Delhi which can withstand in Delhi's high dust pollution rate and may be recommended for landscape planning in Delhi in near future.

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Chapter 11

CITY HEAT AND HEALTH ACTION – A CASE OF CONVERGENCE AND LOCAL CAPACITY BUILDING

Vikas Desai, Anuj Ghanekar, Pradeep Umrigar and Ashish Naik

ABSTRACT

Realizing Heat wave as an ongoing climate and health challenge, Local Self Government& Urban Health and Climate Resilience Centre of Excellence (UHCRCE) developed local evidence based, the first coastal city plan in India, "Heat and Health Action Plan- Surat 2014" and updated annually. Surat experience demonstrated key lessons for urban resilience by activating the inherent potential of cities. Every city has its unique climate challenge and behavior for calamities like heat waves. Intra city variations need special attention in city specific action plans. Weather trends are notstatic. Pattern changes in severity, time duration and intra-city variation. City needs to regularly track the trends for evidence based action. Regular monitoring needs local Multi-stakeholder resource group formation. Team needs learners (Academia) and doers (Administrators), who know the city well. The group plans pre-summer review, analyze weather data and jointly do advocacy and act. Strong Convergence: Heat and Health action requires strong convergence between departments of LSG, academia, public-private actors, NGOs and citizens. Joint capacity building: Cross-learning workshops for all LSG of Gujarat, ("learners" and "doers") reached consensus that climate change and its health impact is a concern of all cities. Phase-wise cautious implementation of plan is necessary. All-cause mortality in Surat was more than direct heat induced mortality. Hence, institutional sensitization was prioritized along with community based interventions. Community engagement is crucial. Involvement of citizens, schools and academia is essential incorporating unique models like urban agriculture and micro-greening promotion, health dialogue forums and peer education processes.

Keywords: *Climate change, Disasters, Extreme Heat, Health Policy Surat City, Urban health.*

Vikas Desai
Technical Director - Urban Health & Climate Resilience Centre of Excellence, Surat, Gujarat, India

Anuj Ghanekar
Consultant - Urban Health & Climate Resilience Centre of Excellence, Surat, Gujarat, India
uhcrce.sms@gmail.com

Pradeep Umrigar
Medical Officer of Health- Surat Municipal Corporation, Gujarat, India

Ashish Naik
Deputy Commissioner Health and Hospital - Surat Municipal Corporation, Gujarat, India

1. INTRODUCTION

1.1 Urban Heat and Health- A Background

Climate change influences the social and environmental determinants of health- clean air, safe drinking water, nourishing food and secure shelter. According to WHO estimates, between 2030 and 2050, climate change is expected to cause approximately 250000 additional deaths per year, from diseases, heat stress and unhealthy lifestyle (WHO, 2014).

Cities in India are growing leaps and bounds. They are more likely to carry the burden of climate change induced diseases. Even within the city, communities from informal settlements suffer more because of deficit of risk reducing infrastructure and poor adaptation capacities. However, on the other side, cities are also the key players in climate and health resilience through actions like resilient infrastructure, information management systems and systematically adapted communities.

Variation in temperatures is one of the worrisome climate change and health impacts. The average temperature in India was "significantly above normal" in year 2018 as per the Statement of Climate on India released by the weather department (Indian Meteorological Department, 2019) A recent study, based on the temperature-mortality relationship predicts that 15 lakh Indians may die due to rise in heat by 2100. (Climate impact lab, 2019) When many of Indian cities are grappling with rising heat patterns, coastal cities experience discomfort in unique ways as a result of a combination of temperature and humidity measured as heat index.The deteriorating air quality and its contribution towards increasing the urban heat island effect is silently and gradually influencing the health of the vulnerable population. In this context, heat stress has been recognized as a biggest challenge by Government of India and several city governments.Rise in temperature also will lead to multi-dimensional impacts. For instance, the most important climate change impacts are negative impact on agriculture and food security, water availability, exacerbation of inequality and migration. (National Intelligence Council, 2009). Also, according to the latest report from NITI Aayog, India is experiencing the worst water crisis in its history and 21 Indian cities are expected to run out of groundwater by 2020. (National Institute for Transforming India, 2020).

Sufficient theoretical understanding about urban heat island effect is a part of climate and health knowledge pool, fig (1) is a self-explanatory info graphic released by Inside Climate News (2018).

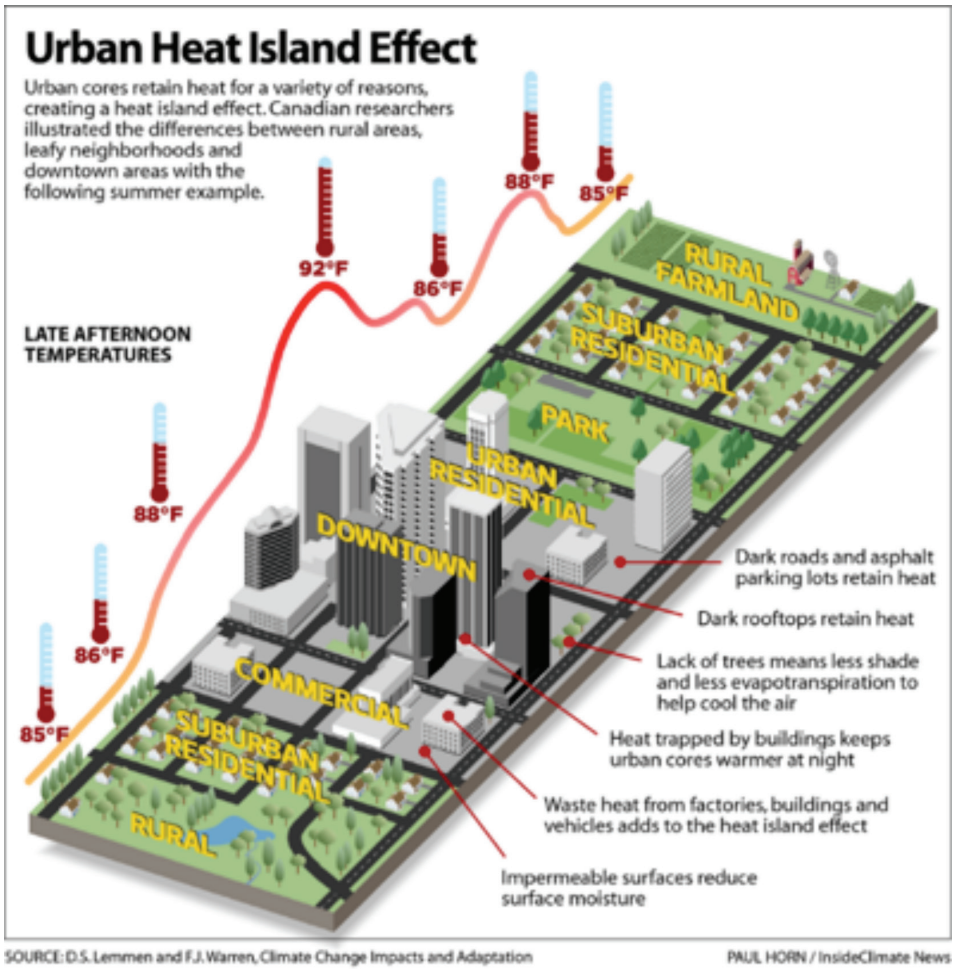


Figure 1 Reference Info-graphic for understanding urban heat island effect

The local unique policy responses, however, to combat rising heat stress and urban heat island effects are need of an hour. For instance, 'Heat wave and Health: Guidance on Warning System Development' explicitly suggests that "Heat waves are among the most dangerous of natural hazards, but rarely receive adequate attention" (World Meteorological Organization and World Health Organization, 2015).

Excessive heat is leading to public health disasters in Indian cities, for example, Odisha in 1998 faced an remarkable heat wave leading to the death of 2042 people (ODSMA, 2007), 2003 heat wave in Andhra Pradesh was cause of death of 1421 individuals (Jafri S., 2003). In Ahmadabad city of Gujarat, May 2010 heat wave caused 1344 all-cause mortality. (Azhar G S et al., 2010) All cause mortality is often considered asan indicatorof heat wave associated health challenge morbidity and mortality.

In India, Ahmedabad Heat Action Plan (HAP) was released in 2013 as a first local urban policy response and has been revised as a 6th published edition in 2019 (NRDC, 2019). This stirred a nationwide momentum to develop and implement the early warning systems and preparedness plans for extreme heat at the city, state, and national levels. For example, media reportage suggests that, in 2018, based on guidance provided by the central government, 13 states and over 30 cities have adopted/ are developing heat action plans.At the national level, the Indian Meteorological Department (IMD) and Indian Meteorological Society expanded forecasts to over 300 cities.

In this context, the present case study brings out the lessons learnt from heat and health action plan developed for coastal city Surat in India. This manuscript initially explains the contextual intricacies of Surat as a coastal city, further elaborates the policy response and draws essential action related lessons. Authors were involved in research, implementation and update activities of this action plan. The lessons drawn from empirical research studies conducted during the process, reviews conducted during and post implementation of the plan and administration experience.

1.2 Surat City Heat and Health Action – Contexts and Triggers

The coastal city Surat, Gujarat, India faces multiple climate and health stressors. Climate stressors majorly contribute in the 'exposure' function of climate vulnerability as described in IPCC framework (IPCC, 2007) and further determine the health outcomes. Socio-demographic stressors add into overall city vulnerability.

According to the World Bank Sustainable Development Network, Surat is among the world's most climate-change affected cities (Rockefeller Foundation, 100 Resilient Cities). It is located on the banks of the Tapti River, which flows into the Arabian Sea, around 16 kilometres from the city centre. Much of the city and its surroundings are less than 10 metres above mean sea level. The city has experienced river floods and since 1914 (25 floods in a century are on record), regular creek flooding and waterlogging in monsoons is common. Surat, being a coastal city, faces climate change impacts of increased temperature and humidity with urban heat island effects, and heat stresses due to high heat index. With prolonged summers, the water demands of the city are also nearing the allocated water resources. This increased demand for water and energy would need development of alternate sources (Dashora, Lalit, 2017). Geo physical and socio demographic environment of the Surat city is conducive to vector born infections. Health risks during and after floods include diarrhoea, malaria, plague, leptospirosis etc.

Surat is the fourth fastest growing city in the world (City Mayors Foundation 2017). Surat has a population of 44, 61,026 as per Census 2011. The city shows a 55.29% recent decadal growth rate and has a density of 13,680 persons per sq.km. during 1951 to 2011, the city area was extended by 326 sq. km, loosing buffer effect of neighbourhood village space, while population increased by

41, 00,000. Surat hosts a large migrant population, large majority of them have settled in slums and in formal settlements along the flood plain of the river since the 1950s (Santha et al., 2015). Around 37% of the total population reside in slums and slum like areas. Trade city Surat, a diamond and textile industry hub is an attraction for more and more industrialization and in-migration. Surat by various agencies has been timely estimated to be one of the world's fastest growing cities.

Number of brain storming interactions was held in Surat under Asian city climate change resilience Network project (2011-2016). Three broad categories of climate impact on health emerged through these interactions: a) impacts directly related to extreme weather/climate trend, b) impacts related to environmental changes in response to climate change, and c) impact arising from the consequences of climate-induced economic dislocation, environmental decline, and conflict. (Desai et al., 2016).

In case of heat stress, health impacts can be categorized as directly associated heat morbidities, overall effect on all cause morbidity and mortality and indirect impacts like changing patterns of vector borne diseases, vulnerability linked to non communicable diseases, effects on mental health etc.

Anecdotal evidences from perception mapping of citizens and institutions often indicate how temperature humidity is rising over period of years, how it varies within city and how citizens health is becoming more and more vulnerable to heat stress. (ACCCRN, 2016, UHCRC, 2016) Even there is growing understanding of factors contributing to heat stress. For example, industrial development is adding to heat stress or private transport burden in the city with highest number of per capita petrol vehicles in Gujarat contributing to carbon emission and heating.

Surat's context and triggers, thus, strongly recommended the need to explore scientific evidence and subsequent formation of heat and health action plan. The present case study highlights the process of piloting the process of city specific Heat and Health Action Plan–Surat (HHAP-S) and the key lessons learnt. The process was pioneering for coastal cities in India and endorses the need of differential approach for the coastal cities. The lessons are useful for policy makers as well as urban practitioners of India involved in building their knowledge and skills for heat stress preparedness.

2 SURAT HEAT AND HEALTH ACTION PLAN (2014) – A POLICY RESPONSE

Global targets focus on urban climate resilience planning as a priority. Sustainable Development Goal 11 ("make cities and human settlements inclusive, safe, resilient and sustainable") sets the target for cities to adopt and implement "integrated policies and planstowards inclusive resource efficiency, mitigation and adaptation to climate change, resilience to disasters, develop

and implement in line with the Sendai Framework for Disaster Risk Reduction 2015–2030, and promote a holistic disaster risk management at all levels." (World Resource Institute, 2017).

Placed in this context, Urban Health & Climate Resilience Centre (UHCRC) project at Surat emphasized on evidence-based advocacy to local self-government and demonstrated the unique models of capacity building of various stakeholders. UHCRC project (2013-2016) was an interdisciplinary research, training, advocacy and network project, the first of its kind, inclusive of health, under Asian City Climate Change Resilience Network of Rockefeller foundation executed by health department of Surat Municipal Corporation.

The project UHCRC has been institutionalized as UHCRCE (Urban Health and Climate Resilience Center of Excellence) as a registered non-profit trust settled by commissioner of SMC in 2017, members of trust board are representing public and private organisations. The geographical scope of UHCRC & UHCRCE is nationwide, primarily Surat city, and urban Gujarat.

As a response to the local need voiced out by city government, UHCRC initiated research on Heat and Health in coastal city Surat (2013), and prepared the evidence based "Heat and Health Action Plan-Surat (HHAP-S)" - the first coastal city plan in India. The plan was implemented as a phase-wise pilot process by health department of SMC.

UHCRC served as a nodal agency, an observatory for Surat heat and health action work. The presence of such an agency is essential for scientific evidence generation, systematic capacity building and pilot-testing of the innovation.

Fig. 2 Phased process of HHAP-S (2013-16) and later handed over to Surat Municipal Corporation for adaptation in their routine disaster action plan.

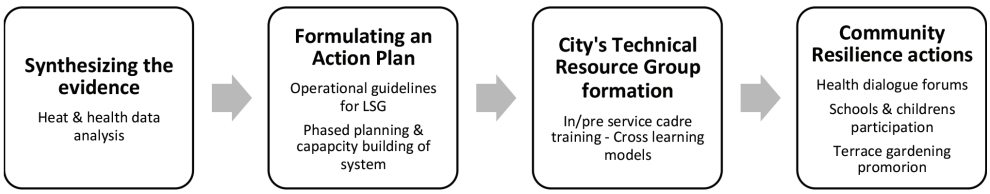


Figure 2 Surat Process for Heat & Health Action

3 KEY LESSONS LEARNT IN PROCESS (HHAP-S)

3.1 Synthesizing the evidence

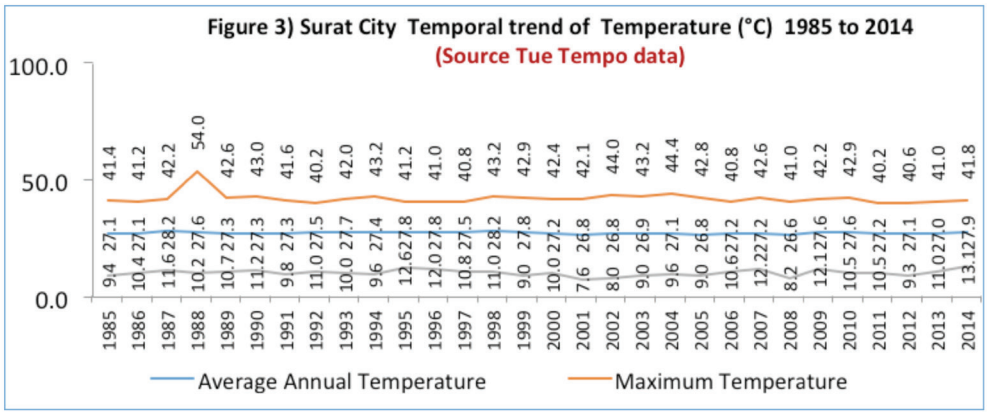
The seasons of Surat city are broadly divided into summer, winter and monsoon with fluctuation in temperature. Due to proximity to sea, it is predominately humid and hot and represents as sub-humid of tropical climate. Summer months (March, April, and May) are relatively hot with temperatures ranging from 37.78 to 44.44°C. The maximum humidity is around 80%.

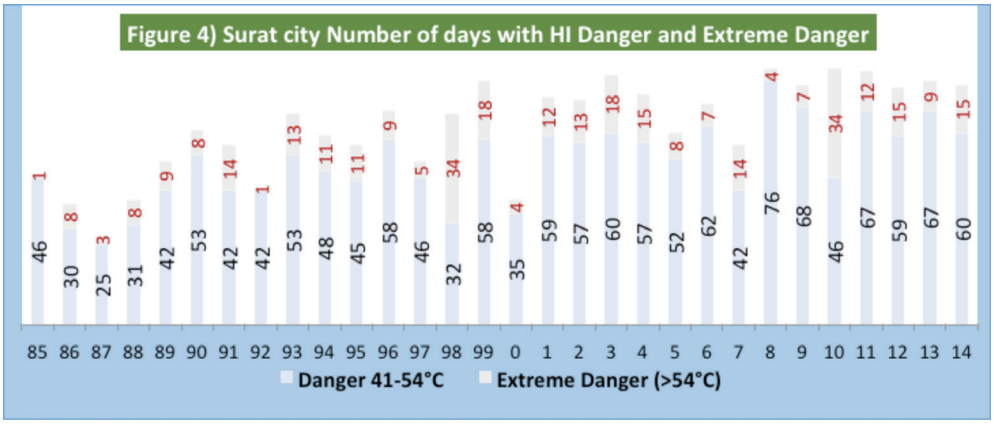
Coastal cities of India behave differently from climate change perspective. Climate and health monitoring becomes essential where city action plans can include data from national as well as local weather monitoring stations and relate it with health data. An observatory system must be in place to systematically analyze, interpret the data, to translate it into short noticed forecast systems and generate the evidence based interventions. In view of changing seasonality pattern, the observatory function becomes the requirement for an entire year and not only during summers. IMD forecast gives temperature data, however, coastal cities needs to focus on Heat Index measure which makes the forecast for coastal cities even more real for action.

The academic research conducted with retrospective and prospective city specific data synthesized the evidence justification of action plan for LSG. The following statistical data presented in this case study is previously published in scientific journals by UHCRC and cited here as a reference to "synthesizing the evidence" phase of HHAP-S.

Temperature and Humidity Variability for Surat (Desai et al, 2015)

When the summer (March to May) variability of temperature and humidity for Surat city was analyzed from1985 – 2014, more frequent maximum temperature spikes identified in the last decade (2005-2014) as compared to previous two decades (1985-1994 and 1995-2004) (Fig.3) Humidity increased from 54.9% to 60.4%. Maximum summer temperature increased to 1.6 degrees Celsius from 2011 to 2014. There were 37 hot days with the maximum temperature 40°C. Out of 425, heat risk days having HI more than 41°C were 384 (Fig. 4). Year 2010 had significantly higher mean summer temperature. This analysis of temperature and humidity indicates dangerous periods of extreme heat with more frequent maximum temperature spikes and rising humidity are more frequent feature of the city.





Effect of ambient heat onall-cause mortality (Desai et al, 2015)

Retrospective analysis of all-cause mortality data with temperature and humidity for the summer months (March–May) of 2001–12 was done. A total of 36,167 deaths in 961 summer days (2001–12) were analyzed. 11% increase in mortality on temperature crossing 40 degrees C was observed. Analysis of all-cause mortality and heat index, reveals 3 (9%) deaths per day during danger-level HI and 6 (18%) deaths per day during extreme danger level HI. The effect of extreme heat on mortality is at a peak on day-2 of the maximum temperature. The study concludes that the impact of ambient heat in the increase of all-cause mortality is clearly evident and HI is more relevant than maximum temperature (18% deaths/day versus 11% deaths/day) for coastal city.

Summer Temperature and Spatial Variability of all-Cause Mortality (Rathi et al, 2017).

Spatial (Administrative Zone wise within city) analysis of heat index and all-cause mortality trends within Surat revealed notable variation between zones south east, East and South show higher temperature than other four zones at same time, on same day. All-cause mortality at ≥ 40°C also shows rise of 61% for Southeast and 30% for East zones. Presence of spatial variation in all-cause mortality and high temperature further endorsed the higher public health vulnerability of South, South East and East zone in a study of UHCRCE (2015).

Opinion mapping of private practitioners of the city.

Interactions under HHAP-S, with practicing doctors of Surat city in private sector indicated that in last five years morbidities in summer have increased by 5-10%, Influence of heat morbidity to other common morbidities is by 20-30%, the chance of missing diagnosis as heat as underlying cause of morbidity is 25-50%. Exploration of health evidence of heat impact through existing health records like IDSP/ SMC surveillance / MCCD data did not document any heat morbidity or heat related death in last decade.

Box 1 Key lessons (1)

- Every city has its unique pattern of climate challenge and extreme weather behavior, like heat waves.
- Intra city variations in seashore city, special attention in action plan.
- As climate and weather trends are not static. Pattern changes in severity, lag time, diurnal variation and intra-city variation.
- City needs to observe and track the trends by regular monitoringfor evidence based action.
- There is a need for system like "climate and health monitoring observatory" in every city specialized in evidence generation.

3.2 Formulating an action plan.

Heat and Health Action Plan – Surat is a comprehensive plan and incorporates convergence between departments of LSG, academia, public-private actors, NGOs and citizens.



Figure- 5: Phase I pilot (20015-2016)

Role of H&H action Plan stakeholders:

Surat Municipal corporation- (A doer): Nodal department Health SMC, steering committee members are representatives of health, hospital, water supply, drainage, slum clearance, garden, urban community development and urban planning departments. Activities envisaged by different departments as per forecast is spelt out in the action plan.

Health and Medical care: Advocacy interactions were done with doctors and nurses of public and private system as well as medical college hospitals, using the information kits prepared, on case detection management and reporting SOPs. Case reporting format was finalized and circulated. Steps to improve heat comfort in general wards discussed and planned. Nursing cadre was oriented for ensuring hydration process of indoor cases.

Article on Surat heat and health analysis experience was released in city IMA newsletter. Joint seminar of all medical associations was organized.

UHCRC (A learner): Prepared and shared the action plan with the authority, provided technical support for meetings, trainings, advocacy and data process. Piloted community participation models like city technical resource group, community forum, children participation, urban agriculture. Analyzed post heat

season data for review. Planned and undertook research on hospital ward heat comfort and health, domestic heat comfort and intra domestic heat humidity and vector born disease.

Box 2 Key lessons (2)

- Regular monitoring needs city specific resource group formation. Team needs learners (Academia) and doers (Administrators), who know the city well. The group plans pre-summer review, analyze weather data and jointly act.
- Phase-wise cautious implementation of plans is necessary.
- Though there are no reports or experience of large number of hospital admissions or deaths due to serious heat related morbidity, all-cause mortality trend and Temperature trend was used for institutional sensitization.
- Strong Convergence: Heat and health action requires strong convergence between departments of LSG, academia, public-private actors, NGOs and citizens.

3.3 City's Technical Resource Group formations.

The focus on inter-sect oral convergence and cross leaning has become more prominent and extensive in governance over the last few decades. Urban health is a product of multiple factors like environment, nutrition, hygiene, access to health care etc., that influence each other significantly. Given its multifaceted nature, integrated approach is needed and inter-disciplinary mode of capacity building is advocated. In order to foster inter-sectoral convergence, unique set of "cross-learning" training courses were organized by UHCRC to form the local teams.

Administrators- Academia peer learning.

Faculties of the medical colleges and municipal corporations of seven cities of Gujarat participated in joint peer learning workshop to sensitize them for need for understanding heat and health analysis and to disseminate Surat city experience. These workshops provided an opportunity to health department of the corporations and faculties of medical colleges and other institutes to form city specific team to work together in the area of urban health and climate change. To leverage the potential of all stakeholders, it is crucial to build their capacity for effective co-management of urban problems through identification and implementation of local strategies. In all, 80 participants including medical

officers of the municipal corporations, faculty of 17 medical colleges of Gujarat actively participated in the workshops. City teams analyzed the data of their respective cities with the technical facilitation by UHCRC faculty.

Pre and post-test analysis revealed that the participants comprehended the relationship between climate change and urban health vulnerability of their city. They could figure out the challenges of resilience building and need for collaboration of experts from different realms in this regard.

The workshops encouraged participants to think about climate focused research. Different research agenda enlisted are, heat waves and morbidity, contributors of changing trend of temperature in their city, climate and mortality trend in the city, data sharing between municipal corporations and city hospitals, climate change and health of vulnerable population, seasonal trend of hospital admissions, asthma and air quality, spatial analysis of epidemics and heat index, climate and vector-borne diseases in the city.

Inter-departmental joint workshops within SMC

Joint cross learning workshop of different departments (health, urban planning, water supply, and urban community development) of SMC was organizedon July 2015 where 24 participants were oriented about Surat city heat and health analysis and need of strong and sustained convergence for heat and health action. Participants discussed role of their department and expectations from other departments and process and areas of convergence.

Participants expressed interest in building their skills for heat-health analysis to facilitate evidence based planning. They also suggested importance of such workshops for all cadres of functionaries.

Common platform for Future urban practitioners from different disciplines

With objective to sensitize future cadre of urban practitioners for climate and health and intersect oral convergence, future urban practitioners workshop was organized in august 2015 involving 19 young post graduate students from diverse backgrounds: social sciences, engineering, urban planning and public health from leading academic institutions of the city. This workshop was to disseminate UHCRC experience of climate and health studies in city, and to facilitate first-hand experience of multidisciplinary team approach for such study and action. Participants undertook small research exercise with their multidisciplinary team.

UHCRC considered this as an attempt to promote interest in heat and health research and value of multidisciplinary research in such subject.

Box 3 Key lessons (3)

Emerging environment of climate science and multidisciplinary, multi stakeholder focus in academic research, program planning and monitoring shall promote conducive environment for evidence based climate and urban health policy.

Joint peer learning workshop of administrators of Municipal corporations and academic researchers of medical colleges ("learners" and "doers"), Joint cross learning workshop of middle cadre officers of different departments of SMC and multi-disciplinary future urban practitioners workshop was instrumental to bring learners (academia) and doers (administrators) on one platform, who know about their city well, to think about climate and health priorities and supporting their city for policy, planning, programming and monitoring.

3.4 Community Resilience Actions.

Surat Alliance for Urban Agriculture and Resilience (SAUAR).

Terrace gardening is a proven cooling strategy for cities. Along with micro greening facilitating cooling and low carbon emission, terrace gardening ensures food security and safety for urban households. Alsoit is a potential livelihood strategy for urban poor. SAUAR is a pilot multi-stakeholder partnership project that promotes cooling through community training for terrace and kitchen gardening. SAUAR also fostered social media based (through What Sapp and e-mail communications) information and support system. During HHAP-S phase, 702 individuals were trained under SAUAR by Krishi vigyankendra. Follow up after a year confirmed that 553 of trained people adopted and sustained kitchen / terrace gardening SAUAR consortium pilot was facilitated by UHCRC and it included academic institutes, civil society organizations and individual experts from the city.

Heat and health dialogue forums (Surat Arogya Samvad).

Some of the UHCRC community resilience actions were documented by ACCCRN (2016). On one side Tin roof covers on terrace, mosaic tiles, green net covers are visible adaptations in the city. On other side community level group interactions reflected their concerns like Surat is heating up, it was never so hot, evenings are pleasant except in wall city and industrial zones, native village is more in comfort zone than Surat city, need to know about personal protection measures from heat, socio-economically challenged population also have access to message on mobile phone if heat forecast is released.

Traditional adaptive methods to combat heat in Surat were revealed including-

Cuisine

Diet is essential in fighting heat stress. Participants of dialogue forum enlisted number of food items- Fruits - sweet lime, orange, watermelon, grapes, tomatoes, Ice apple (Palm fruit), Sakartiti (Musk melon) raw sour mango; Salad items - raw onion, cucumber; Drinks -Chhash (buttermilk), lemon juice, Kairi no baflo, aam/imli/kokam panna, jaljeera, lemonade, coconut water, fresh fruit juices. Diet should contain maximum amount of water. Water should be drunk frequently and in more quantity, especially while going outside.

Clothing

Participants reported that dressing in loose and thin Indian cotton clothing helps. Use of scarf/caps /traditional pagdiand goggles, while going outside is essential. Areas prone to skin infections and heat health hazards should be covered. There should be planning of dressing in summers.

Practices

Intra-domestic comfort should be crated with use of khas made curtains, coolers, fans, air conditioning. Water can be sprinkled outside house in morning and evening to keep space cool. Surat's heat humidity combination encourages mosquito breeding. Mosquito repellents and nets can be used to avoid mosquito borne diseases. According to people, taking bath more than once in a day is also essential. The practice of spending time in parks and urban green spaces should be followed frequently in summer evenings. First aid knowledge for heat health hazards should be there with community members.

Participation of children and schools.

"Climate smart healthy Children"was a model promoted by UHCRC with 4 schools and 340 adolescents. The Peer Educators of a school imparting the knowledge, skills and attitudes of "healthy living action towards climate resilience" to that of another school with vigour and creativity. "Student to student" model creates more interest and dialogue amongst recipient peers. The model involved IEC sessions under heat and health action plan.



Community Resilience Activities under HHAP-S: 1. SAUAR trainings arranged in 2016 for Anganwadi workers by UHCRC, 2. IEC material developed by UHCRC in 2015-16, 3. Innovative communication through children – "U turn Surat" Public event 2016.

Box 4 Key lessons (4)

Community is the answer for climate and health resilience. Traditional knowledge and skills already exist within community to combat heat stress. This must be documented and communicated. Building new practices on traditionally known practices is a Right approach. Right approach at right time with right message and respect for community experience and revising healthy traditional practices promotes participation.Innovative models like SAUAR and children participation can be promoted.

4. CONCLUSION

To rise to the challenge of climate change in Surat UHCRC-E is facilitating a process to develop "Surat City Heat and health action plan" with the support of health department of Surat Municipal Corporation. A direct relationship exists between increased temperatures and increased mortality and morbidity caused by heat stress. UHCRC explorative study reveals that Heat-related illnesses and deaths in future can be largely preventable through better city specific planning, forming local resource group and convergence, developing heat/heat index forecasting system, strengthening heat morbidity monitoring and management system and helping people to avoid conditions making them vulnerable to heat and unique community resilience actions. Lessons from present paper can guide other Indian cities to process their Heat and health action plans.

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Chapter 12

DOES A HEAT WAVE DEFINITION SIGNIFY PUBLIC HEALTH CONCERN?

Jugal Kishore, Sanghamitra Pati, Pratap Kumar Jena, Debakanta Nayak and Parimala Mohanty

ABSTRACT

Upward changes in mean, maximum or minimum temperature in a given place and time, has been traditionally used to quantify heat wave. Heat wave is an extreme weather condition, and adversely affecting human health and its ecology. This has prompted several countries to adopt alert and warning mechanisms. Objectively defining the heat wave is very diverse, and complex. India and other countries issue an area specific heat wave warning notice by measuring changes in maximum surface temperature and heat index. However, lack of uniform definition makes it difficult to comprehend this global phenomenon from a public health intervention point of view. In this context we examined the definition which is more suitable for public health preparedness purposes. This study analyzed diverse heat wave definitions from literature and national weather forecasting systems and compared the public health significance of each definition to identify the most suitable scientific definition for Indian context. The realistic measures consider intensity, duration, frequency, humidity and/or spatial extent to characterize heat wave. All the existing heat wave definitions consider at least one form of temperature (daily max, min, or average) with a predefined threshold for certain duration. There is evidence of a dual threshold of increasing mortality risk. Rise in minimum temperature has more deleterious effect than rise in maximum temperature. Heat index that considers humidity has been proved to be more meaningful to describe the deleterious effect of heat wave. Machine learning based location specific dynamic threshold for minimum and maximum temperature with due consideration for humidity and linked morbidity and mortality would be more useful to characterize heat wave in Indian settings.

Keywords: *Heat wave, Rays, Infrared, Heat stroke, Extreme Heat, Hot temperature.*

Jugal Kishore : *Director Prof., Head, Department of Community Medicine, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi, India*

Sanghamitra Pati : *Director, Regional Medical Research Centre, ICMR, Bhubaneswar, India*

Pratap Kumar Jena✉ : *Associate Prof., KIIT School of Public Health, Bhubaneswar, India, drpratapjena@gmail.com*

Debakanta Nayak, *WHO Consultant (Neglected Tropical Disease)\, Bhubaneswar, India*

Parimala Mohanty : *Ph.D Scholar, Dept of Community Medicine, Institute of Medical Science, SOA University, Bhubaneswar, India*

1. INTRODUCTION

Earth orbits sun in a habitable zone. In other words, the earths' surface temperature is suitable for life (Khandelwal et al., 2018), which is influenced by multiple extrinsic and intrinsic factors such as solar activity, axial tilt of earth, orbit of earth, volcanic activity, blockade of radiation by earth's magnetic field, reflection of solar radiation by cloud and earth surface, trapping of energy by greenhouse gases in the atmosphere, hydrologic and carbon cycle, wind, etc. (McKay, 2014). Cosmic phenomenon such as changes in solar activity would take thousands of years and beyond human comprehension and control, hence we have been always obsessed with proximate and intrinsic factors such as man-made climate change (Patil & Deepa, 2007; Florides G, 2010). Greenhouse gases such as CO^2 helps in warming of surface and atmospheric temperature and without it earths' surface temperature could have been a subzero one and inhabitable for many living organisms (Darkwah, WK et al., 2018). But its increased presence in the atmosphere following industrialization and other man-made activities, has brought long term climatic changes, making the greenhouse gases as a necessary evil (Hess et al., 2018).The commonest manifestation of climate change is gradual global warming, which is measured by recording temperature at various sea levels (Perkins-Kirkpatrick & Gibson, 2017; Xu & Tong, 2017; Florides G, 2017). Increase in mean, maximum or minimum temperature in a geographical area at a given time has been traditionally used to define heat wave (Raei et al., 2018). Heat wave is an extreme weather condition or a dry natural hazard, adversely affecting human health (Xu & Tong, 2017) and ecology that has prompted several countries to adopt alert and warning mechanism (Lowe et al., 2011). Though it appears simple, objectively defining the heat wave is very diverse and complex (Liss et al., 2017). Heat wave will have immediate health consequences (Mukherjee & Mishra, 2018), but elite humans can adapt to the changes by staying indoor, air conditioning, etc., but other members of ecosystem including poor humans, plants, etc., will be completely exposed to heat wave with its consequences (Hess et al., 2018). India with agriculture dependent economy, and manual labour as the major source of economic activity; the reduced food production by plants linked to heat wave and human exposure to heat wave during work is a threat to resilience of the Indian society (Guleria & Gupta, 2018). As shown in Figure 1, India Meteorological Department (IMD) historical data (Diffenbaugh et al., 2017) suggest dramatic increase in number of warmer months (average monthly temperature above 30%) per year, from '4 to 6' during 1901-1910 to '7 to 8' during 2016-17.This change is going to affect all living organisms and ecosystems (Joseph et al., 2018).

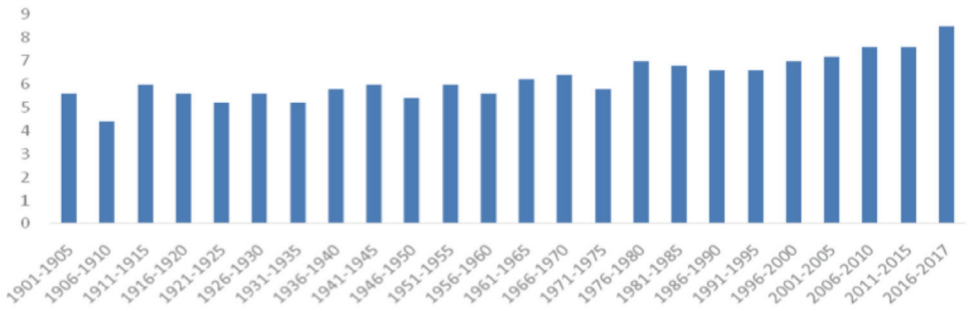


Figure 1: Average number of months per annum having max average temp above 30% in India during 1901-2017

Source: Indian Meteorological Department

The term "heat wave" (HW) appeared first in the scientific papers nine decades back to describe hot periods during 1930s in the United States (Marmor, 1978). Heat wave is complex hydro-climatic phenomenon associated with social, occupational and public health risks. Heat wave in India is characterized by a time-period of relatively high temperatures clearly in excess of the normal maximum temperature. March to June/July is the time period in India where people are exposed to heat wave. The extreme temperatures and resultant atmospheric conditions adversely affect people living in these regions as they cause physiological stress, sometimes resulting in death.

India and other countries issues an area specific heat wave warning notice by measuring changes in maximum surface temperature and heat index. However, lack of uniform definition (Perkins & Alexander, 2012) makes it difficult to comprehend this global phenomenon and for spatial comparison.

In this context, this case study analyzed diverse heat wave definitions from literature and national weather forecasting systems and compared the public health significance of each definitions to identify most suitable scientific definition for Indian public health context.

2. METHODS

This case study is based on secondary data from literature review. The National Library of Medicine (NLM) listed data bases including PubMed, google and yahoo search engines were searched to identify relevant articles and reports. The key words used to search the data base were heat wave, heat stroke, and hot temperature. The obtained information including abstracts were reviewed for the definition of heat wave to include relevant articles and reports. This study used advance search option, limiting the key word search for the titles of journal articles only. Articles or reports conveying the same definition of heat wave were further sorted out considering relevancy and more recent publications. The study also searched the heat wave definitions from professional associations

web portals and national weather portals. The shortlisted articles were further studied to find its relevancy to Indian context.

3. RESULTS & DISCUSSIONS

3.1. The Myriad Definitions

The Glossary of Meteorology formally defines a heat wave as "a period of abnormally and uncomfortably hot and usually humid weather". It is a widely accepted definition and includes heat and humidity as component construct, but it failed to measure the heat wave quantitatively. The World Meteorological Organization (WMO, 2018) has recommended definition of heat wave as 'A period of marked unusual hot weather over a region persisting for at least three consecutive days during the warm period of the year based on local climatological conditions, with thermal conditions recorded above given thresholds.'

The rise in average, minimum or maximum temperature of days or nights in a given area for a duration of one to five days by 5% (9°F) is considered to quantify the heat wave by World Health Organization (WHO). It had also considered increase in minimum daily temperature beyond 95th percentile for one to five days as a heat wave. This is simple and objectively measurable definition.

3.2 Definition of heat wave in different countries:

In the United States, the National Weather Service suggests early warning when the daytime heat index (including adjustment for humidity) reaches 40.6% and a night-time minimum temperature of 26.7°C persists for at least 48 hrs, and issues "excessive heat warnings" when the heat index (accounting also for humidity) exceeds 115°F (46.1%) for any period of time(Yang et al., 2019). Australia Bureau of Meteorology's issues color coded warning sign based on maximum temperature i.e. Deep purple and pink range to 54% and burnt orange to black for 40% to 48%. In the UK, regionally varying thresholds of maximum and minimum temperature must be exceeded for two consecutive days and an intervening night. The Netherlands Meteorological Bureau issues warnings when maximum temperatures are predicted to exceed 25% for five or more days, of which at least 3 days threaten temperatures beyond 30%.

Country	Component	Measurable Criteria
USA the National Weather Service (Barcena-Martin et al., 2019)	Location specific Heat index (including adjustment for humidity)	Suggests early warning when the daytime heat index (including adjustment for humidity) reaches 40.6% and a night-time minimum temperature of 26.7% persists for at least 48 hr.

UK Met Office (Barcena-Martin et al., 2019)	Location specific colour coded maximum and minimum temperature	Thresholds of maximum and minimum temperature must be exceeded for two consecutive days and an intervening night
Netherlands Meteorological Bureau (Barlow et al., 2019)	Location specific color coded maximum temperature	Issues warnings to health services when maximum temperatures are predicted to exceed 25% for at least five days of which at least three days threaten temperatures above 30%
Australia's Bureau of Meteorology's (UC Geography, n.d.)	Location specific colour coded Temperature based warning	Purple 50% or more burnt orange to black 40% to 48%
China Meteorological Administration (Wang, P. et al., 2017)	Location specific colour coded maximum temp	Yellow: Max temp. >35% per day x 2 days Amber: Max. Temp > 37% in 24 hours Red: Max. Temp > 40% in 24 hours
Korea Meteorological Administration (Park & Kim, 2018)	Location specific maximum Temperature	Considers the maximum temperature exceeding 33% for two straight days as a warning sign of heat wave.
India Meteorological Department (IMD) (Campbell et al., 2018; Ratnam et al., 2016)	Location specific colour coded Maximum Temperature based warning	≥ 40% for plains and ≥ 30% for hilly regions A green marks a typical day and red denotes extreme heat for the day and a heat wave persisting for more than six days. Yellow Alert: Hot Day Advisory 41.1% – 43% Orange Alert: Heat Alert Day 43.1% – 44.9% Red Alert: Extreme Heat Alert Day ≥ 45%

Table-1: Country specific heat wave definitions

3.3 Definition of heat wave in scientific literature (Table-2):

Perkins-Kirkpatrick et al., (2017) has defined heat wave as excessive heat for prolonged periods that severely affect human health, infrastructure and biophysical systems. Della-Martha et al. (2007) defined heat wave as the

number of consecutive three-day periods in summer that exceed the long-term daily 80th percentile of daily maximum temperature. While Srivastava et al., (2009) defined the event if the maximum temperature at a grid point is 3% or more than the normal temperature, consecutively for three days or more. Mishra et al., (2015) considered HW as periods during which the daily maximum temperature stayed above the empirical 99thpercentile consecutively for six or more days. Apart from temperature, large scale circulation has also been used to define HW, by Lee et al., (2016). Sharma & Majumdar (2017) defined as consecutive extreme hot days (3, 5 and 10 days) above different thresholds (85th, 90th and 95th percentile) of daily maximum temperature and suggested a Heat wave Magnitude Index daily (HWMId) that combines the magnitude and duration of heat wave.

Li et al., (2019) defined four distinct heat wave definitions based on different temperature metrics, including mean, maximum, and minimum temperatures. His model suggested maximum temperature-based heat wave definition is linked to mortality. Otu-Larbi et al (2019) considered both daily maximum and minimum air temperatures exceeding the corresponding climatologically 90thpercentile for three days or longer as heat wave.

In order to find a particular threshold for heat wave several studies have considered relative risk and/or odds ratios under different definitions related to intensity and /or duration of temperature. Earlier mostly deductive reasoning was used to make assumptions then seek validation using heat wave outcomes, none have investigated a tipping point where human health effects rapidly change, which should be closely related to the definition of a heat wave. (Park & Kim, 2018).

Source of Definition	Component	Measurable Criteria
World Health Organization (WHO, n.d.)	Average, minimum, or maximum daily temperatures	average maximum temperature by 5 °C (9 °F)"25, or "when minimum daily temperature exceeds 95th percentile /1-5days
Della-Marta et al.(2007)	Temperature	HW as the number of consecutive 3-day periods in summer that exceed the long-term daily 80th percentile of daily maximum temperature.
Srivastava et al., (2009)	Temperature	If the maximum temperature at a grid point is 3°C or more than the normal temperature, consecutively for 3 days or more.
Mishra et al. (2015)	Temperature	HW as periods during which the daily maximum temperature stayed above the empirical 99th-percentile consecutively for six or more days.

Tao & Zhang (2019)	Temperature, large scale circulation	Apart from temperature, large scale circulation has also been used to define HW
Joseph et al., (2018)	Temperature large scale circulation	Temperature and large-scale circulation has also been used to define HW
Li et al., (2019)	Maximum daily temperature	Tested four distinct heat wave definitions based on different temperature metrics, including mean, maximum, and minimum temperatures. HW4 defines heat waves as extreme temperatures lasting for one day or longer, but the remaining three definitions require extreme temperatures to continue for at least two days
Cecinati F et al., (2019)	Morbidity from tweets	A study concluded that social media based heat wave identification can complement climatic data and can be used to: (1) study heat wave impacts at large scales or in developing countries, where mortality data are difficult to obtain and uncertain, and (2) to track dangerous heat wave events in real time
Raei et al., (2018)	Excess heat factor (EHF) approach, and standardized heat index	Consider intensity, duration, frequency and spatial extent while characterizing heat wave. Excess heat factor (EHF) approach and standardized heat index (SHI) method.
Liss et al., (2017)	Daily maximum temperature	Daily maximum temperature ≥ 92.5th percentile with duration ≥3 days produced the best model fit.
Sharma & Mujumdar (2017)	Temperature, Heat wave Magnitude Index daily	Defined as consecutive extreme hot days (3, 5 and 10 days) above different thresholds (85th, 90th and 95th percentile) of daily maximum temperature. We estimate the Heat wave Magnitude Index daily (HWMId) which combines the magnitude and duration of heat waves
Machine learning technique (Park & Kim, 2018)	Temperature and Heat Index	Considers heat wave when average maximum temperature for two consecutive days was greater than 32.58°C and a heat index higher than 79.64 which is linked to dramatic increase in morbidity.

Table-2: Heat wave definition in various scientific literatures

3.4 Public Health Significance of Heat waves:

In India, more than 2300 deaths happened due to heat wave in 2015 (Ratnam et al., 2016), mostly in Andhra Pradesh, Telangana, Punjab, Odisha and Bihar. In sync with rise in global temperature in 2016, India had witnessed one of the severe heat wave conditions during April 2016 (Guleria & Gupta, 2018).

Heat wave induced health effect is closely linked to rise in temperatures beyond a certain threshold and moderated by the degree of exposure, and individual's capacity to adapt to the situation (Patil & Deepa, 2007; Azhar et al., 2014; Dutta et al., 2020). Therefore, the young, the elderly, the ill, the workers (traffic police, vendors, laborers) etc., are more vulnerable. Mortality increases with rise in temperature. Such dry heat risks are exacerbated with increase in humidity. Dehydration, cramps, exhaustion and heatstroke are common health manifestations of heat wave. Excess deaths were seen during the European heat wave of 2003 in France, Germany, Italy, Spain, etc. (Emergency Events Database, 2015). Excess and significant deaths have been reported from Russia, Australia, Japan, Mexico and the USA in recent years.

As a large number of the population is engaged in outdoor work in India, heat is an occupational hazard. Health impacts due to heat waves are more severe in urban areas where residents get exposed to higher and nocturnally sustained temperatures compared to surrounding areas due to a phenomenon called the Urban Heat Island (UHI) effect (Shastri et al., 2017). UHI is caused by a combination of various factors like more heat absorbing surfaces (rooftops, buildings and paved surfaces), the trapping of hot air between buildings, limited tree cover and other heat trapping and heat inducing factors such as fuel combustion and air conditioning. Factors such as pollution, climate change, sprawl, lifestyle and urban design increase UHI intensity. Higher urban temperatures mean: Greater energy use during the summer, increased air pollution and greenhouse gas emissions, negative effects on human health and comfort.

The heat induced discomfort is influenced by air temperature, humidity, wind, direct sunshine, clothing, occupation, accommodation, pre-existing illness, fitness, age and ability of body to adapt (Mukherjee & Mishra, 2018). It reminds us to do vulnerability assessment considering all these factors for mapping vulnerable population and designing appropriate high risk as well as population-based strategy. Uncertainty in pre-monsoon shower and El Niño makes the maximum temperature rise.

The WHO report lists at least fifteen different exposure metrics used to categorize heat exposure. Apart from temperature threshold, location and calendar day specific temperature threshold, now a days excess heat factor and standardized heat index are being used to characterize the heat wave.

3.5 Linking Heat wave Definition with Health Implications

Though the health impact of heat wave was studied in many parts of the world, relatively little information is available from the South Asia region. Defining heat wave at various threshold levels based on morbidity and mortality is critical for public health policy, interventions and to develop early warning systems.

There is a strong and positive association between daily maximum temperature and mortality for the hot months like April ($r=0.69$, $p<0.001$), May ($r=0.77$, $p<0.001$), and June ($r=0.39$, $p<0.05$). The India Meteorological Department (IMD) definitions may underestimate the impacts of extreme heat on health because under the current systems IMD threshold does not formally account for public health effects of extreme heat. The IMD definition does not help in making a grade's public health response to heat wave. Since the IMD definition focuses only on maximum day temperature, it may not correlate well with public health outcomes more directly. (Azhar GS et al., 2014).

Based on a study from eastern India, there is a dual thresholds of mortality risk at Tmax of >36.2% and 40.5% with 2% increase in mortality risk for every 1-degree Celsius rise in temperature above 36.2% and even more for temperature above 40.5%. Deleterious effect was maximum when median Tmin was higher i.e. (> 25.6%) (Dutta et al., 2020).

3.6 Summary of Components of Heat wave Definitions and Public Health Significance

The realistic measures consider intensity, duration, frequency, humidity and/or spatial extent to characterize heat wave. All the existing heat wave definitions consider at least one form of temperature (daily max, min, or average) with a predefined threshold for certain duration. The identification of thresholds is of utmost importance and must include the effect of heat on humans and other living organisms and require a finer balance as it can change the impact considerably. (Sharma & Mujumdar, 2017).

Social media data mining can be useful to complement climatic data for assessing the impact of heat wave on mortality on real time particularly where data is limited.(Joseph et al., 2018) Machine learning approaches to link temperature change and morbidity can be helpful in redefining the contextual threshold. (Li et al., 2019).

The World Health Organization(WHO) recognizes the overall health impacts of a changing climate as overwhelmingly negative, with regions exhibiting the poorest health infrastructure being the least able to adapt, prepare and respond to the variety of increased health risks likely in a changing climate (Campbell et al., 2018).

4. CONCLUSION

Studies measuring specific and all cause mortality due to change in minimum, maximum, average temperature and humidity need to be carried out for each IMD station to make the heat wave definition more significant for public health action purposes. Instead of a fixed reference period, a moving reference period for maximum and minimum temperature will be more useful. We further propose defining a HW by analysis of daily maximum temperature and minimum temperature, because minimum temperature provides a more accurate assessment of thermal discomfort. Current IMD definition needs to be dynamic and sensitive to the public health needs of our population. Inclusion of location specific minimum temperature threshold, factoring into humidity, inclusion of machine learning based linkage with morbidity and mortality in the existing is the need of the hour.

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Chapter 13

INDIA'S HEAT ACTION PLAN: A SUCCESSFUL PUBLIC HEALTH POLICY RESPONSE TO EXTREME HEAT EVENTS

Mahaveer Jain Golechha, Priyanka Shah, Sujata Saunik and Dileep Mavalankar

ABSTRACT

Human health has always been influenced by climate and weather. The world is severely affected with climate variability and change, and threatening to undermine progress towards human development if substantive action is not taken.There is global consensus that human activity in the last 50 years has altered the natural eco and climate system. Climate change is now widely accepted as a result of Greenhouse Gas (GHG) accumulation in the atmosphere.It is also reported that current trends in energy usage, production and population growth would result in continued and more extreme heat events.Excessive heat can disrupt human thermoregulatory mechanism, resulting in adverse effects such as heat exhaustion and heat stroke. Heat and radiation from the sun can cause a range of biological effects such as lethargy, dizziness, headaches,dehydration, heat stress, heat stroke, and even death. Adequate public health policy response to temperature-related impacts of climate change involve a sound risk management process, robust early warning system, adequate community awareness strategy and inter agency coordination strategies.Ahmedabad in the Indian state of Gujarat is an example of a smart city in a low-or middle-income setting that mainstreams heat risks and climate adaptation into policies through its South Asia's first Heat Action Plan. The Indian Institute of Public Health-Gandhinagar (IIPHG) has led the threshold based heat action plans in collaboration with other partners including Ahmedabad city government, Natural Resources Defense Council (NRDC)-USA, Indian Meteorological Department (IMD), Government of India, University of Washington and other stakeholders. Ahmedabad low cost Heat Action plan has been proven highly impactful in preventing and controlling morbidity and mortality due to heat related illnesses.

Keywords: *Heat Action Plan, IIPH-Gandhinagar, Extreme Heat Events, Public Policy, Climate Change, Public Health, Early Warning System, India, Environment Health.*

Mahaveer Jain Golechha✉
Associate Professor and Project Lead-Climate Change and Health, Centre of Excellence for Climate Change (Heat Health), Indian Institute of Public Health-Gandhinagar, Gujarat, India, mahaveeraiims@yahoo.co.in
Priyanka Shah
Centre of Excellence for Climate Change (Heat Health), Indian Institute of Public Health-Gandhinagar, Gujarat, India
Sujata Saunik
Skill Development and Entrepreneurship Department, Government of Maharashtra, Mumbai, Maharashtra, India
Dileep Mavalankar
Centre of Excellence for Climate Change (Heat Health), Indian Institute of Public Health-Gandhinagar, Gujarat, India

1. INTRODUCTION

The extreme heat events are becoming more intense, longer-lasting, and more frequent, posing a new global challenge to health sectors worldwide. These threats are of particular interest in low-middle income economies with limited public health resources and a growing urban population (Geirinhas et al., 2020).

Climate change has brought changes in temperature and humidity, affecting living and working conditions. An understanding about effects of global temperature changes on human health is required to inform the continued implementation of the Paris Climate Agreement and to increase global ambitions for greater cuts in emissions (Andrews et al., 2020). The diverse, widespread, long-term and inequitable distribution of health risks due to climate change makes it a truly global health challenge.

Climate change has also posed challenge against control of infectious diseases. Many of the major killers are highly climate sensitive, including cholera and the diarrhoeal diseases, as well as vector borne diseases including malaria, dengue and other infections (WHO, 2009). Evidence of increasing the frequency and length of extreme temperature events comes from the study of long-term climate records (Fischer and Schar, 2010). Changes in temperature-related health outcomes over time could provide valuable insight into whether populations have more recently adapted to hot temperatures.

Heatwaves can have a significant impact on the health of the population, including increased mortality (Guaet al., 2017) and morbidity (Olives et al., 2014). Some have been linked with large numbers of all-cause and cause-specific deaths in historic heatwaves, especially in France (Vandentorrenet al., 2003), Germany (Bacciniet al., 2008), Chicago (Naughton et al., 2002) and California (Knowlton et al., 2009). Every year, heatwaves claim the lives of infants, older people, and vulnerable population. Anderson et al (2010) analyzed heat waves in 43 U.S. cities and heat wave mortality risk increased 2.49% for every 1°F increase in heat wave intensity and 0.38% for every 1-day increase in heat wave duration (Anderson and Bell, 2011). Knowlton et al (2008) reported that the 2006 heat wave had a substantial effect on morbidity in California and observed significant increase in relative risks for hospitalizations due to heat-related illnesses (RR = 10.15; 95% CI, 7.79–13.43), acute renal failure, electrolyte imbalance, and nephritis (Knowlton et al., 2009). India's historically hot summers are being intensified by climate change, with deadly consequences. The India Meteorological Department (IMD) has predicted that heatwave conditions are likely to be severe in 2020 (NDMA, 2019). In Churu, Rajasthan, the maximum temperatures were up to 50.8° C (123.4° F) recorded last year (IMD, 2019). In previous year, the heatwave has been classified as 32 days, making it the second longest ever recorded (Carleton et al., 2019).

Estimates of the mortality-temperature relationship are used to generate projections of future climate change impacts on mortality rates across the globe. High emissions result in a significant rise in excess deaths due to Indian temperature. As per WHO (2014) report the global estimate for increases in heat-related deaths (annual estimate) is 92,207 (64,458–12,1464) additional deaths in 2030 and 255486 (19,1816–36,4002) additional deaths in 2050 (assuming no adaptation) (WHO, 2014).

2. HEAT WAVES IN INDIA

In India heat -waves typically occur between March to June, and in some cases even extend till July. The Indian subcontinent's heat waves have catastrophic health consequences and also termed as a "silent disaster". There is a direct link between higher temperatures and increased mortality and morbidity due to heat stress. Significant increases in global and regional surface air temperatures have been observed during last century (Jones and Moberg; IPCC, 2014). The global average combined surface temperature of land and sea indicates a cumulative warming trend of 0.85° C between 1880 and 2012 (IPCC, 2014). India's temperatures also displayed a significant warming trend. The Indian Meteorological Department's annual climate report on India (IMD) shows that the country's average annual land surface air temperature has risen at a rate of 0.66° C per 100 years over the past 117 years, with a significant increase in the maximum temperature trend of 1.06 ° C/100 years (IMD, 2018).

Recent research studies suggest, that if global warming continues, 360 million people will be exposed to extreme heat in 142 Indian cities by 2050. Furthermore, 215 million poor urban residents living in slums in more than 490 cities would face growing risks to the environment (Down to Earth, 2018).

As per IMD, in India, heat waves are described when the actual maximum temperature of a station reaches a certain threshold and is above the normal value of temperature by a certain magnitude.Heat wave is regarded if a station's peak temperature for Plains is at least 40°C, 37°C in coastal areas and 30°C for Hilly regions. Once these thresholds are reached, it is called Heat Wave (HW) when actual maximum temperature ≥45°C; and Severe Heat Wave (SHW) when actual maximum temperature ≥47°C, irrespective of deviation from normal (NDMA, 2019).

The Lancet Countdown report on health and climate change, mentioned that average temperatures in India are projected to rise alarmingly. Between 1901 and 2007, India's mean temperature increased by more than 0.5 degree Celsius. Overall, India lost nearly 75,000 million hours of labor in 2017, relative to about 43,000 million hours in 2000, an increase of over 30,000 million hours over two decades (Watts et al., 2019).

Mazdiyasni et al, reported that even moderate increases in mean temperatures may cause great increases in heat-related mortality and therefore, efforts of governments and international organizations for building up the resilience of these vulnerable regions to more severe heat waves are urgently required (Mazdiyasni et al., 2017).

Governments and communities need to prepare systematically and proactively to respond and adapt to climate hazards. Combating heat waves and climate change is a significant social challenge and will involve both fast carbon emission mitigation and widespread implementation of urban climate adaptation policies.

Relative Humidity %	Temperature °C																
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
40	27	28	29	30	31	32	34	35	37	39	41	43	46	48	51	54	57
45	27	28	29	30	32	33	35	37	39	41	43	46	49	51	54	57	
50	27	28	30	31	33	35	36	38	41	43	46	49	52	55	58		
55	28	29	30	32	34	36	38	40	43	46	48	52	54	58			
60	28	29	31	33	35	37	40	42	45	48	51	55	59				
65	28	30	32	34	36	39	41	44	48	51	55	59					
70	29	31	33	35	38	40	43	47	50	54	58						
75	29	31	34	36	39	42	46	49	53	58							
80	30	32	35	38	41	44	48	52	57								
85	30	33	36	39	43	47	51	55									
90	31	34	37	41	45	49	54										
95	31	35	38	42	47	51	57										
100	32	36	40	44	49	56											

Caution | Extreme Caution | Danger | Extreme Danger

Source: Calculated °F to °C from NOAA's National Weather Service.

Figure 1:Temperature/ Humidity Index

3. HEAT WAVES SCENARIO IN AHMEDABAD

In India, heat wave caused 25,716 deaths from 1992 to 2016 across various states. State governments reported 2,040 deaths in 2015 and 1,111 deaths in 2016 (NDMA, 2017). The vulnerable populations are significantly affected due to heat waves on account of gaps in health services, housing and basic amenities. Heat wave also caused the death of wildlife, birds, poultry, etc. across the country. Moreover, Indian cities are vulnerable due to the urban heat island effect (Yang et al., 2016). For example, urban sprawl adds more built up areas generating heat emissions, and increasing impermeable surfaces and requiring longer travel distances; the latter, in turn, lead to more vehicle trips as well as air pollution. The substantial attributable anthropogenic component may raise temperatures by 1-2°C and reinforce positive feedback loops via added air conditioning (Basu, 2009).

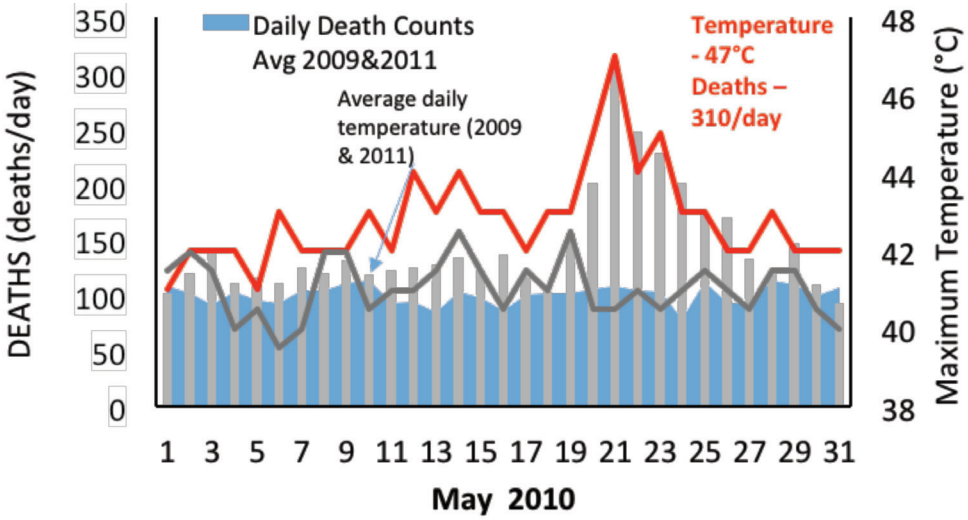


Figure 2. Daily Temperature and all-cause mortality correlation graph

In the city of Ahmedabad, located in the hot and dry north-western region of India. The year 2010 was one such intense year for the city, as the temperature soared beyond 46°C. Our study has reported that in the city of Ahmedabad additional 1344 deaths were in the month of May as compared to the year before and after (Figure 2). On the peak day of 2010, the all-cause mortality grew nearly three times. This is the first time that anybody in tropical countries has reported such a gross rise in mortality during the heat wave. Except for the heat wave, there was no obvious reason for this large rise in mortality (Azhar et al., 2014).

To address this public health emergency, a coalition of academic, health and environmental groups, led by the Natural Resources Defense Council (NRDC), Climate and Development Knowledge Network (CDKN), and the Indian Institute of Public Health Gandhinagar (IIPHG), worked together with the Ahmedabad Municipal Corporation (AMC) (City Administration) to develop and implement scientific Heat Action Plan (HAP) for management and prevention of heat related illnesses in the city of Ahmedabad, through activities including an early warning system and heat preparedness plan (Knowlton et al., 2014). The HAP was based on learning from western experiences in managing heat related mortality and morbidity and also local situations (Kothawale et al., 2010). Ahmedabad Heat Action plan has proven highly impactful in preventing and controlling morbidity and mortality due to heat related illnesses in the city.

4. HEAT ACTION PLAN (HAP)

The HAP has been designed as apublic health policy mechanism that would identify heat emergency levels for the city and explain activities and standard protocols for various line department of the city administration. The HAP

has been developed to incorporate best practices from various countries, strategies and a robust community outreach campaign (Knowlton et al., 2014). Temperature thresholds trigger the heat alerts of the HAP, with flexibility in the source of temperature forecast data along with four different color signalscorresponding to different levels of heat-health alerts and temperature thresholds, ranging from "no alert" to "extreme heat alert day. Identification of most vulnerable to extreme heat, including their places of residence and work andrecognition and prioritization policies and programs to address current and projected future health risk were incorporated.

Alert Category	Alert Name	Temperature Threshold (°C)
RED ALERT	Extreme Heat Alert Day	≥ 45.5°C
ORANGE ALERT	Heat Alert Day	43.7°C – 45.4°C
YELLOW ALERT	Hot Day Advisory	42.1°C- 43.6°C
WHITE	No Alert	≤42°C

Figure 3: Early warning system

4.1 Why Heat Action Plan (HAP) is important- Rationale

India is a rapidly developing country wherein many climate-sensitive illnesses are also rising. Temperatures are highest in summer (March-May), averaging between 30-35°C in summer. Daily maximum temperature may reach to 40°C and exceed up to 48°C in some north and north-west regions. The problem is further going to be magnified with ongoing climate change. In Ahmedabad, there were 315 deaths due to all causes during the peak heat day of the 2010 heat wave, compared to about 100 deaths during that year's normal summer day. This is a rise in daily mortality of 300 percent (Azhar et al., 2014). Nonetheless, the death figure is likely to be much higher, as heat-related illnesses are often inaccurately recorded and rural statistics are difficult to obtain. Vegetable vendors, car repair mechanics, cab drivers, construction workers, police, roadside kiosk operators and mostly poorer sections of society have to work in extreme heat to reach their ends and are highly vulnerable to the adverse effects of heat waves such as dehydration, heat and sunstrokes. As mentioned about critical situation during 2010 summer months in Ahmedabad brought government and non-government agencies to look for some effective measures to combat against heat illness. Due to increase in extreme heat events and heat related illnesses, there was an urgent need to study the temperature mortality correlation, developing local threshold and devising HAP to prevent and manage heat related morbidity and mortality. In response to the same Heat Action Plan (HAP) was implemented in 2013.

Adaptation is a crucial response technique in these circumstances to reduce possible deaths and other adverse health effects of heat waves.The heat action plan is comprehensive and involve early warning system used during heat waves. The HAP is cost effective, affordable and easy to implement and sensible to create similar heat preparedness plans across Indian cities and states. It is more realistic to calculate the overall ability of the Heat Action Plan to forecast heat waves effectively, educate and alert the public and inform actions or save lives using a scientific quantitative method.

4.2 Standard Operating Protocol (Ahmedabad Heat Action Plan, 2019).

The HAP is implemented through a standard operating protocol. In which, roles and responsibilities of various department such as department of health and family welfare, department of education, district and block administration, public health engineering department can act as a support agency and providing action, sharing of data, triggers of activation, mapping of vulnerable populations and analysis of extreme heat wave impact. Precise and sound knowledge from various mentioned departments required for the managements of heat wave in Ahmedabad.

Key strategies of HAP

- Create early warning system and inter-agency emergency response plan.
- Arrangements for public awareness and community outreach.
- Capacity building of health care professionals.
- Health system capacity building.
- Collaboration with non-governmental and civil society.
- Assessing the impact of heat Figure 4: Heat Action Plan components.

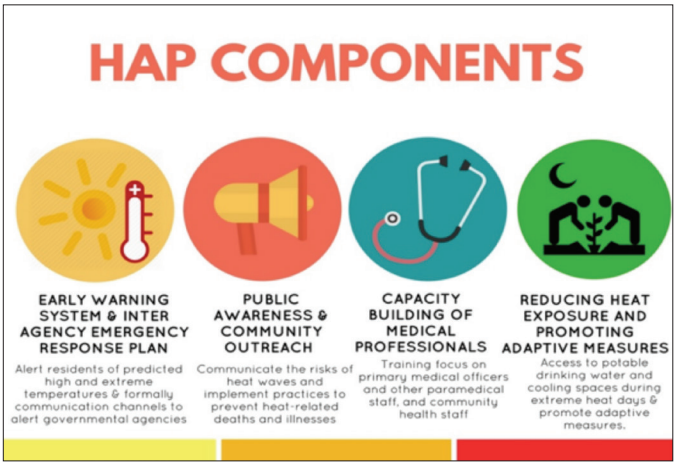


Figure 4: Heat Action Plan components

One of the fundamental strategies of HAP is mass public awareness and community awareness. The IIPH-Gandhinagar has developed several Information, Education and Communication posters for awareness about identifying symptoms, prevention and managing heat related illnesses. As heat related illnesses are avoidable conditions, therefore, public awareness is pivotal (Figure 5).

The capacity building of health care workers and other stakeholder from line department is also essential for effective implementation of HAP. The effective and efficient implementation of heat action plan requires coordination between various line departments-health, education, water, electricity, garden, civil engineering, transportation, women and child development and fire. Therefore, capacity building of officials from line department is very essential. The IIPH-Gandhinagar has conductedseveral workshops for training, sensitization and capacity building of stakeholder from various departments (Figure 6).



Figure 5- IEC pamphlet for public awareness



Figure 6: Capacity Building and sensitization workshop at Nagpur Municipal Corporation

There are five reasons why the Ahmedabad Heat Action Plan works and saves lives and why it can be role action plan for low middle income countries (Ahmedabad Heat Action Plan, 2019):

- Simplicity: The Ahmedabad Heat Action Plan uses a simple, color-coded, early warning "heat alert" system that alerts residents and city offices of predicted high and extreme temperatures.
- Partnership: The partnership between HAP development agencies, implementing agencies (city administration and health system), and IMD for heat alerts is the base of the plan. This coordination lead Ahmedabad Municipal Corporation (AMC) to deploy Nodal officer and create formal communication channels to alert governmental agencies, the Met Centre, health officials and hospitals, emergency responders, local community groups and media outlets of forecasted extreme temperatures.
- Communication: Direct communication-focused on behavior change-is at the heart of saving lives through the heat action plan. Building public awareness and community outreach is vital to communicating the risks of heat waves and implementing practices to prevent heat-related deaths and illnesses. Ahmedabad HAP used print, electric and social media to release heat alerts.
- Innovation: An early warning system for extreme heat events to protect residents of Ahmedabad was first of its kind.
- Leadership: Strong local government leadership enables the highly effective implementation of the heat action plan that has proven effective in decreasing mortality by as much as 25 percent in the Ahmedabad city.

4.3 Impact of the Heat Action Plan (HAP)

IIPH-Gandhinagar and other supporting agencies implemented HAP in the year 2013. The plan piloted an early warning system and interagency disaster risk education plans to increase the flexibility of vulnerable communities in Ahmedabad. This plan provides a framework for the emulation and protection of other Indian cities from extreme heat. A preliminary health outcome evaluation analysis suggests there was at least a 25% decrease in May's excess all-cause mortality in the two years since the HAP was launched (Hess et al., 2018). In addition to providing early warnings and interventions when heat waves strike, building awareness of and training medical workers, municipal agencies and vulnerable communities for extreme heat threats to health may have already saved lives in Ahmedabad. One estimate is that Ahmedabad heat action plan saves hundreds of lives every summer (Hess et al., 2018). Hess et al., (2018) found a decrease in all-cause mortality in the first two years (2014–2015) after the HAP was implemented 29. The results of this ecological study indicate that the HAP was associated with reduced mortality during the heat seasons 2014–2015, especially at higher temperatures. The maximum pre-HAP RR (RRs-Rate Ratios) was 2.34 (95% CI 1.98–2.76) at 47°C (lag 0), and the maximum post-HAP RR was 1.25 (1.02–1.53) estimated at 47°C (lag 0). Post-to-pre-HAP non-lagged mortality IRR (IPR-Incidence Rate Ratios) for Tmax over 40°C was 0.95 (0.93-1.22) and 0.73 (0.29-1.81) for Tmax over 45°C. An estimated 2,380 (95% CI 324-4,435) deaths were avoided in the post-HAP period. Temperatures and HAP warning days post-HAP implementation were associated with decreased summer time all-cause mortality rates, with the largest declines at the highest temperatures (Hess et al., 2018).

4.4 Scale-up in other cities and states: Heat action plan status in other cities and states

The heat-wave action plan is intended to mobilize individuals and communities to helpprotect themselves against avoidable health problems during spells of very hot weather. Ahmedabad Heat Action Plan proven as one of the successful environment public health intervention. The Indian national government has developed guidelines based on the Ahmedabad HAP[12] and worked to scale up early warning systems and action plans to 11 states and 30 cities in India, with several new or existing HAPs being created (Natural Resources Defense Council, 2017). In some of the cities IIPH-Gandhinagar initiated correlating last 15-20 years' climatic data with mortality and morbidity data of cities for preparing Heat Stress Index and city specific threshold. Vulnerable areas and population are also identifying by using GIS and Satellite imagery for targeted actions to prevent vulnerable populations from heat related illnesses.

In 2018, with support from the Department of Science and Technology under the National Mission on Strategic Knowledge for Climate Change (NMSKCC) of Government of India IIPH-Gandhinagar helped Jhansi in Uttar Pradesh and

Sagar in Madhya Pradesh, for implementing HAPs. Nagpur city in the state of Maharashtra, has also developed HAP similar to Ahmedabad. They have been using the same thresholds as Ahmedabad for calling yellow, orange and red alerts. Chandrapur city (Maharashtra state) has been working on HAP since 2016. In 2018, as part of the heat action plan Chandrapur city in central India took up community outreach programs that range from awareness marches to "WhatsApp" alerts to reach people based on earlier efforts.

4.5 HAP in developing countries Climate Services Forum for Health (CSF-Health)

Many countries particularly across Asia and Africa are particularly vulnerable to negative impacts of climate and weather extremes.The health risks of extreme heat waves are an emerging priority in the world specially in South Asia Region. Consecutive extreme heat waves in 2015 and 2016 resulted in thousands of deaths, a range of heat stress and dehydration related illnesses, losses in productivity, and overburdening of health systems, particularly in India and Pakistan 31.These heat waves are part of the observed trend that the numbers of heat waves have increased across most of Asia since about 1950, and heat wave frequency has likely increased since the middle of the 20th century in large parts of Asia. These high impact events, along with the observed trends and projections have catalyzed the public health community to improve the evidence base of heat-health impacts, and advocate for accelerated national, state, and local action. In 2015, nations across South Asia experienced the traumatic and devastating effects of a heatwave which took thousands of lives and stressed critical social systems.In response, health and meteorological partners from across the South Asia region organized this first CSF-Health in Colombo, Sri Lanka (Climate Services Forum for Health, 2016). The main focus of CSF-Health on how to improve the management of extreme heat events in South Asia. Thus, there are systematic efforts to build heat wave action planning in many countries of South Asiabased on Ahmedabad HAP, as this is feasible, cost effective and affordable.

5. LIMITATIONS

- One of the important limitation for effective development and implementation of heat action plan is unavailability of health related data about heat related illness on daily or weekly basis. Without health related data city specific temperature threshold and heat stress index cannot be worked out.
- Due to efforts of National Disaster Management Authority, Indian Meteorological Department, IIPH-Gandhinagar, the HAP has gain significant importance. However, most cities developed the heat action plan based on Ahmedabad, but effective implementation is lacking, as there is no state level monitoring.

- Another limitation is lack of India specific or region specific Heat Stress Index. The present early warning system is largely based on temperature. However, from the perspective of physiological science, the heat stress experienced by humans is a combination of temperature as well as humidity. Many countries have well developed heat stress indices.
- Further, the HAP is mainly focused towards improving resilience of communities and system against extreme heat events. Little attention has given toward mitigation strategies like building climate-resilient infrastructure, such as energy, water and transportation.
- Some of the cities have implemented the HAP, however, monitoring and evaluation of HAP has not been carried. Without proper monitoring and evaluation, true understanding about impact of HAP is not possible. The momentum for HAP development is started in big cities. However, small towns and village also require HAP. For instance, the 2015 heat wave resulted in over 2,000 deaths in rural Andhra Pradesh. Additionally, heat stress in rural areas adversely impacts local economies. Further, extreme heat adversely impacts livestock.

6. RECOMMENDATIONS

- The government should invest in improving availability of health related data like IMD is providing climatic data. This would improve understanding about impact of heat waves on morbidity and mortality and will also help in developing city specific threshold and heat stress index. New thresholds for issuing heat-related warnings could incorporate information based on temperature-humidity combinations. Further, scientific efforts should be targeted towards developing India specific Heat Stress Index.
- At every Municipal Corporation or city level, there should be a nodal person trained in Environment Public Health for coordinating various activities of heat action plan with line departments. As effective and efficient implementation of HAP require multi-stakeholder collaboration and coordination. The cities should monitor and evaluate heat-action plans. Successful plans require constant monitoring and evaluation for processes as well as outcomes. Each year plan should be updated.
- The government should scale up heat-warning systems in rural areas for protecting communities, livestock and rural economies from extreme heat events.

7. CONCLUSION

India is already experiencing warmer summers because of climate change. In this decade (post-2000), 16 of the 18 hottest summers recorded over the past 100 years have occurred. It is expectd that each consecutive year will be warmer

than last year. Although the heat-related mortality and reporting precision are affected by inaccuracy for instance, few causes of deaths and deaths among homeless are not recorded.The heat action plan is comprehensive and involve early warning system used during heat waves, health education and promotion of vulnerable community about prevention from heat related illnesses, awareness programs in schools, inter-departmental coordination to alert citizens of predicted high temperatures, training for health care professionals to prevent and treat heat-related illnesses and death, developing innovative IEC material in local language and mapping of high-risk areas and community. This Heat Action Plan (HAP) was first of its kind in South Asia. A combination of public awareness campaigns, training for medical staff and simple and easy policy changes have prevented thousands of mortality at low price. The present paper provides an evidence based guide to public health policymakers across globally for improving resilience of communities against extreme heat events and for prevention and management of heat related illnesses.

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AIR RELATED DISASTERS

Chapter 14

COMBATING AIR POLLUTION IN DELHI: COURSE TO CLEAN AIR AND BLUE SKIES

Tanu Anand, Jugal Kishore and Shekhar Grover

ABSTRACT

Air pollution in Delhi is the worst among major cities of the world. According to Ambient Air Pollution report 2014, Delhi had the highest 2.5 Particulate Matter (PM) in the world. It is pertinent to restore air quality parameters to safe levels to ensure health of the citizens and tourists. In this regard, several unique initiatives have been taken both by the government and citizens of Delhi that have resulted in some decline in air pollutant levels in Delhi over the years. Odd and even scheme, 7 point action plan to curb air pollution, banning of diesel vehicles and generators etc. are some of the initiatives that have had resulted in moderate reduction of air pollution. Though the battle to combat air pollution requires sustained efforts and the situation is complex, yet, it is worth discussing the steps taken uptil now to combat the menace of air pollution in Delhi. The present paper aims to discuss the strategies adopted by the government over last 5 years and their impact on air pollution

Keywords: *Particulate matter, Health, Air pollution, Odd even scheme.*

Tanu Anand✉
Scientist-D (Medical), Indian Council of Medical Research, New Delhi, India
drtanu.anand@gmail.com

Jugal Kishore
Director Professor & Head, Department of Community Medicine, Vardhaman Mahavir Medical College & Safdarjung Hospital, New Delhi, India

Shekhar Grover
Consultant, Mobile Oral Health Project, National Health Mission, Maulana Azad Institute of Dental Sciences, New Delhi, India

1. INTRODUCTION

Air pollution ranks as the topmost environmental health risk impacting both human health as well as the climate. According to World Health Organization (WHO), air pollution causes 7 million deaths worldwide every year (WHO, 2016). Around 4.2 million deaths are due to exposure to outdoor air pollution (WHO, 2016). It is also estimated that nine out of every 10 people are breathing air contaminated with high level of pollutants, particularly those residing in developing countries (WHO, 2016).

Air pollution is a two edged sword. While it is well known that air pollution causes cancer, heart disease, respiratory infections and stroke, its effect on already vulnerable climate is also worrisome. On one hand, particulate matters (black carbon) released due to combustion of fuels contributes to global warming, particulate sulfates cause relative cooling of the atmosphere. Ground level ozone formed by mix of air pollutants released from urban sewage, agriculture and vehicles, causes warming of air (WHO, 2019). The inter linkage between air pollution and climate change further exacerbates the health and well being of the individuals across the globe, more so in middle and low income countries including India (India State-Level Disease Burden Initiative Air Pollution Collaborators, 2019).

Air pollution in India has been a matter of public health concern in recent times. In 2017, air pollution contributed to 8% of the total disease burden in the country with 11% premature mortality in people younger than 70 years (India State-Level Disease Burden Initiative Air Pollution Collaborators, 2019). Rapid unplanned urbanization, conventional agricultural practices along with vehicular and industrial emissions are largely responsible for declining air quality in majority of cities in India (Checkley et. al., 2016). According to WHO, 13 Indian cities among 20 mega cities in the world have worst air quality in terms of particulate matter (WHO, 2016). Further, Delhi holds the undesirable distinction of being among twenty of the most polluted cities in the world (Cheng et. al., 2016).

Being the capital of India and hub of national and international commerce, industry and education, Delhi has grown rapidly in terms of population and economy over the years. However, the burgeoning urbanization and energy consumption have resulted in city facing serious environmental concerns, particularly air pollution lately so. The present paper aims to discuss the problem of air pollution in Delhi, its sources and mitigation measures taken by the government and people so far.

2. SOURCES OF AIR POLLUTION IN DELHI

There are four major aspects that determine the air quality in Delhi. These are: climate, geographic location, land use and human activities (Aijaz, 2019). Delhi has semi-arid climate. It is located between Indo-Gangetic plains to the

east, semi arid regions of Rajasthan to the west and south-west and Himalayas to the north (Tiwari et. al, 2018). It is postulated that during winters, north-easterly and westerly winds blow in Delhi, thereby colliding with hot smoke produced due to stubble burning and vehicular and industrial emissions. The local weather conditions coupled with excess moisture prevents the dissipation of pollutants at the ground level resulting in a cloud of trapped pollutants referred as smog (Mishra, 2019).

Inefficient land use also leads to air pollution in Delhi. The barren or unused land acts as a potential source of dust which often mixes with smoke during dry season and pollute the environment. This is particularly seen around lands alongside roads or highways (Aijaz, 2019). Further, exploitation of natural resources like water, forests etc. aggravates the situation.

Human activities can be classified as individual level factors (pertaining to individual behaviour) and societal level factors (Bhalla, et.al., 2018). Individual level factors for air pollution in Delhi include: rampant use of diesel based generators, biomass/waste burning, vehicular emission, increased number of cars, road dust due to traffic, fossil fuel burning, bursting fire crackers and poor management of construction waste/dust. Societal level factors include: aerosol emission from power or waste processing plants and industries, pollution from neighboring states (stubble burning in Punjab & Haryana), commercial vehicular emissions (trucks) and lack of efficient public transport system (Bhalla, et.al., 2018).

According to a report on source appointment of particulate matter $(PM)_{2.5}$ (fine particulate matter with aerodynamic diameter <2.5 microns) & PM10 concentrations (fine particulate matter with aerodynamic diameter <10 microns) in Delhi, transport/vehicular emissions contribute to 28% of $PM_{2.5}$ concentrations while industries contribute 30% and biomass burning is accounting for 14% during winters. Dust (unused land, road and construction) have a share of 17%. On the other hand, dust is contributing to 38% of $PM_{2.5}$ concentrations during summers followed by industries (22%), transport (17%) and biomass burning (15%). Other sources contribute to 11% in winters and 8% during summers. Share of transport sector in PM_{10} concentrations in Delhi is 24% during winters. While industries and dust are accounting for 27% and 25% respectively, biomass burning has share of 13% in PM_{10} concentrations. During summers, dust is contributing to 42% of the share in PM_{10} concentrations whereas industries account for 22% and biomass burning and transport are accounting equally with 15% each (ARAI, TERI, 2018).

3. PUBLIC HEALTH INTERVENTIONS BY GOVERNMENT AGAINST AIR POLLUTION

The issue of air pollution in Delhi is not new. The city has breathed contaminated air since 1990s. Since the reasons and context of air pollution in the current

scenario varies from that in 1990s, it has been classified in two phases: From early 1990s to 2015 and 2015 to the present state. It is interesting to note that the approach to combat air pollution during both times has been unique and situational. The case study of Delhi highlights the fact that "not single shoe fits all".

3.1 From early 1990s to 2015-Historical perspective of the air pollution problem in Delhi: The deterioration in air quality of city began in 1990s, despite couple of strong pollution related legislations in place since 1980's (these included Air (Prevention and Control of Pollution) Act in 1981 & Environment (protection) Act in 1986). This wave of air pollution was due to rapid urbanization and economic growth that took place in the state at that time. Due to active intervention of the Supreme Court during that time, Delhi Government submitted its action plan to combat the declining air quality. Further, Ministry of Environment & Forest (MoEF now as MoEF and Climate Change) constituted Environment Pollution (Prevention & Control) Authority in January 1998 to advise the courts on pollution and to monitor the implementation of its orders. Some of the direct actions included, decrease in sulphur content of diesel and petrol from 1 and 0.2 per cent respectively to 0.05 per cent for both fuels during 1996 to 2001. Also premixed combination of lubricating oil with petrol was used for two wheelers and loose availability of fuels was banned in 1998. Another landmark initiative of those times was conversion of all commercial passenger vehicles- buses, taxis and three wheelers-to use of compressed natural gas (CNG). The court also ordered banning of more than 15 years old commercial vehicles to be used for transportation on roads (Narain and Krupnick, 2007). Interventions to curb vehicular air pollution also included the notification of first set of emission standards for Indian vehicles with stricter compliance between 1996 to 2000 and equipping all new passenger vehicles with catalytic converters to further reduce emissions. Finally, a mass rapid transit system, known as Delhi Metro was introduced in early 2000's.

Other government efforts in this regard comprised of categorizing industries as hazardous under Delhi Master Plan in 1996 and closing them down. Some of the industries were relocated to towns and industrial areas just outside the border areas of Delhi (now referred as National Capital Region). Thermal power stations in Delhi began the use of beneficiated coal with less ash content as against conventional coal with ash content of 40 per cent (Narain and Krupnick, 2007).

All these actions culminated in improvement in air quality. Government continued to implement innovative approaches for air pollution control. Bharat Stage (BS) IV standards for vehicular technology and fuel were adopted in Delhi in 2010 followed by BS V norms in 2016. It is worth mentioning here that studies have shown that concentrations of sulfur dioxide (SO2) have remained well under the control due to policy directives pertaining to clean

fuel technology and following of BS standards over time (ENVIS, 2016). MoEFCC revised the National Air Quality Standards for 12 pollutants for clean air in 2009 that helped in establishing regulatory monitoring of $PM_{2.5}$ as several hundred monitoring stations were established across the country. The National Air Quality Index (AQI) was launched by MoEFCC in 2014 as 'One number-one colour-one description' for common man to understand air quality within his or her vicinity (PIB, 2014).

3.2 From 2015 to the present state:

Rapid rise in demand for energy, faster growth of NCR and and increase in crop residue burning resulted in accelerating the problem of air pollution. The gains from fuel switching and fuel quality improvement got negated by increase in number of diesel vehicles over time with increase in population due to migration in and around city. The total number of vehicles increased from 4.24 million in 2004 to more than 10.8 million in March 2018 (Raman and Mukherjee, 2019). Even though, there was slight dip in PM concentrations in Delhi, the nitrous oxide (NO_2) concentrations have continued to remain high largely attributable to traffic load in the city.

It would be pertinent to discuss here the issue of stubble burning emerging as one of the major contributors to toxic air in Delhi in last decade. While Ministry of Agriculture considers increase in on-farm crop burning to the shortage of labor (Ministry of Agriculture, 2014), experts apprehenddelay in crop sowing imposed under the Punjab Preservation of Subsoil Water Act 2009 to be the reason behind increase in farm fires in last few years (Singh et. al, 2019).

Taking into account of these issues, several measures have been undertaken by the government. Three phases of 'Odd-Even scheme' have already been implemented by the state government from 2016 to 2019. Under the scheme, vehicles have to be run according to the registration numbers (odd or even number) on alternate days. However, there is limited evidence of impact of scheme on air quality (Tiwari et. al, 2018). Delhi government has launched car free day campaign "Ab Bus Karien' since 22nd October 2015 to be observed on 22nd of every month. Entry of overloaded trucks in Delhi has been prohibited and 'Green tax' or environmental tax has been imposed on them. Construction and opening of western and eastern expressways have helped in diverting non-destined traffic to Delhi.

Another landmark action has been the development and implementation of Graded Response Action Plan (GRAP) for Delhi and NCR since 2017 (PIB, 2017). It comprises of measures such as prohibition on entry of trucks into Delhi; ban on construction activities, introduction of odd and even scheme for private vehicles, shutting of schools, closure of brick kilns, hot mix plants and stone crushers; shutting down of Badarpur power plant, ban on diesel generator sets, garbage burning in landfills and plying of visibly polluting vehicles etc. These

measures are to be implemented in the entire NCR after due consideration by authorities concerned and after taking into account the level of air pollution. Besides, Government of Punjab is entrusted with task of implementing action against stubble burning (PIB, 2017). EPCA has expanded the monitoring network in Delhi-NCR with the help of Central Pollution Control Board (CPCB). Currently, there is a centralized open portal that provides data from 52 monitoring stations (Raman and Mukherjee, 2019). In 2018, Central government has formulated comprehensive action plan (CAP) to outlay long term measures to manage air pollution in Delhi, particularly focusing on parking policy in the city along with upgradation of public transport system.

The Government of Delhi in September, 2019 announced 7 point action plan comprising of implementation of odd even scheme, distribution of pollution masks, celebration of community Diwali through laser show, environment marshals (home guards are tasked to stop people from burning garbage, dry leaves, plastic and other waste material while stopping them also for creating dust pollution) hotspot control, dust controls and tree challenge. Biomass burning is already banned in the city.

4. LEARNING FROM DELHI CASE STUDY OF AIR POLLUTION

Delhi experience to curb air pollution reinstates the fact that restoration and maintenance of clean air quality requires cohesive action from all stakeholders. It furthers reconsideration of air pollution as a regional problem rather than a problem of a particular city or state. Strong and sustained political will is the need of the hour. Beside all these reforms, there is need to develop the concept of sustainable development of the cities where green lifestyle (in which less and efficient use of resources) should be promoted. In case of Delhi, judicial interventions have worked well having forced governments over the years to change their approach from reactive to proactive. To conclude, the battle to combat air pollution in India, more precisely Delhi is still not won. Yet, the momentum achieved through various interventions need to be sustained for times to come. It must be well understood that improving air quality is a "win-win strategy" for both climate and health.

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Chapter 15

STUDY OF IDENTIFICATION OF SOURCES, EXPOSURE AND POSSIBLE HEALTH EFFECTS OF INDOOR AIR POLLUTION IN DHANAS VILLAGE, CHANDIGARH

Kirti Singh, Jaskiran Kaur and Manoj Kr Sharma

ABSTRACT

Many studies have shown that air pollution levels inside the house may be two to five times higher than the outside. Possible indoor contaminants include outdoor air, biologic agents (molds) dust, aerosols, asbestos, ozone, environmental tobacco smoke, wood stoves, and other heating devices, inhalable particulate matter, building materials, radiations, dampness, chemical agents like cleaning agents such as phenols, (vaporizers and mosquito repellent coils) etc. In this study, 400 out of 1845 households (selected randomly) from different localities in a village, were studied for identification of possible sources of indoor air pollution. This cluster is of particular interest as it is a densely populated village (overcrowding) with around 56% population non-working (low per capita income) including 14% population comprising under 6 years of age, making them highly vulnerable to impacts of indoor pollution. A questionnaire and door to door survey of the households were used for data collection. The ill effects of indoor air pollution have been associated to increased morbidity and mortality due to pneumonia, chronic obstructive pulmonary disease (COPD), lung cancer and other acute respiratory tract infections.

Keywords: *Crowding, Smoke, Aeroallergens, Chemical Pollutants, Sick Building Syndrome (SBS), Volatile Organic Compounds (VOCs).*

Kirti Singh✉
Student, Centre for Public Health, Panjab University, Chandigarh, India
keertee@gmail.com

Jaskiran Kaur
Student, Centre for Public Health, Panjab University, Chandigarh, India

Manoj Kr Sharma
Assistant Professor, Centre for Public Health, Panjab University, Chandigarh, India

1. INTRODUCTION

It's a worldwide belief that the air inside our homes is cleaner and better than the air outside. We have always felt safe from pollutants inside the closed windows and doors, but its gradually being realized that it might be a misconception and the air inside might be 2-10 times more polluted than the air outside. More than 65% or 2/3 of the studies and combined literature on indoor and outdoor air quality has found indoor air pollution concentrations higher than outdoors. (Leung, 2015) Pollutants in the outside air are frequently transported and dispersed by the wind flow, local turbulence, precipitation, sedimentation (Watson et al., 1988) which is not completely possible inside the houses. As people, especially, women, children and elderly tend to spend maximum time indoors which is more than 80-90%. (Jenkins, P.L et al., 1992) Though it varies with season, age, gender, type of work, health of inhabitants etc. women and children are the most vulnerable group.

Among the more important indoor contaminants associated with ill health or irritation are kitchen smoke, passive tobacco smoke, Carbon monoxide, Nitrogen and Sulfur dioxide, volatile organic compounds (VOCs), formaldehyde, asbestos fibers, micro organisms and dust.

In the technologically advanced era of globalization, 80% of the rural population still depends upon wood or biomass (cow dung) energy for sustenance in developing countries like India. (Baines, ESMAP) The health impacts from indoor exposure to combustion products from fuel combustion, cooking and heating have been observed to be significant.

Tobacco smoke exposure can be of 3 types: A person, who smokes, within the house, is exposed to first hand smoke himself, other occupants inhaling the fumes but not actually smoking, inhale second hand smoke. The fume particles settle on the furniture, furnishings, hair, clothes and floor. It remains suspended there for a long time, even after smoker has left. This is third hand smoking (Apte et al., 2016).

Particular substances known as volatile organic compounds (VOCs), which arise from paints, varnishes, solvents and preservatives are the indoor polluters of major concern.

Deteriorated structure of the building exposes the inhabitants to asbestos microfibers. Silicon particles are found in abundance in houses made of bricks and cement.

Inhalable biological particles (microorganisms, moldy dust, pollens) act as aeroallergens and induce illness by affecting immune system, infections or direct toxicity. Incense sticks, mosquito repellents, anti pest sprays for cockroaches, rats, ants, termites etc, other chemicals used for cleaning purposes, aerosol

producing deodorants and artificial room fragrances are some of the other sources of indoor pollutants.

Mosquito repellent coils are made up of 0.1% of active repellent pyrethroids and the remaining 99.9% contains binders, resins and inflammable material like coal dust and coconut husks. Previous studies had shown that burning of one such coil emits particulate matter (PM) equivalent to burning 100 cigarettes and poly aromatic hydrocarbons (PAH) equivalent to 50 cigarettes. Recently it has been shown that levels of $PM_{2.5}$ and CO are 2200 times and 10 times the limit permissible by the WHO respectively, when it is burnt with doors and windows closed. Other forms of mosquito repellents such as vaporizers, sprays, ointments, and medicated papers do not produce as much PM but produce gaseous air pollutants which are irritants to the airway mucosa. (Apte et al., 2016).

Perfumes, scents, deodorants, air fresheners, scented candles, laundry products, personal care products and various cleaning agents which are commonly used in the households have been observed to emit the Volatile Organic Compounds (VOCs). A study by Steinemann identified 156 different VOCs, of which the USFDA classified at least 42 as toxic and hazardous. (Apte et al 2016).

Burning of fragrances like incense sticks or agarbattis, oil lit lamps, burn smoke sticks (dhoop) and candles during the prayer services, emits high levels of PAHs, benzene, nitrous oxide and Carbon monoxide. Candles produce $PM_{2.5}$ and PM_{10}.

Gadgets such as computers, tablets, printers, mobile phones have been implicated in increased levels of ozone in the houses. (Apte et al 2016).

Faulty plumbing, poor construction materials and weather conditions (rainy season) often leads to dampness on the walls and flooring. These damp walls are breeding grounds for fungi (Alternaria, Aspergillus, Cladosporium and Penicillium) as well as gram positive and negative bacteria (Streptococcus, Micrococcus, Staphylococcus, Mycobacterium, Streptomyces etc). Budding spores of fungi, microbial particulates, VOCs, mycotoxins and endotoxins of bacteria contribute to household pollution.

Bacterial droplets, viral droplets, fungal spores remain suspended in the house air for variable amount of time after an infection in the family. Overcrowding inside the house and poor ventilation leads to further spread of infection.

Outdoor sources also contribute to the indoor contamination. Vicinity to an industry or agricultural lands or main highways with heavy vehicular traffic and movements adds to the pollutants entering the house. Carbon particles, diesel and petrol exhaust particle-laden dust, pollens and organic particulate matter find their way into nearby households (Apte, K. et al 2016). Refer to Table 1.

Health problems due to indoor air pollutants are more widespread than those caused by outdoor air pollutants because:

- Inhabitants are in close proximity to the source and for longer duration.
- A report by WHO in 2001 gave 'the rule of 1000' which states that an indoor pollutant is 1000 times more likely to reach the lungs than outdoors.
- Women, children and elderly spend more time indoors.
- Rural areas indoor air pollution is responsible for much greater mortality than ambient air pollution. (Air Pollution and Human Health, CPCB, Sep 2001)

Documented Findings on health effects of indoor air pollution in Indian scenario:

1	Use of fuel other than LPG was associated with acute lower respiratory tract infection compared to clean fuel users.
2	prevalence of COPD was higher among biomass fuel users.
3	exposure to high pollution fuel among mothers was found to be associated with low birth weight of the baby.
4	use of biomass fuel significantly increased child mortality at 1-4 years of age.
5	risk of low birth weight babies increased 49% among those exposed to biomass fuels.
6	exposure to solid fuels among non smoker women increased chances of developing lung cancer.
7	age dependent cataract was found to be associated with use of wood.
8	prevalence of asthma was found to be associated with use of biomass fuels among elderly men and women.
9	biomass fuel was significantly associated with prevalence of active tuberculosis.
10	use of biomass fuel during pregnancy resulted in 50% excess risk of still birth.

(Source: Kankaria et al., 2014)

Table 1 Indoor and Outdoor Air Pollutants; their emission sources with examples (based on some recent Indian studies).

Type	Sources	Pollutants	Examples
Predominantly Indoor pollutants	Cooking by LPG or electricity	$PM_{2.5\ and}$ PM_{10}	Stir frying, deep frying, roasting meat, grilling, baking
	Tobacco smoke	CO, NO_2, benzene, cyanide, formaldehyde, terpenoids, phenols, nicotine, heavy metals	Cigarette, beedi, hookah, E-cigarettes,
	Indoor fragrances	VOCs, PM_{10}	Incense sticks, candles, oil lamps, dhoop, air fresheners
	Insecticides and pest control	$PM_{2.5,10}$, PAH CO,	Coils, vaporisers, flammable paper mats, pest sprays
	Chemicals for cleaning, personal care, etc.	VOCs, polybrominated diphenyl ethers	Phenyl or Lysol, Stain removers, paints, varnishes, carpet solvents
	Fungi and bacteria	Mouldy dust, spores, microbial particulates, toxins	Damp walls, ill maintained air conditioners
	Pets	Pet dander, fur	Dog, cat, cow, buffalo
	Electronic gadgets	ozone	Computers, tablets, printers, mobile phones
Indoor and outdoor pollutants	Biomass fuels	$NO_{2,}$ $SO_{2,}$ CO Aldehydes, dioxins, Particulate matter	Wood, cow dung cakes, crop residue, charcoal
	Polluted air, SMOG	NO2, SO2, CO, Pb, Cd, PAH, Benzene, butadiene, formaldehyde, tetrachloroethylene, PCDD, PCDF, polycyclic aromatics, mutagenic heterocyclic amines	Vehicular exhaust, industrial exhaust, garbage burning

Source: Apte et al.2016

2. DEMOGRAPHY

The study village, Dhanas panchayat lies on the outskirts of city Chandigarh. It is the second biggest (area 5 km^2) and second most populated village in the district. The population was about 7094, where population density was around 1418 persons per km^2 as per the last census 2011. Population of the village has increased by 132.2% in the last 10 years. Total literacy rate of the village is about 85 % (89% male and 79% female). Data after census 2011 is not available.

It mostly comprises economically weaker section (EWS) (income <1 lakh per annum), and lower income group (Rs.1-2 lakh p.a). The village has 5-6 localities within the panchayat namely Chaman colony, Aman colony, Milkman colony, Ambedkar nagar, Kacchi basti and the old village area. Population mostly falls in economically lower group in the community with members, mostly males; work in temporary or contractual jobs. Kacchi basti and the old village area have the economically weaker population with most people being daily wage laborers. The quality of life greatly varies among the localities. Aman colony, Chaman colony, Ambedkar colony and milk colony have houses made of bricks and cement with plot sizes as small as 66.24 sqm. Houses are built crammed together, wall to wall, back to back, 2-3 storied, with a front door and a single window. Very few houses have built skylights for ventilation. Average 4-5 persons live in a house. Kacchi basti has mud houses which are mostly in dilapidated conditions. The village faces the problem of crowding due to high density of population. Streets are narrow and crowded.

Garbage dump yard of the city is located nearby the village. There is a series of marble stores and granite shops along the highway in the vicinity. Dust from stone cutting is a common pollutant too. It is surrounded by agricultural fields on either side where stubble burning has begun for this season in some. Therefore, the air outside the houses is also potentially polluted.

3. MATERIALS AND METHODS

This preliminary observational survey summarizes the generation of indoor air pollutants (IAPs) through the use of household products, certain habitual activities, and the ventilation of the houses in the locality. The probable health symptoms due to IAPs were also discussed with the inhabitants, by the means of a questionnaire and brief informal interview in the 3 localities in the Dhanas village, namely Aman colony, Chaman colony and Ambedkar Nagar. The door to door survey was conducted from the last week of the month of September 2019 till the first week of November 2019. Total 400 residences were surveyed and these were selected randomly as per the availability or convenience of the residents. Respondents are mostly female members of the households as survey was conducted during the working hours in the daytime, and working female population is very low. Survey was conducted by using a questionnaire and door to door interaction.

1 PERSONAL INFORMATION

- Name of a member of the family:
- Gender:
- Address:
- Yearly Family Income: <1-2lakhs/ 2-4 lakhs/ 4-6 lakhs
- Number of dependent family members:

2 GENERAL INFORMATION (tick the correct answer)

A. Which cooking fuel do you use?
   - LPG gas
   - Wood
   - Biomass/ cow dung
   - Electric
   - Kerosene stove

B. Is the kitchen separate from the rest of the house? Yes / No. Does it have window, exhaust fan or chimney? Yes / No

C. Does anybody inside the house smokes cigarette\bidi\hookah\weed? Yes / No

D. Is the house newly constructed/ renovated\ painted? Yes / No

E. Are the walls/ carpet/ curtains damp? Yes/ No

F. Do you regularly use insect repellants for mosquitoes, cockroaches, ants, termites etc? Yes/ No

G. Is there a persistent odor inside the house? Yes / No

H. Do you use any aerosol sprays\ room freshener\ deodorants/ agarbatti or dhoop? Yes/ No

I. Do you use any of these chemicals used frequently in the house?
   - Furniture polish/varnish
   - Floor cleaner /phenols
   - Tile cleaners
   - Spot removers/wood stain remover
   - Bleaching agents

J. Are these hobby/occupation products used in the house?
   - Paint thinner

- Artist paints
- Turpentine oil
- Lubricating oils/grease
- Kerosene oil

K. Is there water seepage in the walls / leaky roof/ wet basement/ leaky pipes? Yes / No

L. Do you use air conditioner / cooler? Yes / No

M. Is it unusually dusty inside the house? Yes / No

N. Do you own a furry pet inside the house? Yes / No

O. Is the house properly ventilated at all times? Yes / No

3. HEALTH INFORMATION

Q. Does the member/members feel any of these symptoms? Please tick

HEALTH PROBLEMS	AGE 0-5yrs	AGE 5-15yrs	AGE 15-25yrs	AGE 25-45yrs	AGE 45-60 yrs
Eye irritation/ Burning					
Nasal/ throat congestion					
Breathing difficulty/ respiratory problems					
Chronic Sneezing/ coughing					
Headache/ Dizziness					
Skin irritation					
Increased susceptibility to infections					

- If yes,
- Do the symptoms occur in some specific room or portion of the house? Yes/ No
- Do the symptoms occur at some specific time? Day/ Afternoon/ Evening/ Night
- Does the symptom occur at some particular season or time of the year? Winters/ summer/ Rainy/ during change in seasonal variation?
- How long have been the symptoms occurring? >3months />6months / > 1yrs / >2-3 yrs / > 5yrs

4. SURVEY REPORT AND DISCUSSION

The survey identified that the household activities like cooking, cleaning and use of many products on a regular basis, which contain synthetic chemicals. These generate lot of pollutants inside the house, as earlier researches have observed their harmful effects. According to the survey, the localities have shifted from using biomass (cow dung) fuel chulhas to cleaner LPG stoves. Majority of the houses have poorly ventilated kitchens inside the house but they have started to use exhaust fans and skylights for ventilation. A few households have put up electric chimney too. Though in Kacchi basti and old village areas, there are still many households relying on wood and cow dung as fuels for cooking.

Mosquito repellants (both coils and vaporizers), anti cockroach sprays, phenyl based floor cleaners and Hydrochloric acid based bathroom tile cleaners (Harpic) are used daily in almost all the households as per the survey. Damp walls, leaky plumbing and dilapidated walls/ plaster is a major problem in the households. Some residents have solved this problem by putting up tiles all over the walls inside and outside the house. But it still remains a health hazard for many other inhabitants. There is a persistent odor inside the houses and air is not circulated properly due to lack of windows and open areas. Air coolers are a commonly used appliance which adds to the dampness. Incense sticks (Agarbattis) dhoop, candles and oil lamps are very often used products in more than 200 households, as per the survey. Very few residents admitted to smoking inside the houses. Kachchi basti and Milk colony houses have cows and buffaloes domesticated inside the houses. Sanitation and hygiene of these areas is in a poor condition. Furry pets like dogs and cats are domesticated by none of the households. Use of carpets, curtains, room fresheners, perfumes and deodorants are rarely used in the houses as per the responses. Only 10 out of 150 houses in Chaman colony reported of getting the house renovated and painted recently in the last one year. None of the respondents admitted to having moldy walls, carpets, curtains and mattresses in the house. Except smoke and dust, these Indoor Air Pollutants may not be visible to the eye and be physically apparent, but their presence is felt by the increased incidences of nasal irritation, allergic rhinitis, chronic cough, itchy and red eyes, as reported by the respondents, mostly among the 25-60 yr age-group women and children. Many ladies in age group 30-45 and above complained of having chronic headaches and dizziness, mostly in the summers. Many elderly residents also reported of having chronic joint and muscle aches. Frequent Sneezing and coughing has become a normal part of the life, such that the respondents don't count it as an ailment. Refer to Table 3. People of the village are ignorant and unaware of various chemicals which pose health and environmental hazards in our daily life. With the survey result, it is apparent that indoor pollution with its acute health problems such as various allergic tendencies might be present in the population. An extensive and elaborate study about the health effects and associated chronic diseases would be of benefit to the medical fraternity and the society at large.

Table 3 Established and Observed Symptoms By Indoor Air Pollutants

Household Products Being Used Commonly Used By The Villagers	Established Health Impacts	Symptoms Observed During the Survey
Persistent odor, home cleaners, paints and varnishes, insect repellants, kerosene, turpentine oil, tobacco smoke, pesticides, carpet	Lung cancer, mesothelioma, headache, nausea, impaired vision, impaired mental functioning, eye nose and throat irritation, allergic reaction, acute asthma, decreased lung function, liver kidney, brain damage, bronchitis, pneumonia in children, asthma in pre-school children, heart diseases, gene mutation	Respiratory irritation, allergic reactions, influenza , eye nose throat irritation, chronic coughing and sneezing during the changing seasons mostly
Dust, air conditioner, leaky roofs and walls, furry pets, old carpets	Allergic reactions, asthma, eye, nose and throat irritation, humidifier fever, influenza and other infections	Frequent allergies to dust, rashes, eye nose throat irritation.
New construction, tobacco smoke, paints and varnishes	Aggravated asthma, bronchitis, pneumonia, allergic reactions etc	Eye nose throat irritation, allergies, respiratory irritations,

Source: Sarkar et al., 2014

Efforts to assess health risks associated with indoor air pollution are limited by insufficient information about the number of people exposed, the pattern and severity of exposures, and the health consequences of exposures. (Spengler et al 1983) This statement still holds true.

5. CONCLUSION

The developing countries have seen a drastic surge in population in the last century. Demand and supply for housing is imbalanced. Last decade has witnessed a growth spurt of housing colonies and societies throughout the outskirts of Chandigarh city. To cut the construction costs and to utilize the maximum space for maximum number of houses, the poor and lower socioeconomic strata of society are left with no choice other than to live in ill ventilated and

ill lit houses. Housing board constructors often use low quality construction materials, leading to plumbing and electrical faults. Improper ventilation and overall poor architecture may further worsen the indoor air quality. Change in attitudes towards well being and healthy environment, both within the government and the society, is the need of the hour. More attention has to be paid to evaluate the crucial long term impacts of sick building syndrome (SBS) on the occupants well being, health status and productivity.

Health education and awareness among the masses will play a crucial role in safe and responsible use of chemicals and substances inside the homes. An overall strategy should be developed to investigate indoor exposures, health effects, control options, public policy.

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CROSS-CUTTING ISSUES

Chapter 16

MAINSTREAMING SAFETY WITHIN HOSPITALS & INSTITUTIONALIZING EMERGENCY PREPAREDNESS IN HEALTHCARE SECTOR

Saurabh Dalal and Priyanka Singh

ABSTRACT

Preparedness does not pay off instantly. The National Disaster Management Authority (NDMA) 2016 guidelines on hospital safety mandates that every hospital within the country should have their Hospital Disaster Management Plan that should be in lines with the district disaster management plan. It also says that the plan should be functionally rehearsed and tested through periodic mock-drills as well as updated after the learnings. Since the AMRI hospital fire to the most recent All India Institute of Medical Science (AIIMS), New Delhi hospital fire, Bihar and Chennai flooding to hospital handling CBRN emergencies various incidents have brought in light a different hospital safety aspects and has made one thing quite clear that "one size doesn't fit all and each plan should be unique in nature as per its local vulnerabilities and hazards. Aspects of mitigation such as structural and nonstructural safety, adherence to BIS (Bureau of Indian Standards) codes and National Accreditation Board of Hospitals (NABH) emergency preparedness standards, activation of disaster wards, developing Standard Operating Procedures (SOP) for each cadre of healthcare workers and institutionalization of hospital incident command system are some of the robust steps that can ensure the safety, business continuity and resilience of a healthcare facility.

Keywords: *Hospital Disaster Preparedness, Health Sector Emergency preparedness and planning, Health Resilience, Mass Casualty Management, Triage, Pre hospital Care.*

Saurabh Dalal✉
Public Health Emergency Management Fellow, Centre for Disease Control and prevention, Atlanta
drsaurabhdalal@gmail.com

Priyanka Singh
Consultant, Capacity Building in Public Health Emergency Management, National Institute of Health & Family Welfare)

1. INTRODUCTION

Indian subcontinent is quite vulnerable to natural disasters but at the same time manmade threats are also emerging on daily basis as a result what we see is a foray of Hybrid and Complex disasters, Hence our Response to them should be also more integrated and innovative.

Since March 2016, the whole world is working on the Sendai Disaster Risk Reduction (DRR) Framework Implementation lines and strategies and the health sector is one of most significant components. The key factors in reducing the risk are mainstreaming DRR in every development sector public knowledge with appropriate use of science and technology. Globally and within the India, there is an effort to improve global preparedness for disasters that routinely affect most communities around the world.

INDIAN SCENARIO

India's complex geo-climatic conditions, topographic variability and multiple climate zones make it susceptible to natural disasters such as flooding, drought, cyclone, earthquake, and epidemics / pandemics. The dimensions of man-made disasters are road/rail/air, fire, chemical/nuclear accidents or terrorism. However, common denominator of all disasters is injuries and diseases due to the effects of the hazard(s), or deaths. Paradigm shift in all phases of Disaster Management Cycle continuum was ushered with enactment of the Disaster Management Act on 23rd December 2005.

2. LEGAL AND INSTITUTIONAL MECHANISM

National Disaster Management Authority's proactive institutionalization steps of "all hazard" emergency medical response framework in disasters envisage for incident site initial medical management by the medical first responders within the 'golden hour', then evacuation in critical care equipment fitted ambulances, followed by prompt treatment in the hospitals and followed by disease/disability, and lastly, prevention of epidemics, management of long term health effects and psycho-social care, these entail:

i) Immediate rescue by trained responders like National Disaster Response Force/State Disaster Response Force/Civil Defence rendering basic Medicare.

ii) Well designed Hospital Disaster Management Plans.

iii) Training of doctors and paramedics for basic emergency care and response.

iv) Surge capacities healthcare facilities.

v) Safe Hospital to function in post-disaster scenario.

vi) Hospital with facilities of Burn wards and Trauma Centres.

vii) Casualty evacuation by specialized medical transport.

viii) Disaster resilient communication to facilitate medical response.

ix) Community Awareness in First Aid and basic emergency care.

x) Licensed Blood banks networked to cater for surge requirement.

xi) Establishment of Bio-Safety laboratories and disease surveillance networks.

xii) Tele-medicine.

xiii) Full-fledged containerized field hospital.

xiv) Efficacy of Disaster Management Plans and Standard Operating Procedures tested and refined through training, seminars and mock drills.

xv) Alternative systems of medicinal remedies of AYUSH.

Hospitals are the first place where anyone in pain no matter a disaster or not, goes to find cure and help, so are one of the most critical facilities that needs to be not only preserved but to remain operational beyond normal working capacities during any type of emergency.

Health sector Emergency Preparedness and planning is a key to achieve measurable resilience for any country. Hospitals need to have a Hospital Disaster Management plan which should align to the District Disaster Management Plan. Training a large force of health care professionals covering both public and private sector is much needed so that more hospitals equip and prepare themselves for complex crisis scenarios.

3. CASE STUDIES AND LESSONS LEARNT

Recent lack of infield triage of patients after Elphinstone road stampede (Mumbai) in 2017 shows how ill prepared healthcare systems are with regards to dealing with multiple patients in lesser amount of time in crisis. In recent events of disasters, the hospitals' operational failure has raised concerns about the safety of affected people who are in need of supervision/care.

In 2001, total collapse of Bhuj Civil Hospital killed more than 150 patients,18 people died in MIOT Hospital, Chennai during floods due to power failure. Fire killed 22 people in SUM hospital, Bhubaneswar and a stampede in Murshidabad hospital after fire killed two. India has been a witness to several incidents ranging from AMRI hospital fire, 26-11 attacks on Kama hospital and Ahmedabad civil hospital serial blasts. Multiple incidences of fire in our lifeline buildings and issues like inadequacies to accommodate surge patients of dengue or any

infectious disease outbreak or death of several children due to lack of oxygen in Gorakhpur shows wherever contingency and emergency planning is applicable our healthcare facilities fail. The lifeline buildings are becoming vulnerable.

The devastating earthquake that struck the western part of Gujarat in 2001 was one of the worst disasters of this decade. Several thousand lives were lost and many more were injured. The earthquake also destroyed many critical services among them hundreds of health structures. The worst hit was the General Hospital in the city of Bhuj, near the epicenter of the earthquake. The hospital was completely destroyed and patients were buried in the debris. This facility was the only one in about hundred kilometer radius and was expected to help the affected population during the earthquake. However, its own destruction led to many more loss of lives as the injured could not be treated in time.

Over the years, similar scale of disasters has caused destruction of health facilities thereby adding to loss of lives. The 2004 Indian Ocean Tsunami wreaked havoc in health facilities across India, Indonesia, Sri Lanka and the Maldives. More recently, hospitals and health facilities have also become targets of terrorist attacks. In 2008, two such incidents took place in India at Kama Hospital in Mumbai after 26/11 terror attacks and in Ahmedabad Civil Hospital attack during serial bomb blasts causing loss of lives and panic among the health workers and in patients.

3.1 Detailed case study: Preparedness pays off in a long run.

A case study of Tughlakabad leakage of 2-CHLORO-5-(CHLOROMETHYL) PYRIDINE and how efficient planning, preparedness and response averted mortality, gives a vivid comparison of status of chemical response and hospital preparedness, since the World worst Industrial Disaster of Bhopal Gas tragedy occurred on the night of 2nd December, 1984 at the Union Carbide India Limited (UCIL) Pesticide plant in Bhopal which was the Indian subsidiary of Union Carbide Corporation, USA. The accident occurred due to leakage of Methyl Iso Cynate (MIC) and other chemicals due to ingression of water and the resulting reaction affected a large number of persons. 35 years down the line chemical safety, Hospital safety and emergence of Disaster risk reduction as a specialty and comprehensive disaster preparedness also involving health sector has paid off dividend in long run.

In the early morning of on 6th May 2017, the driver of a truck carrying a container with eighty drums of an agrochemical pesticide powder, observed leakage from some containers. A total of six drums had sprung leaks and, at 0730 h, local laborers spread soil over the ground spill and poured water to wash the crystals away. This triggered a chemical reaction that caused release of toxic fumes. The chemical cloud carried downwind into a local school where students inhaled the gas and developed burning sensation in the eyes, breathlessness, pain abdomen and nausea. A total of 578 symptomatic girl students and 37 teachers were shifted to hospitals and treated. 310 were sent to Hakim Abdul

Hamid Jamia (Majeediya) Centenary hospital, 66 to Apollo hospital, 171 to Okhla ESI hospital, 65 to Batra hospital and 03 to the AIIMS Trauma center and Safdurjung hospitals where they were given first aid and treatment, many were discharged after 6-7 hours of observation, a few others in HDU and ICU were discharged weeks and days later.

Significant lessons learnt:

- The event resulted in zero mortality and zero morbidity which is an ideal sendai framework resilience indicator despite of 615 people getting affected.
- Hospitals activated their Disaster Management plan since they had one and well-rehearsed mechanism of being activated during the mock drills in past few years by the district authorities.
- The Hospital expanded their surge capacity and took patients triaged and treated them well and referred them only on stabilization.
- Networking between the hospitals help, them manage and share patient loads.
- Trained staff and sensitizations done prior to the event accustomed the healthcare staff to design and execute the response. Prehospital infield and intrahospital triage happened at all levels.
- Well connect with the district authorities helped hospitals in being involved in unified command despite of being a Saturday.
- Hospitals with well-rehearsed DM plan tend to do better in such emergencies.

a) Importance of focus on local vulnerability - Life and fire safety

Hospital Fire Safety in India is one of the prime concerns as far as hospital and life safety is concerned.Past incidences of fire in Hospital due to various reasons like short circuits, bomb blasts at places like AMRI, Murshidabad and the recent one in SUM hospital Odisha and AIIMS, New Delhi has claimed innumerable innocent lives as well as extensive loss of valuable equipment, years of research and infrastructure. just because of fire. These fireincidents not only claim lives but also leaves a tremendous psychosocial imprint on the minds of community along with causing damage to infrastructure and incurring financial losses.

b) Other threats and risks

There are also other challenges that affect healthcare facilities and need a critical addressal like;

- Ambulance fire.
- MRI accidents Mumbai.
- CSSD blast.
- Ventilators power supply failure.
- Lab fire.
- Hospitals being targeted by terrorism.
- Attacks / violence on doctors.
- Flooding and submergence of power generators.
- Location of hospitals in old complexes with narrow evacuation routes.

c) Minimum standards of preparedness in hospitals.

National Guidelines on Hospital Safety which is considered the benchmark document which aims to mainstream disaster prevention, mitigation, preparedness and response activities in hospitals. It is envisioned that through the guidelines, all hospitals in India will be structurally and functionally safer from disasters, so that the risks to human life and infrastructure are minimized. Preparation of Hospital Disaster Management Plan is mandated in National Disaster Management Authority, Hospital Safety guidelines. Various building block of hospital safety like triage, fire safety, CBRN Preparedness, Timeline based Standard operational procedures and developing an incident command system for flawless execution of protocols whether day or night, mock drills and how to avoid operational failures be it human or mechanical should be focused while preparing a plan.

Making hospitals ranging from smallest primary healthcare center to largest multispecialty hospital, resilient and solve their purpose of providing aid without fail needs human and technological interface to be utilized for safety of our healthcare facilities, enhanced humanitarian medical response is also required in future, which can be easily used by any personnel of hospital and assistance can also be solicited.

The plan may vary depending on size, capacity, location and function of hospital, however best efforts have been taken into consideration to incorporate various standards like laws from National Disaster Management Authority (NDMA), Ministry of Health and Family welfare (MoHFW), National Board of Accreditation of Hospitals (NABH), Clinical Establishment Acts, National Building Codes (NBC), Joint Commission International (JCI) and World Health Organization (WHO - Standards).

4. COMPONENTS OF HOSPITAL DISASTER PLAN

It is advisable that the Hospital Disaster Management Plan is divided into thefollowing sections:

• Section I - Introduction
• Section II - Responsibilities
• Section III - Action Plan
• Section IV - Checklists
• Section V - Rehearsal / Drill Plan and Schedule

In the process of preparation of HDMP the division of responsibilities during emergency is done in a way that clarifies.

- ***Role of Person within the Department***
- ***Role of Department within the Hospital***
- ***Role of Hospital within the Community***

Rather than documents, charts are always preferred for making the task simpler, making standard operating procedures for the following staff working in the hospitals to let them know what exactly needs to be done during emergencies, should be included in the plan. The SOPs should be included and pasted in their respective work areas. “in case of emergency” tag for-

- Doctors (Emergency Room and other specialists)
- Nurses
- Pharmacist
- Administrators
- Finance
- HR department
- Security
- Support staff
- Maintenance team
- Volunteers
- Reception/ registration

5. BUILDING HEALTH RESILIENCE

Protecting the lives of patients and health workers by ensuring the structural resilience of health facilities come under Building Health resilience; The loss of

lives in case of hospitals can be due to two main factors – one, due to structural failure, that is collapse of building or parts of the building itself, and second, due to falling hazards. Falling hazards are caused by non-structural elements of the building like partition walls, glass windows; by furniture and storage racks that may fall over people, equipment and other vital infrastructure that may break or get destroyed. Both-structural failure and falling hazards can potentially cause injury or even death for building occupants. They can block exit routes preventing timely evacuation. Thus protecting lives from such causes would entail measures that include-Strengthening building parts using appropriate retrofit technologies; Ensuring that new buildings are made using disaster resistant technologies and ensuring infrastructure within the building is firmly secured. This would ensure buildings are safe and the occupants are protected. Equally important would be to ensure that even if the buildings do not collapse, the occupants are still protected from falling hazards. Furniture and equipment need to be laid out in a manner that can prevent injury. Evacuation routes should be clear and easy to identify. These measures require investments in time and monetary resources. However, they yield maximum returns in protecting lives within the hospital thus ensuring their continuity and capacity to handle serious disaster situations.

Make sure health facilities and health services are able to function in the aftermath of emergencies and disasters, when they are most needed; and ensuring functionality: During the event of disaster, it is required that by all means the critical functions such as the Intensive Care Unit, Operation Theatres, incubators for infants, and other such critical services remain functional, not only for handling mass casualty situations, but also for occupants who are already present at the time of disaster. Contingency plans to ensure functionality would comprise set of actions for disaster preparedness. These actions constitute critical decisions taken by the Hospital Management through prompt and efficient communication, on ensuring that the hospital is ready to handle surge of patients.

Improve the resilience of both hospitals and healthcare workers including emergency management. Hospitals need to be aware of the potential risks and hazards as well as measures that are needed to reduce them. This translates in terms of knowledge and training to staff and workers to act sensibly and as per the predefined protocols during the time of emergency. With good capacity to handle crisis situations, hospitals are able to recover rapidly and thereby able to reduce potential loss of lives in the community and also rapidly return to their usual business and avoid financial and infrastructure loss.

6. MONITORING AND IMPLEMENTATION

Recently NDMA has also issued a monitoring checklist to the states to ensure the implementation of NDMA hospital Safety Guidelines. Category of Hospitals

included in the same are Govt hospitals, Semi Govt/ Trust Hospitals, Private Hospitals, Nursing Homes, Medical Colleges, Research Institutes, CHC, PHC, UHC, RHC, DH, Primary, Secondary, Tertiary Care Hospitals, AYUSH Hospitals, Special Hospitals (Tb/Mental/ Infectious Disease/ Trauma Centres/ Maternity Care Home/Referral Centres/ ESI / Diagnostic Centres / Railway / Public Health Facilities And Others.

It also ensures to monitor whether the implementation has the Hospital Safety Advisory committee constituted at the state level? Has the State submitted the state action plan for the implementation of the guidelines?

Focus on series of levels of interventions is required at the district and hospital level like .

- Number of Districts where Hospital Safety Advisory Committee has been constituted.
- Number of hospitals that have prepared their Hospital Disaster Management Plans (HDMP's).
- Number of hospitals that have conducted safety audits both a) Structural and b) Non-structural.
- Number of hospitals which have conducted annual Hospital Safety Mock Drills.
- Number of hospital which have obtained annual NOC from Fire Dept.
- Number of hospitals which have obtained / renewed accreditations.
- Number of hospitals/ Medical Colleges where Disaster management is taught as a part of their curriculum.
- Number of Hospitals where hospital staff have undergone regular training on Hospital safety and Disaster preparedness & Life and Fire Safety.
- Any major Initiative on Hospital Safety or emergency preparedness like preparedness of Mass Casualty management Protocols/ District level Coordination networking exercise among hospitals/ Workshops/ ratings of health facilities/ Geo-tagging of health facilities.
- Does the Districts have in place action plan to deal with major disease outbreaks, mass casualty incidents, Public Health emergencies, Mass gatherings etc.

Such an extent of monitoring mechanism slowly and steadily ensures the overall increase in awareness and encourages states, districts as well as hospitals to ensure their own as well as patient safety. This also enables mechanisms to

identify gaps, effective resource sharing and sharing of best practices among the healthcare organisations.

The focus is not just to ensure the compliance in metro cities but also to ramp up the preparedness in semi and peri urban areas as well as rural areas to boost uniform capacity development.

7. CRITICAL IMPORTANCE OF HOSPITALS AND LINKAGE WITH LONG TERM RESILIENCE

Hospitals are symbol of faith for the communities. They are not only expected to provide a good medical care but also be in a position to offer critical assistance to local communities at the time of disasters. It is, therefore, absolutely vital that they remain functional at the worst of the times. To ensure this, the lives of health staff, equipment, drugs and the buildings must be secured at all costs. Moreover, disasters that damage health systems affect a country's ability to achieve the UN Millennium Sustainable Development Goals. Gains in development and access to health-care services are seriously compromised when disasters occur.

Several initiatives on Hospital Safety and Medical Preparedness supported by NDMA highlight the emphasis on securing the most essential critical infrastructure. The hospitals also prepare and enable them to deliver more exceeding health care needs in testing times of disasters. In its efforts towards ensuring the structural and functional safety of hospitals so as to minimize risks to human lives as well as critical healthcare infrastructure during and after disasters, contextualizing the need for hospital safety as a national priority in the overall scheme of Disaster Risk Reduction (DRR) initiatives, there is a need to coordinate with all stakeholders to make public health infrastructure risk resilient. In this regard, the role of NDMA guidelines on Hospital Safety for preparing Hospital Disaster Management Plans is quite vital.

Sharing information and experiences in implementing hospital safety and preparedness programmes, the need and importance of hospital simulation exercises to address issues relating to patient safety in disaster situation is crucial. The concept of structurally safe and energy efficient green hospitals, have been increasingly gaining importance across the country as a holistic approach to hospital resilience relating it with DRR, Sustainable Development Goals (SDGs) and Climate Change Adaptation (CCA) frameworks. The need to strengthen hospitals by way of regular capacity building training, exercises, existing training programmes and a road map to standardize the same as per the NDMA guidelines is required.

8. WAY FORWARD

- Health sector networks preparing and implementing the regional model of hospital safety will play an important role in long term capacity building in health sector as well as developing resilience of healthcare facilities.
- Customized module for training and capacity building as per the NDMA guidelines for three basic categories like hospital administrators, doctors, nurses, security, and other staffs needs to be rolled out and developed, this module should cover the skill matrix and the minimum knowledge requirement for the particular cadre of healthcare staff. This also ensures the integration of incident management system within the hospital and focuses on the concept of "who needs to do what when and how?" during the times of disaster and minimises confusion.
- Awider database of tools, websites, mobile applications and other repositories to facilitate the preparation of hospital disaster management plans inline with the district disaster management plan needs to be developed.
- A comprehensive database and decision support system with GIS mapping of healthcare facilities, real time bed capacity, stock inventory, patient database, online support, health sector networking will slowly emerge as a virtual health sector emergency preparedness and planning platform.
- Our country and regional level real time response capacity should showcase and minimum baseline data which would also ensure adequate and timely response as well as speed up post disaster need assessment and enhance reconstruction and recovery process.
- A long time gap analysis also aid better planning of healthcare infrastructure, spread and distribution of Healthcare facilities, adequate and timely management of human Resource elements and its efficient use for the betterment of the communities.
- Health sector emergency preparedness and planning and efficient Hospital disaster management planning in long run will help significantly in reducing the mortality and morbidity post disasters, efficiently manage the mass fatality situations.

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Chapter 17

EXTREME WEATHER EVENTS, ITS EFFECTS AND HEALTH RESILIENCE

Priyanka Singh and Saurabh Dalal

ABSTRACT

Those from the most vulnerable sections of society often confront environmental ills. Climate change has the potential to influence the earth's biological systems and health. With high population density, India might experience grave human health effects because of climate change. These effects could include shifts in patterns and timings as well as intensity of infectious diseases such as malaria, chikungunya, and water-borne illnesses as well as emergence of newer diseases and pathogens, which were not potentially endemic within a country earlier. Monitoring the spread of infectious diseases will require early warning systems, which have both health and economic benefits. Public health and health care systems must understand these impacts to properly pursue preparedness and prevention activities,this has been evidently elaborated with a case study on India's efforts to effectively deal with health related impact of Heat waves. All of health aspects will very likely to be affected and certain medical specialties are likely to be more significantly burdened based on their clinical activity, ease of public healthcare access and public health roles. capacity building and health sector preparedness need to be strengthened for multi-layered social resilience framework to emphasize the interactions between enabling factors and capacities operating at different levels of society/community.

Keywords: *Climate change, infectious diseases, early warning systems, Public health, health care systems, medicine, Health sector Preparedness, resilience framework, Air pollution, Heatwave, Extreme Weather events.*

Priyanka Singh✉
Consultant, Capacity Building in Public Health Emergency Management, National Institute of Health & Family Welfare, New Delhi, India
drpsinghdalal@gmail.com

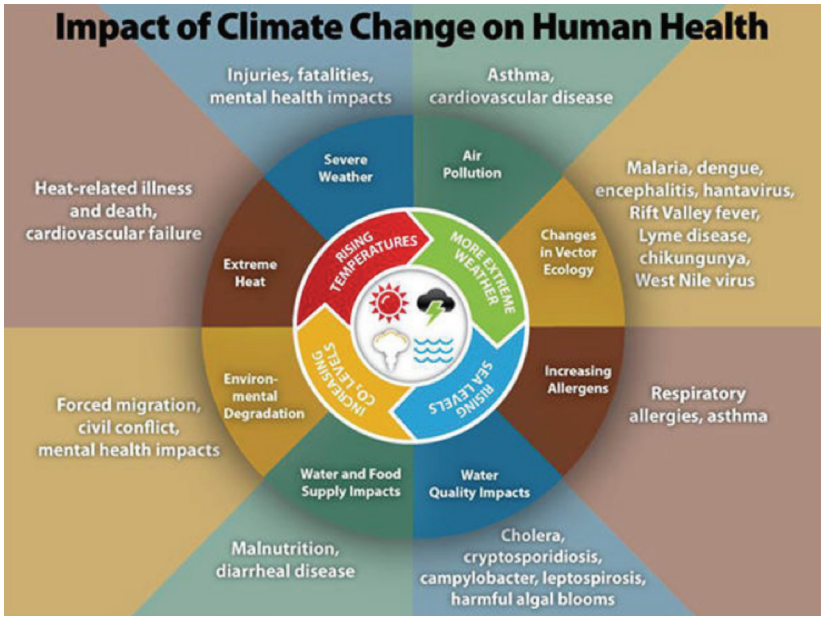
Saurabh Dalal
Public Health Emergency Management Fellow, Centre for Disease Control and prevention, Atlanta

1. INTRODUCTION

Climate change effects are emerging as asevere public health issue in all countries, which usually happens due to manmade activitieslike fossil fuel combustion-identified as main cause of the climatic change observed since early twentieth century. The effects of these activities are disrupting the environment on which we all are dependent, which lead to threaten our collective future through very serious effects on health of human as well as animals.

Pattern of health impacts from climate change is already recognized i.e. Increased cardiopulmonary episodes, infectious, allergic, cancerous and mental illnesses. On the same time climate change leads to disaster like flood, drought, earthquake, avalanches, land sliding, tsunami and cyclone which ultimately cause various type of diseases for instance, waterborne disease, vector borne diseases, fractures and other weather related injuries.

The impacts related to air pollution, infection occurs due to water and food contamination, disease spread through animals (carrier) and extreme weather events have been amplified in the present scenario. Old age, chronically ill patients, disabled people, pregnant woman and children are more prone to said infection and diseases. Food and drinking water issues, socio-economic loss, political, migration, instability and conflict highly disrupts human life and public health.



Sources: Climate Effects on Health-CDC, Atlanta https://www.cdc.gov/climateandhealth/effects/default.htm September 9, 2019

2. LINKAGES: CLIMATE AND HEALTH

There are three major linkages of transmission of infectious disease with climatic variations.

First - Associations between local weather variability and infectious ailment occurrences, which are already, present in the environment.

Second - Early indicators of already-emerging infectious outbreaks and their impact due to long-term local weather change.

Third - making use of the above proof to create predictive models to estimate the future burden of infectious diseases in view of projected climate change scenarios

As per Indian scenario, farmers are largely dependent on monsoons for the agriculture, a large part of India, undoubtedly even share markets may vary due to the same reason, henceforth the country's economy and food security disrupts if monsoons fail. However, global warming affects the weather system, which affects the all categories of the farmers and all those who depend on agriculture for their livelihood. Possible effects of climate change on fresh water supplies, food and agriculture and human health in the event of 1-50 C rise in temperature are given in Table 2.

Type of Impact	Eventual Temperature Rise Relative to Pre-Industrial Temperatures				
	1°C	2°C	3°C	4°C	5°C
Freshwater Supplies	Small glaciers in the Andes disappear, threatening water supplies for 50 million people	Potential water supply decrease of 20-30% in some regions (Southern Africa and Mediterranean)	1-4 billion more people suffer water shortages Serious droughts in Southern Europe every 10 years	Potential water supply decrease of 30-50% in Southern Africa and Mediterranean	Large glaciers in Himalayas possibly disappear, affecting ¼ of China's population
Food and Agriculture	Modest increase in yields in temperature regions	Declines in crop yields in tropical regions (5-10% in Africa)	150-550 million more people at risk of hunger Yields likely to peak at higher latitudes	Yields decline by 15-35% in Africa Some entire regions out of agricultural production	Increase in ocean acidity possibly reduces fish stocks
Human Health	At least 300,000 die each year from climate-related diseases Reduction in winter mortality in high latitudes	40-60 million more exposed to malaria in Africa	1-3 million more potentially people die annually from malnutrition	Up to 80 million more people exposed to malaria in Africa	Further disease increase and substantial burdens on health care services

Table 2: Possible Effects of Climate Change
(Sources: Stern, 2007; IPCC, 2007)

Weather conditions play a very important role in transmission of vector-borne & waterborne diseases to a significant extent. In areas of western Rajasthan and Gujarat, malaria epidemics have often followed by flood or heavy rainfall. In parts of eastern UP, the recurrence of Japanese encephalitis has been a threat to public health. Emergence of novel strains of bird flu and swine flu as well as genetic mutations in characteristics of expressions of re-emerging pathogens have increased a significant burden on health systems.

3. CASE STUDY: INDIA'S SUCCESS STORY IN REDUCING PREVENTABLE DEATHS FROM HEAT WAVES – A SILENT DISASTER.

Extreme heat waves are becoming common worldwide phenomenon because of rising average global temperatures which are increasing by nearly a degree centigrade per decade. This weather pattern, coupled with El-Nino effect, is increasing temperatures in Asia with weather experts in India warning that rising temperatures will lead to more floods, heat-waves, storms, rise in sea levels and unpredictable farm yields. Climate change is causing increase in extreme weather events as well as severity and frequency of natural disasters. Global climate change will necessarily be accompanied by increased frequency and intensity of heat waves, as well as warmer summers and milder winters. Predictive modelling studies, using climate scenarios estimate an increase in future temperature-related mortality. Public recognition of the magnitude of hazards is rising due to warming climate and increasing frequency of heat events. However, there are areas of concern:

- Lack of health surveillance data to ascertain magnitude of vulnerability.
- Inadequate preparedness measures that weaken administrative systems that support heat wave response plans.
- Lack of community awareness.
- Poor understanding of the web of interactions between ecosystems, climate and human societies and how it can influence occurrence of disease and infections.

Increased occurrence and severity of heat-wave induced conditions is a wake-up call for prevention, preparedness and outreach to save lives of masses, livestock and wildlife. Indian government's target of zero deaths due to heat waves endorses the conviction that prevention is possible. In 2016, national action plans were launched with guidelines, especially for cities which were vulnerable to heat-waves. The death toll from intense heat that strikes India each year between March and July has dropped drastically over past three years. From 2422 deaths in 2015 to 22 in the first 7 months of 2018.

In 2015, over 1,700 people died in Andhra Pradesh. In response to the tragedy, the state developed interagency coordination across health, labour and

transport departments, as well as set up 1168 stations for weather forecasting and modelling. Other states like Telangana in the south and Odisha in the east developed heat action plans and local thresholds to analyze vulnerability of communities.

Intense and sustained efforts for reduction in mortality were initiated with the National Disaster Management Authority (NDMA) setting a target of zero deaths from heat waves. A national level action plan was formulated in the summer of 2016 with guidelines on managing heat waves. The commitment to ensure no one dies due to a heat stroke was backed by policy frameworks, guidelines, technologies and location specific plans. Vulnerable states, cities and districts were identified and interventions carried out across all cross-sectional levels translating policy to pubic interface. Indian Meteorological Department (IMD) for temperature /weather forecasting, National Centre for Disease Control – Integrated Disease Surveillance Programme for reporting and surveillance of Illnesses and deaths, state and district disaster management mechanism and other stakeholders were assigned specific roles and responsibilities to handle and be prepared for upcoming seasons.

The emphasis was on: developing national and sub-national level Heat Action Plans: State and city governments prepared heat action plans taking into account inter-agency coordination, early warning messages, area specific temperature thresholds, painting roofs white to reduce heat absorption, adjusting working hours to avoid exposure in extreme hot weather periods, opening drinking water kiosks, ensuring uninterrupted supply by water tankers, opening special shelters, unlocking gates of public gardens during the day, launching media awareness campaigns, stepping up medical preparedness measures, incorporating real-time research data, encouraging a culture of innovation and developing other low-cost measures.

The primary modes of interventions that yielded results were.

- Focusing on health vulnerabilities: Case fatality ratio was assessed and evaluated along with death-to-illness ratio and other aspects of health vulnerabilities. The IMD warned that higher daily peak temperatures were getting longer with more frequent and intense heat waves striking not just traditionally known hot areas but even where temperatures had been relatively lower.
- Launching aggressive awareness campaigns: These reiterated common-sense measures like staying hydrated or covering one's head before venturing outdoors during daytime, through posters as well as social media platforms. Using media to promote basic awareness: print and electronic media along with news and mobile alerts can be used through targeted interventions, keeping in mind how perceptive the community is. Also, if it can yield better results in sensitizing general population on health and climate change.

- Reducing heat related illnesses: There was growing realization that while it is critical to move towards the goal of zero deaths on account of heat waves, it was as important to reduce heat related illnesses. City officials worked with community leaders to combat heat waves by giving out suitable warnings, preparing hospitals and emergency response systems and building robust community awareness programmes. There was greater emphasis on systematic research on climate change phenomena and adaptive techniques or human exposure to climatic extremes in addition to scientifically generated experimental data from heat-exposed working populations, with reference to morbidity of heat disorders and heat stress.
- Developing multi-sectoral perspectives: Livelihood, livestock management, agriculture, labour, transport and farming can benefit from global indicators like forecast and modelling, Wet Bulb Globe Temperature, use of heat stress sensors and now casts. These are being increasingly applied to intensify efforts to combat future heat wave impacts.
- Measuring success of the heat wave related initiative: This can be gauged with the response of a common man in any of the cities/ district which is frequently affected by heat waves when she can immediately identify the yellow, orange and red alert signs to denote the intensity and what he and others must do to stay safe.

4. SOLUTIONS, ALTERNATIVE AND ADAPTIVE SUSTAINABLE STRATEGIES TO REDUCE IMPACT

The strategies identified by international organizations such as the Intergovernmental Panel on Climate change (IPCC) and World Health Organisation (WHO), also by national and sub-national health agencies aims to reduce the effects of climate change. Largely health changes may be accomplished through well-designed version of policies that will decrease the health risks or improve health outcomes directly or indirectly. It will happen as adaptation strategies that will help in creating health benefits beyond the scope of the initial targets of health improvement and not just focussing on the treatment side a larger emphasis needs to be laid on preventive and mitigation aspects as well as strengthening the public health infrastructure to deal with emerging threats.

On the contrary, adaptation measures may cause risks to health if, not well planned and implemented according to human health considerations. These evaluations on health systems are to recognize that how adaptation techniques undertaken via public health authorities can affect the health and fitness of the population. These records will utilize in the manner of decision-making to sorting out the improvement and execution of particular measures to guard humans from the effects of local weather changes.

The recent example of how India managed heat waves and brought down the number of deaths to a significantly low, by series of policy to ground level

interventions and methodically updating the action plan based on scientific evidence, lessons learnt and research bases is a classical example of risk reduction effort to mitigate impact of climate change on health.

Still there is need of a comprehensive assessment of risk analysis of local weather trade vis-à-vis health adaptation strategies to improve social capital as major aspects of efforts to address environmental change. Systems, for example, expanded or improved shade and green spaces, well-organized street plan, the creation and support of bicycle ways, and improvement to open transportation are recommended by the law and government, Usage and promotion of green and plastic free sustainable solutions, setting up targets to achieve reduction in carbon emissions, sustainable planning strategies and advocating a better quality of life enhances overall health indicators and reduces public health burden. Green spaces have additionally appeared to add to flood chance relief thus can improve network security. The subsequent profits by these adaptive measures can have both prompt and long term positive effects on general wellbeing and financial outcomes.

Methodologies to lessen heat stress by tending to the urban heat island impact (e.g., expanding green spaces, decreasing warmth retaining concrete or cleared surfaces) and to diminish air contamination by updating transportation foundation (e.g., fabricating more bicycle ways and more brilliant street frameworks) and through better urban planning (e.g., densification, walkable neighbourhoods) may likewise essentially diminish noxious gases. These interventions helpto reduce the speed of environmental change and its associated health effects.

5. THE ROLE OF THE HEALTH SECTOR

The wellbeing segment has the essential job in securing the wellbeing and prosperity of population from the effects of environmental change. This incorporates both the preventive and treatment capacities that are under direct control of the health department.

In the course of the most recent 25 years, WHO has created and scaled up its programme on environmental change and wellbeing with an expanding centre around working with national Ministries of Health, and different accomplices like United National Environmental Programme (UNEP) and World Meteorological Organisation (WMO), to support and guide national governments to develop and work on comprehensive strategies. Countries are currently laying out a more precise and far reaching way to deal with wellbeing assurance from environmental change. Environmental change contrasts from numerous traditional medical problems, which is subject to various vulnerabilities, depending on social and financial determinants.

The work of strengthening the health systems does not depend solely on health departments but also comprehensively on other sectors. It subsequently

requires an action that expands on better healthcare system capacities and capabilities. Health systems needs to evolve over a period of time in lieu of upcoming global polices and frameworks like Universal Health Coverage, International Health Regulations, Global Health Security Agenda and other regional and global derivative frameworks. Its also high time that health systems do not repeat the mistakes of past and learn and devise their policies from global lessons learnt.

6. CONCLUSION

- The health department needs to involve meteorological department to plan for multi-hazard disaster plan to deal with the emergencies occurring due to any disaster.
- Public health programmes needs to be revised or changed not just limiting it to disease but covering the climate change aspects as well.
- The health department and the meteorological department should workout to devise methods to translate temperature and other meteorological parameters into action based standard operating procedures that can be widely circulated and easily understood by medical doctors.
- It should be ensured that the participation of community and other stakeholders exist in the area.
- Civil society should be empowered so that strengthening of community-based risk reduction can be developed and implemented in the regional all-hazards health emergency and disaster risk management projects according to the climate change and risk.
- New advancements are now changing the manner in which medicinal services are overseen in numerous nations around the globe, from inventive e-Health information the board frameworks, tech based processes, customized information observing, and medicinal advancements with lower vitality necessities. Some of these advancements have the additional advantage of improving the versatility of the healthcare systems, diminishing its ecological effect.
- Healthcare systems can plan their programmes as per environmental variability, by including the risk reduction and mitigation measures for cost effectiveness, and improvement of patients care.
- Not just healthcare, but a comprehensive planning strategy is needed to be well though upon to combat and nullify the impact of climate change on human health.
- A sustainable model for healthcare which is far reaching as well as cost effective can be built by focussing not on the traditional treatment aspect but also largely promoting and incentivising holistic and preventive aspects taking into consideration future climatic risk, lifestyle related issues and long term behavioural change.

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Chapter 18

KEEPING HEALTH FACILITIES FUNCTIONAL DURING AND IN THE AFTERMATH OF DISASTER EMERGENCIES: A CASE OF KERALA FLOODS 2018

Mohd Mudassir, Hari Kumar and Pranav Sethi

ABSTRACT

The paper presents a case study on the Kerala floods of 2018, its impact on hospitals including safety as well functionality of hospitals, during and post flood situations. The recent flooding in Kerala affected as close to 332 health facilities, 61 Ayurveda institutions and 59 homeopathic centers as per Post Disaster Need Assessment (PDNA) report developed by UNDP. If a major community hospital is out of service during and after an emergency, it renders the community without proper health care, exacerbating a number of mortalities, morbidities, disabilities and other social and economic losses. Thus, it is critical that hospitals continue to function during and post disaster situation, as the community rushes to the nearest hospitals. However, to ensure the continuity of essential services and respond to mass casualty incident, the functionality of a hospital depends on several factors. The staff should be safe and be prepared to take in patients; medical equipment should remain operational; critical utilities (water, electricity, medical gases etc.) should not be affected by disasters; hospital buildings should be able to withstand disasters by ensuring structural safety of critical departments; and hospitals should have a robust climate preparedness and response plan etc. to help manage mass casualty incidents.

Keywords: *Hospitals Safety, Functionality, Kerala Flood, Climate Change; Health.*

Mohd Mudassir
Disaster Risk Reduction Specialist, GeoHazards Society, New Delhi, India
mudassirkhanafz75@gmail.com

Hari Kumar
President of GeoHazards Society, GeoHazards Society, New Delhi, India

Pranav Sethi
Disaster Risk Reduction Specialist, GeoHazards Society, New Delhi, India

1. INTRODUCTION

Climate change and its impact on health has become a matter of serious discussions globally. The intergovernmental panel on climate change (IPCC) defines climate change as any change in climate for a long term which is caused by human activities or natural imbalance (T.F. Stocker, 2013). Health sector (especially hospitals) is one of the sectors affected by climate change. India is not an exception to this and has witnessed various climate emergencies ranging from heat wave, cold wave, tsunami, cyclone, rains and floods etc. in the past. Climate change in the form of extreme weather events have dramatic impact on the health of people, especially living in coastal areas. Kerala, which is one of the coastal states of India is prone to multiple hazards due to its unique location in between the Western Ghats and the Arabian Sea. In the 2018 unprecedented floods, twelve out of fourteen of the districts were affected leading to the worst flood disaster in the State since 1924. The life losses would have been much more, had it not been for the swift responses by the National and State Governments, uniformed forces, NDRF, dynamic bureaucrats and an aware community willing to help and be helped.

The incessant rains from August 14th to 17th, 2018 caused significant amount of damage in the state of Kerala and also induced a number of landslides. Between the floods and the landslides, so many people lost their lives. The health sector also suffered badly causing substantial impact, as close to 332 health facilities were fully or partially destroyed. Furthermore, 61 Ayurveda institutions and 59 homeopathic institutions were damaged as a result of the floods. The total damage to the health sector is estimated at INR 273 crore for health, which is mostly of health facilities. The total loss of the sector is estimated at INR 26 crore. The total recovery cost of health would come to INR 447 crore (UNDP, 2018).

2. IMPORTANCE OF HOSPITAL FUNCTIONALITY

Hospitals have a critical role in a post-flood scenario as a number of people with a range of injuries will be converging in the facility. In a hospital, which overflows with patients and bystanders even in normal times, such an influx will be difficult to handle if incapacitated by structural and non-structural losses due to a disastrous event.

The loss of critical services during emergencies and disasters severely lessens the possibility of saving lives and reducing other health consequences. Thus, it is critical that hospitals continue to function during and after disastrous events since the community rushes to the nearest hospital for medical assistance when emergencies occur, expecting it to remain functional. Hence, it is important to assess the level of safety and functionality the hospitals will be able to provide before a disastrous event occurs.



Figure 1: Elements of functional hospital, GeoHazards International, 2010

As the figure (1) above denotes, for a hospital to remain functional in a post disaster scenario especially to respond to a mass casualty situation, several aspects have to remain functional. The buildings have to remain safe and unaffected. The staff should be safe and prepared to take care of the in patients and to receive mass casualty situations. Critical medical equipment should not be affected by hazards and be functional. This will also depend on the functionality of the critical utilities-Electric supply, Water supply and Medical gases supply. During Kerala floods, it was reported that many hospitals in the Kochi district had to postpone routine operations and OPD as the hospitals ran out of oxygen supplies and have limited stock of fuel to operate generators (Devasia, 2018). One of the many cases is from Lisie hospital, which had to cancel surgeries as the hospital did not have diesel availability and enough oxygen supplies (TNN, 2018). The hospital gets supplies of oxygen from Bengaluru, and the vehicle got stuck in Thrissur due to cut off of the road. In many other cases, it was reported that hospitals were running mostly on generators as the Keara State Electricity Board (KSEB) has shut down several transmission units due to the severe floods.

It is important to note that there have been many initiatives by the Government of India to ensure the safe functionality of the hospitals. A few of the initiatives have been highlighted on the legal mandates undertaken by the Government of India that focus on various aspects of hospital safety and functionality. The National Policy on Disaster Management 2009 on Medical Preparedness and Mass Casualty Management considers medical preparedness a crucial component

of any DM Plan (NDMA, 2009). The National Disaster Management Guidelines on Medical Preparedness and Mass Casualty Management also emphasizes on hospital disaster management planning at the hospital level. The National Disaster Management Guidelines on Hospital Safety highlights "Each hospital shall have its own Hospital Disaster Management Committee (HDMC) responsible for developing a Hospital Disaster Management Plan (HDMP)" (NDMA, Hospital Safety, 2016).

3. HOSPITAL DISASTER PREPAREDNESS IN KERALA

At present there are 1,283 health institutions with 37,945 beds and 5,887 doctors under Health services department consisting of 682 PHCs, 170 Family Health Centers, 224 Community Health Centers (CHCs), 86 taluk headquarters hospitals, 18 District hospitals, 18 general hospitals 3 mental health hospitals, 8 women and children hospitals, 3 leprosy hospitals, 18 TB clinics, 2 TB hospitals, 5 other speciality hospitals and 46 other hospitals in Kerala State. PHCs are institutions providing comprehensive primary care services including preventive and curative care. CHCs and taluk level institutions form the basic secondary care institutions. District hospitals, general hospitals and maternity hospitals provide speciality services and some super speciality services (Kerala, Economic Review, 2018).

The floods of 2018 was way beyond the health system preparedness and resources, as the scale of the disaster was unlike any other in the past 90 years. Health care institutions themselves suffered complete/partial destruction and loss of equipment and supplies. The health department worked in co-ordination with the rescue efforts at all levels. Many hospitals, both government as well as private in Ernakulam, Pathanamthitta, Thrissur and Alappuzha districts were directly hit by flood. The functioning of hospitals were severely crippled as the flood water entered in the hospital's premises. Several hospitals had to postpone surgeries and evacuated patients and staff (Devasia, 2018).

As the concept of hospital safety towards climatic hazards is emerging in the country so is it in Kerala. After the 2018 floods, there is a concerted effort through the Rebuild Kerala Programme to assist hospitals to develop and test disaster management plans. (Kerala, Rebuild Kerala Program, 2018). As of now, Kerala is the only state in India that has trained medical and non-medical personnel on disaster preparedness planning followed by hospital disaster management plan of all the 14 district major hospitals under hospital safety program carried out by Kerala State Disaster Management Authority (KSDMA), Directorate of Health Services, Govt of Kerala and UNDP with technical support from GeoHazards Society, India.

Despite this fact, the response to crisis was one of widespread and selfless public actions by the administration and citizens. The spontaneous social commitment and the spirit of fraternity shown by fish workers and youth, who

led some of the most heroic rescue and relief efforts, were exemplary. The speedy, meticulous, and people-oriented handling of crisis by the State has won admiration from other parts of India and the world (Economic Review, 2018).

As it has been largely observed in various disastrous events in the past that no single hospital, even a big one, cannot provide optimal care to all affected communities. At the same time, affected patients cannot be deprived of admission in the hospitals. In this situation, networking becomes very important that helps one hospital transfers patients, procuring medical equipment and bringing in human resource from other nearby hospitals to ensure optimal care of patients. The similar cases were reported during flooding in Kerala, for example, Aster Medcity shifted all its patients to nearby hospitals as a safety precaution. The doctors from Aster Medcity reportedly shifted 350 patients to nearby hospitals as they had to cut off power supply (P Nair 2018). Moreover, the reason Aster Medcity shifted patients to nearby hospitals was due to the fact that generator of the hospital was kept in the basement that got flooded affecting functionality of the hospital. The CIMAR Fertility Centre and Paravur Taluk hospital have also shifted many of its patients to nearby hospitals. Amrita Institute of Medical Sciences has consolidated medical and surgical patients on one floor and discharged some patients to a hospital's guest house.

The hospitals that were located at the high latitude have received patients more than their existing bed capacity. These hospitals converted their wards / units into treatment areas. The Government Medical College in Ernakulum has arranged three ICUs at its burn unit (MK Sunil, 2018). Hospitals also reported shortage of staff as the strength of paramedical staff went down given that many of them either were in the relief camps or stranded in the flood. Staff shortage was considered one of the major challenges as only 30-35% staff was present, while bed occupancy was reported at 80% - 90% (P Nair, 2018). Local volunteers and private hospitals were contacted to overcome staff shortage problems. The mass casualty management of hospitals shows reasonably better level of preparedness as many hospitals were not well prepared to take in patients, but the dynamic link between various hospitals for augmentation or optimization of available resources made it possible.

It is to be highlighted that there was no epidemic outbreak following the floods as many hospitals mobilized their medical team to respond to the affected communities. However, many suspected and confirmed cases and including deaths were reported due to leptospirosis after the flood water has started to recede. Leptospirosis is a bacterial disease also known as rat fever. It caused 246 cases (14 deaths) in August, 854 cases (41 deaths) in September, and 208 cases (6 deaths) in October 2018 (Kerala, Data on communicable diseases, 2018). The Directorate of Health Services of Kerala put up an action plan for the post-flood control of leptospirosis. Hospitals have also played an important

role in reporting leptospirosis cases and deaths, which enables authorities to better implement disease control measures. Health authorities also marked out special sites within hospitals to isolate and treat leptospirosis patients (M Ramanathan et. al, 2018).

4. RISK MITIGATION

Kerala is known for its robust healthcare system - maternal mortality rate here is 61 deaths per 100,000 live births (India average is 130) and neonatal mortality rate is 6 deaths per 1,000 live births (M Ramanathan et. al, 2018). The concept Navam Kerala given by Hon'ble CM embedding idea of building green and resilient Kerala is an important initiative towards hospital risk mitigation. The PDNA also focuses on this idea through adequate budget and required resources for those hospitals that are located in hazard prone areas. Multiple risk mitigation goals are being envisaged. The short term plan highlights to focus on training and building capacity of health professionals, developing hospital safety plans etc. The emphasis in medium term plan envisages improving access by restoring damaged health facilities and advocating DRR to make health sector resilient. The long term risk mitigation plan underlines to bring about change in the health sector reforms, formulation of health sector plans and inculcate the culture of safety and resilience. A new program focuses on constructing and retrofitting health infrastructure in hazard-prone areas to increase safety and also to develop a model law to insure all critical infrastructure including hospitals (Kerala, Rebuild Kerala Program, 2018). The action to build a green and climate resilient health infrastructure is well envisaged. As Kerala experienced such natural hazard after nearly 100 years. It is usually common to see that when disasters are not experienced for a long period of time, it leads to the development of a perception of low risk among communities and other stakeholders. When the community largely remains unaware, the critical sectors (e.g. hospitals) also remain unsafe and unprepared causing unprecedented losses. Hence, it is important to conduct multi-hazard risk and vulnerability assessment of those hospitals located in hazard prone areas. The green hospital approach has been visualized that could be extended beyond the 482 damaged Allopathy hospitals to the reconstruction of the 1219 Anganwadi Centers (PDNA, 2018). There are efforts being pulled to bring about shift in the concept of safe hospital to a smart hospital by linking structural and operational safety with green interventions in Kerala.

5. RESPONSE – A CASE OF GENERAL HOSPITAL, ERNAKULUM

The case of the General Hospital Ernakulum (GHE) is interesting to highlight with respect to hospital response during and the post flood situation. The hospital formed a Rapid Response Team in 2010 that has put concerted efforts during 2018 floods and was awarded by the District Medical Office, National Health Mission, Ernakulum, for the outstanding services rendered in the flood relief

and epidemic control activities. The following findings are based on a personal interview with Nodal Officer for Trauma Care, General Hospital, Ernakulum.

As soon as torrential rains and the news on dams being opened were reported, a district control room was shifted to Pathadippalam. On 15th and 16th August 2018, key staff members from GHE were present at the Pathadippalam guest house. A Rapid Response Team (RRT) was formed and first dispatched to Aster Medicity Hospital where flood water had started entering. The RRT team evacuated most seriously ill and patients on ventilators, and shifted them to a nearby hospital. The same night, RTT received a call to evacuate Varapuzha CHC from where they evacuated 29 patients, mostly bed ridden, to Sree Sudhindra Medical Mission Hospital. Just 4 hours later, the entire hospital flooded and the timely action of the RRT was appreciated.

On the 17th of August, the team was also dispatched with essential medicines, foods and lifesaving support systems to Puthenvelikkara and Kadungalloor area near Alwa that were totally isolated since last few days. However, the team could not reach due to high rise level of water, but on the way back, the team treated a person who was suffering from epilepsy and throwing seizures. The team managed the patient on the road itself by inserting IV cannulas and administering Inj. Eptoin.

On the 17th afternoon, the team rushed to help evacuate North Paravur Taluk hospital; 6 patients were shifted to GHE, of the two were in labor pains. One had delivered at labor room at GH few minutes after reaching there.

As the high demand of medical services after any disaster incidents can be anticipated, GHE also expected the need of services to rise, and therefore decided in the mid night of 17th August to set up a 24x7 Medical Control Room at press conference hall of GHE. On the 18th morning onwards, medical relief center 24x7 started functioning in full-fledged manner. Since, GHE ran short of medicines and human resources, requests for the same were put on social media to mobilize resources and essential medicines. The requests received overwhelming responses. Dr. Junaid Rahman, currently working as medical superintendent of Sree Sudhindra Medical Mission Hospital mobilized medicines worth 4 lakh rupees and Cochin cardiac forum donated Rs 1 lakh for procuring medicines. Medicines worth 10 lakh were mobilized from Karunya Medical Store by Dr Mathews Numpelli, DPM. Since the helpline number went viral on social media hence many requests for rescue also came, which were reported to district control room. For rescue requests, the team asked for the latitude and longitude of the location of the callers, which was sent by Whatsapp and then forwarded to the navy.

Most of the medicines that reached GHE came in loaded trucks with the total of 360 loads of trucks during flood times. The RRT team has done excellent work to unload the trucks as no usual method was available during such time.

The work of sorting medicines, checking expiry dates followed by packing up these medicines in order to distribute them to various relief camps etc. were carried out by the team efficiently. Sorting and packing of medicines was uninterruptedly done by 200 peoples including pharmacists, staff nurses and volunteers, which was a herculean task. Team also prepared kits for medical air drop to handover to the navy officials. The total medicines distributed were 570 kits including air drops.

The GHE has also came up with an idea of medical helpline number in order to reach out to the other affected areas. A helpline number (+91) 9946992995 became functional and spread through social media sources. A dedicated team was deployed to attend and verify calls. The genuine requests were directed to link up to that number. The person sitting in the GHE conference hall would attend the call, note down the issue and project it on the LCD placed in the hall. A person was also dedicated to follow up the complaints. Color coding was also established to segregate status of specific complaint. Initial calls were mainly related to rescue as water level was rising up but following days, many requests came for medicines and bleaching powders etc. This idea was supported by IT company NEST group, who also provided their staff for 6 days to address any technical glitches. The team received around 500 calls through the helpline of which most of the calls were for rescue that were reported to district control room. The total of 140 issues were resolved.

In addition, the RRT received support from various medical fraternity, including IMA, other Paramedical associations, staff nurses associations and all other volunteers who were willing to work for a common cause were coordinated at the Conference Hall of GHE. For better coordination, debriefing sessions were held every evening at the medical control center to understand the needs, progress and status of the situation.

6. PSYCHOSOCIAL CARE

It is also usual that those who have been affected by flood or any other disasters are prone to Acute Stress Reaction which can lead to Post-Traumatic Stress Disorder (PTSD). The health department of Kerala took this seriously and trained close to 1000 volunteers to help affected people overcome the situation (George 2018). Many qualified psychiatrists from various hospitals went to camps and helped people provide them psychosocial support. Many helplines were also opened to support those who have acute stress reactions. This was possible because Kerala is the only State in India where District Mental Health Program (DMHP) is available in all the districts. The Mental Health Disaster Management team conducted 1.23 lakh house visits and 706 camp visits using 122 intervention teams in the flood-affected districts. They provided psycho-social intervention to 2.04 lakh patients and pharmacotherapy to 1543 patients

(UNDP, 2018). District Disaster Management team comprising 4–5 members, including a psychiatrist, clinical psychologist, and social workers, was deployed in every district to support the affected community. Agencies of the United Nations such as WHO and UNICEF assisted the Department of Health and district administrations (UNDP, 2018).

The role of community health units such as PHCs, CHCs and Accredited Social Health Activist (ASHA) workers etc. have also been proactive in terms of providing either mobile emergency care on the site of incident or providing intermediate stabilization and forward referral of serious patients to the nearest networked hospital. These health workers were mobilized, trained, and then sent off to multiple relief camps to assist flood victims. Since the emergency plan of such small health units largely depend upon the concept of hospital networking and these units augmented and utilized their available services to help affected hospitals.

7. CONCLUSION

The evidence is clear that climate change is already having a serious impact on human lives and health. The effect of future climatic hazards on hospitals may further increase and may render hospitals with limited services, if the preparedness measures are not put in advance. During and after a disastrous event, hospitals play critical role in reducing casualties, and the emergency preparedness role of the hospital may extend beyond those hazards which could directly affect the safety of the hospital. In view of this, there is a need to transform healthcare facility infrastructure to mitigate climate change threat as well as prepare themselves to be operational during stressful climate events. Identifying issues and gaps in climate preparedness for efficient health delivery, including pre-planning and post disaster response is the key to climate change risk mitigation. The climate risk mitigation strategies should identify implementation measures for new facilities, retrofitting for existing ones, establishing dynamic link among networked health facilities for a successful transformation to a climate-smart healthcare. The efforts made by hospitals in Kerala in mobilizing medical teams for offering medical assistance and also to prevent the outbreak of any contagious diseases has been noteworthy. The case of Kerala can help inspire other state health authorities on to the path of hospital preparedness and response.

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Chapter 19

CLIMATE - BASED SPATIAL MODELLING FOR PREDICTING MALARIA RISK MAP OF ANDHRA PRADESH

Roopam Shukla, Mahima Uttreja, Meena Sehgal and Vidhu Gupta

ABSTRACT

Malaria poses immense economic and public health burden based on the prospective climate change variability. This in turn affects the distribution of health burden and risk spatially as not all locations are prone to higher incidences of malaria outbreak. The aim of this study is to identify, classify and map the potential malaria hotspots along with the health centres to improve health resilience using targeted interventions in Andhra Pradesh. A GIS- based spatial tool was developed for malaria risk assessment using meteorological (humidity, rainfall, minimum temperature, maximum temperature) and physical (Normalized Difference Vegetation Index (NDVI), elevation, Normalized Difference Water Index (NDWI) variables. The meteorological variables data was extracted from 100 monitoring stations across the state, physical variables were generated using remote sensing input and healthcare centres data from the national surveys for the year 2015-16. The weightage of each variable was computed using Analytical Hierarchical Process (AHP) and spatial overlay analysis generated a risk- zone map. The correlation analysis showed NDVI (0.72) and rainfall (0.85) as the two most significant variables. Almost 56.6% of the state falls under the very high-risk zone with Vishakhapatnam, East Godavari, and Vizanagaram as the top three districts. A statistically significant correlation of 0.68 was obtained after validation from malaria occurrence data (2014-16). The model identified around 25.2% health centres in the high malaria risk zone that will require urgent preventive strategies. Thus, this approach will help in implementation of climate-based targeted interventions at malarial hotspots for its elimination and better control.

Keywords: *Analytical Hierarchical Process (AHP), Andhra Pradesh, Climate change, Malaria incidence, Spatial analysis.*

Roopam Shukla
Postdoctoral Researcher, Potsdam Institute for Climate Impact Research, Germany

Mahima Uttreja
Research Associate, The Energy and Resources Institute (TERI), New Delhi, India

Meena Sehgal✉
Senior Fellow, The Energy and Resources Institute (TERI), New Delhi, India, meenas@teri.res.in

Vidhu Gupta
Associate Fellow, The Energy and Resources Institute (TERI), New Delhi, India

1. INTRODUCTION

Malaria continues to be one of the major public health challenges in the tropical and sub- tropical parts of the world including India. According to the World Malaria report (2018), almost 94% of India's population that is around 1.25 billion are at risk of malaria. As per the recent Lancet report (2019), India ranks fourth in the malaria cases reported globally. Numerous studies have predicted malaria distribution in India expanding to higher latitudes and altitudes and shifting from central to south-western Indian States. In future, the northern States will also become prone with wider transmission window (Bhattacharya et. al., 2006; Singh et. al., 2017). The extreme weather events have been shown to lead to a conducive environment for malaria transmission. For example, stagnant water due to flooding provides breeding ground for the mosquitoes (Ahern et. al., 2005).

International Panel on Climate Change (IPCC) predicts that by 2050 malaria may threaten the unexposed parts of the world and will thus cause a 50% upsurge in the probability of malaria cases (World Bank, 2012). IPCC has concluded that the potential effects of climate change will alter distribution of malaria putting children below five years of age and pregnant women at risk. Malaria eradication in this way comes in direct line with the fulfilment of broader Sustainable Development Goals (SDGs) in terms of universal health coverage, reducing poverty and promoting equity along with addressing the economic and public health burden of malaria.

Malaria is identified to be one of the most climate-sensitive diseases, with profound evidence showing associations between malaria transmission and changes in temperature, rainfall and humidity (WHO & WMO, 2009). The epidemiology of malaria is multifactorial and climate change can alter vector geographical distribution, longevity, growth cycle and transmission dynamics (Rogers et. al., 1996). This results in an increase in the transmission of malaria in endemic areas and simultaneously re-emergence in regions which have previously eliminated malaria (Zhou et. al., 2005; Ivanescu et. al., 2016). The association between climate changeand malaria transmission is potentially complex but it is essential to understand in order to eradicate malaria. The spatial models can be used to study the modifications in spatial and temporal windows of malaria transmission due to global climate change (Tanser et. al., 2003). A systematic review by Canelas et al., (2016) highlighted extreme importance of spatial analysis in enhancing the effectiveness of malaria control program at a global level. This review identified geo-analytical, geostatistical models with Bayesian framework as most commonly applied methods. As well

as, Kriging interpolations, geographical weighted regression and Kuldorff's spatial scan as important techniques to create malaria risk maps.

The spatial variation in malaria risk is highly correlated with the geographical and meteorological parameters (Kazembe et al., 2006; Mwakalinga et al., 2018). Research has identified several physical and topographical parameters for dispersion of malaria such as elevation (Bhatt & Joshi, 2014; Ali et al., 2018), slope (Hanafi-Bojd et al., 2012), presence of water bodies (Zhou et al., 2012; Ferrao et al., 2018), vegetation (Ferrao et al., 2018), and drainage density (Bhatt & Joshi, 2014). Moreover, climatological parameters like minimum temperature, maximum temperature (Kazambe et al., 2006; Bhattacharya et al., 2006), relative humidity (Srimath-Tirumula-Peddinti et al., 2015), and rainfall (Kumar et al., 2014) have been identified to influence the vector ecology (Figure 1).

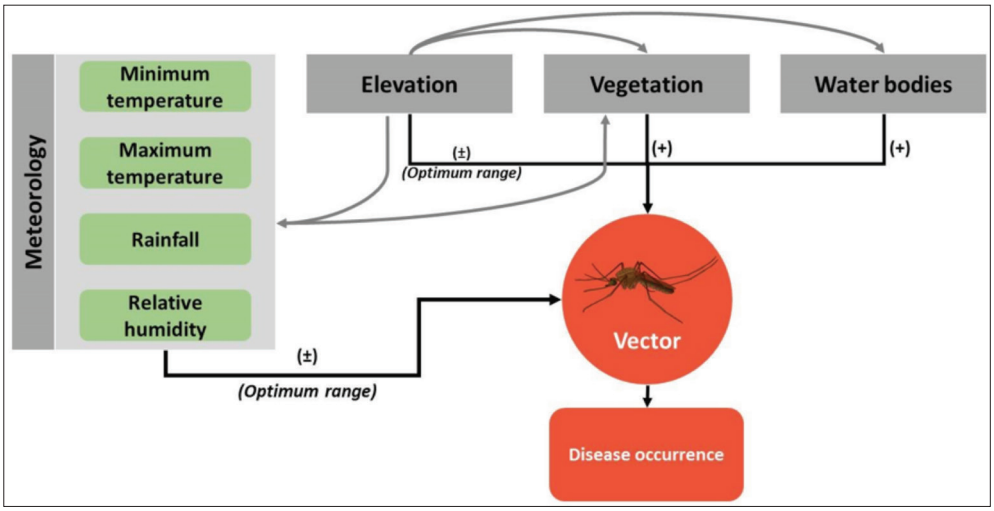


Figure 1. Relational pathway of malaria occurrence. '+' sign denotes a positive relationship and '±' denote that the breeding of vector is influenced by an optimal range of the variable

The potentiality of spatial analysis to study malaria distribution has been identified to unravel indispensable information that aid in better control strategies to eradicate malaria (Bousema et al., 2012). Integration of Multi-Criteria Decision Making (MCDM) tools, such as Analytical Hierarchical Process (AHP) method, has received considerable attention for this purpose. Therefore, the aim of this study was to determine the malaria risk situation based on climate variability and provide a risk map to eradicate malaria from Andhra Pradesh.

2. OBJECTIVE

The aim of this study was to identify, classify and map the prospective malaria risk zones along with the health care centres (primary and community) for Andhra Pradesh districts. The study will develop a GIS- based spatial tool utilizing meteorological and physical variables for risk assessment using Analytical Hierarchical Process (AHP). The study aims to highlight malarial hotspots and improve health resilience usingtargeted-interventions to reduce malaria burden in Andhra Pradesh.

3. METHODOLOGY

3.1 Study Area

The state of Andhra Pradesh covers an area of 162,970 km^2 and forms the eighth largest state of India with a total population of 49,386,799 (Govt. of AP, 2014). It is a coastal state with a coastline extending upto 974 km. and a tropical climate with generally hot and humid conditions. The summer season extends from March-June with high moisture levels and mean temperature of 20°C-40°C. It is followed by the monsoon season with heavy tropical rains till September. The winters are mild and pleasant lasting from October- February with temperature between 13ºC-30ºC. However, there is large variation in rainfall distribution with average rainfall in coastal regions ranging from 70- 150 cm while the driest parts getting 30- 50 cm (Govt. of AP, 2011).

The health indicators in Andhra Pradesh remain stagnantin the past and the State is facing crippling health problems from child immunization, malnutrition, maternal health and high prevalence of vector borne diseases (Govt. of AP, 2011). A World Bank study identified 20% of the ill-health problems in Andhra Pradesh are due to environmental causes (World Bank, 2001). Malaria is one of the most prevalent vector-borne diseases and endemic owing to water logging and pollution problem in the state. Hence, the transmission continues throughout the year due to the naturally favorable environmental conditions. The four main vectors responsible for malaria transmission in Andhra Pradesh are Anopheles culicifacies, A. stephenis, A. annularis and A. Fluviatilis (Singh et. al., 2017). Figure 2 shows the load of malaria cases (per lakh population) for the 13 districts of Andhra Pradesh.

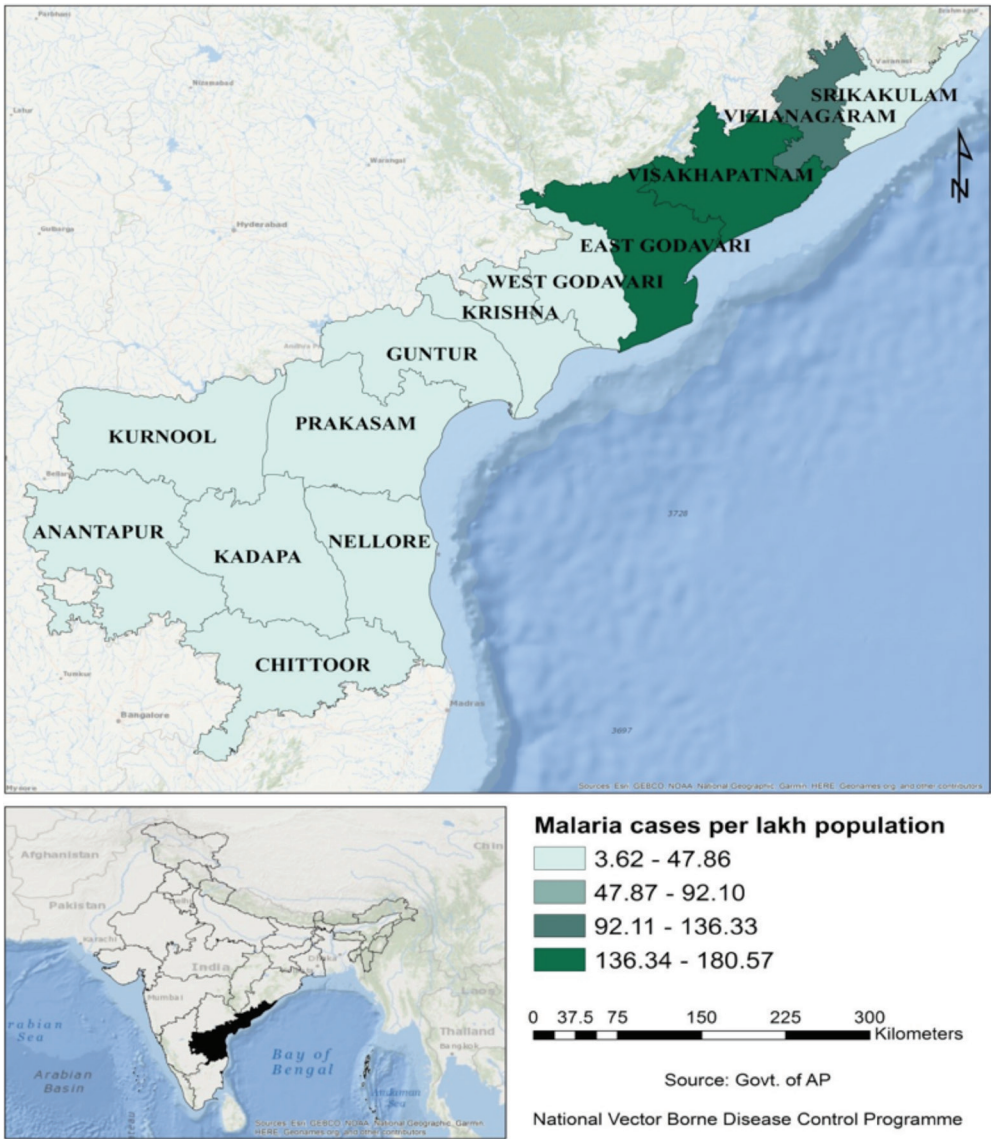


Figure 2. District map of Andhra Pradesh showing malaria cases for the year 2016

3.2 Study Design

The overall methodological approach followed in the present study is shown in figure 3. The spatial and temporal distribution of malaria risk is highly correlated with the physical and climatological parameters. At first, identification ofphysical and meteorological variables was done using existing literature. Secondly, the variables were rankedby spatial overlay analysis using

AHP – a multi- criteria analysis tool.Finally, malaria risk zone map was prepared and further the Primary Health Centers (PHCs) andCommunity Health Centers (CHCs) falling in the high-risk zones were identified.

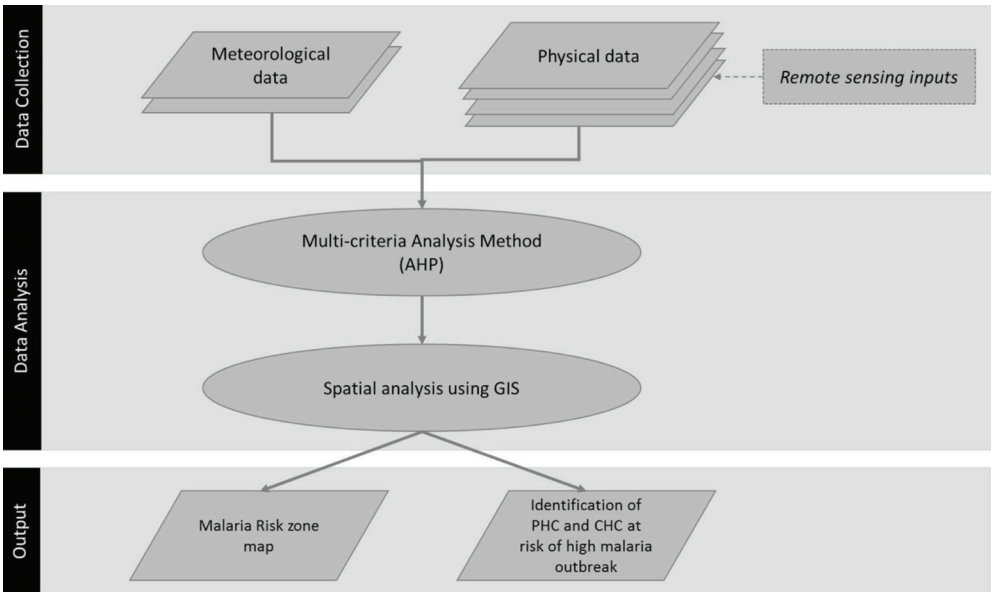


Figure 3. Flowchart of study design

3.3 Selection of Model Variables

Previous studies on spatial mapping of malaria risk zones have used several climatic, physical environmental, and location parameters. Based on India-specific literature we identified humidity, rainfall, minimum temperature, maximum temperature, vegetation, moisture, and elevation as the main variables in determining malaria risk.

Data on physical variables was generated using remote sensing input (Landsat 8 imagery). For vegetation, the Normalized Difference Vegetation Index (NDVI) was calculated and Normalized Difference Water Index (NDWI) was estimated as a proxy for wetness index, both indices vary from +1 to -1. Elevation data was extracted from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) GDEM (Global Digital Elevation Model) Version 2. District wise weekly average data on meteorological variables was extracted from the extensive network of 100 monitoring stations across the state for the year 2015-16. Continuous surfaces for each of the meteorological variables were generated from the 100 data points using interpolation techniques.

3.4 Spatial Modeling

3.4.1 Classification of Variables

Values of each variable were categorized into five classes of risk potential namely very low, low, moderate, high and very high. The range of values under each class was guided by the optimum range values mentioned in the literature given in Table 1.

Table 1. Optimum range and functional relationship of variables with malaria prevalence

Variable	Optimal range	Relationship	References	Study region
Humidity	1. 55 - 80%		Bhattacharya et al., 2006	Pan-India
	2. 66 - 81%		Srimath-Tirumula-Peddinti et al., 2015	Visakhapatnam
Rainfall	Higher rainfall correlated with higher malaria incidence		Kumar et al., 2014 Srimath-Tirumula-Peddinti et al., 2015	Delhi; Visakhapatnam
Minimum Temperature	15° - 19°C		Bhattacharya et al., 2006	Pan-India
Maximum Temperature	33°C - 39°C		Bhattacharya et al., 2006	Pan-India
NDVI (Vegetation)	Higher NDVI correlated with higher malaria cases		Ferrao et al., 2018	Mozambique
NDWI (Water)	Higher NDWI correlated with higher malaria incidence		Ferrao et al., 2018	Malaysia; Mozambique
Elevation	0-100 m (flat surface) correlates with higher malaria incidence		Bhatt and Joshi., 2014; Aliet al., 2018	Gujarat; West Bengal

3.4.2 Multi-criteria Analysis

A hierarchical structure of the variables was established under the two main dimensions of physical and meteorological variables. The relative scale of comparison, as proposed by Saaty (2008) ranged from 1 to 9, where 1 means equal importance and 9 is extremely important, was used in pair-wise comparison matrix. The computation of AHP weights was done using the Super Decisions software (Table 2). The degree of consistency in judgment of weights was measured by the Consistency Ratio (CR). The value of CR was less than 0.1 for all the comparisons. Equal weightage was given to physical and meteorological parameters both i.e. 0.5 each. NDVI was given the maximum weightage (0.6) amongst the physical parameters while relative humidity and rainfall received maximum weightage of 0.3 each within meteorological parameters (Table 2). Along with the ranks given by the experts, these weights were also guided by the knowledge gained from literature (Bhatt & Joshi, 2014; Ferro et al., 2018). Finally, each of the raster layers of the climatic and physical parameter was multiplied with the corresponding weights form AHP and aggregated to generate a risk map. Further, classified the PHCs and CHCs to strengthen health resilience and decided the design of targeted-interventionsto eliminate malaria in Andhra Pradesh.

Table 2 List of identified variables with their weights assigned using AHP

Parameter Category	Variables	Source	Weight	Total Weight
Physical	Normalized Difference Vegetation Index (NDVI)	LANDSAT 8	0.6	0.5
	Elevation	ASTER GDEM 2	0.3	
	Normalized Difference Water Index (NDWI)	LANDSAT 8	0.1	
Meteorological	Relative Humidity (%)	Govt. of AP	0.3	0.5
	Rainfall (mm^2)	Govt. of AP	0.3	
	Minimum Temperature (°C)	Govt. of AP	0.22	
	Maximum Temperature (°C)	Govt. of AP	0.18	

4. RESULTS

In the process of developing a malaria risk map for Andhra Pradesh, we used physical and meteorological variables. Based on the nature and role of the

variable in changing/altering the malaria incidence, these variables were classified into four zones. By using the pair-wise comparison, AHP provided an effective platform for ranking and weighing all the variables on the basis of their potential and influence in malarial outbreak.

4.1 Predictive Risk Map

The predictive risk map of malaria is shown in figure 4 along with the generated four risk zone. Out of the total state area, 31.28% was classified as low risk zone (majorly in Anantpur, Kurnool and some parts of Nellore districts), 39.05% as medium risk zone, 48.67% as high-risk zone, and more than half of the area i.e. 56.60% classified as very high- risk zone mainly in Vishakhapatnam, East Godavari and Vizianagram districts.

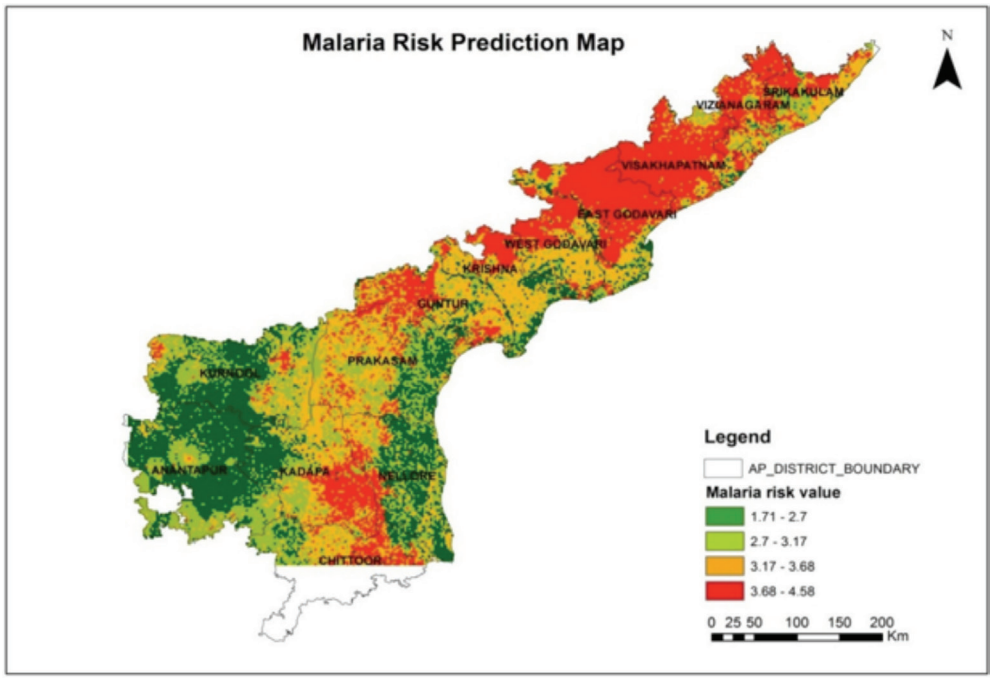


Figure 4. Malaria risk zones of Andhra Pradesh showing distribution of low risk (1.71-2.7), medium risk (2.7-3.17), high risk (3.17-3.68) and very high- risk areas (3.68-4.58)

Table 3 gives the details of the percentage distribution of the four risk zones across the 13 districts of Andhra Pradesh.

Table 3 Percentage area of a district falling within the four malaria risk zones

District	Low risk (%)	Medium risk (%)	High risk (%)	Very high risk (%)
Anantapur	60.64	34.86	4.15	0.35
Chittoor	14.74	32.23	32.23	20.80
East Godavari	9.43	7.28	18.72	64.58
Guntur	10.29	18.29	39.77	31.65
Kadapa	19.02	24.69	31.95	24.34
Krishna	18.18	12.92	46.03	22.87
Kurnool	41.92	37.54	17.4	3.10
Nellore	40.96	29.19	20.39	9.45
Prakasham	17.45	35.72	36.44	10.39
Srikakulam	5.99	22.29	36.12	35.60
Visakhapatnam	2.37	5.98	15.58	76.07
Vizianagaram	2.07	11.53	23.25	63.15
West Godavari	11.73	9.10	43.50	35.68

These results show that there is a clustering of very high-risk zones spatially, and the physical and meteorological parameters have a significant role in identification of the malaria risk zones. The most significant physical variable was identified to be NDVI with a correlation of 0.72 when regressed with the final malaria risk map, and amongst the meteorological variables rainfall was the most significant determinant with the correlation of 0.85. This could be due to provision of favorable conditions for the malaria vector through optimum rainfall and the denser vegetation provides excellent breeding sites to the adult mosquitoes.

4.2 Risk-based classification of health care centers

In order to realize the public health implications of the spatial risk mapping and identification of malaria risk zones, we classified all the Primary Health Centers (PHC) and Community Health Centers (CHC) within the state. This classification reflected the malaria risk within four classes ranging from least risk (18.61%), low (21.17%), moderate (29.64%) to high risk (25.21%) areas (Figure 5), based on the approach and strategies the health centers would need to combat malaria burden.We propose that almost 25.21% high-risk centers would need urgent preventive approach and greater external aid for developing effective control strategies. The advanced understanding of the biology and transmission of malaria (Gachelin et al., 2018) enthuse the need of health centers to opt for large-scale larvae management strategies to control the outbreak. The map

can advise areas to be targeted, and the cost estimates of scaling-up can be calculatedconsidering the at-risk population estimates. Such a method is cost-effective in designing the response mechanism for reducing predicted malaria risk.

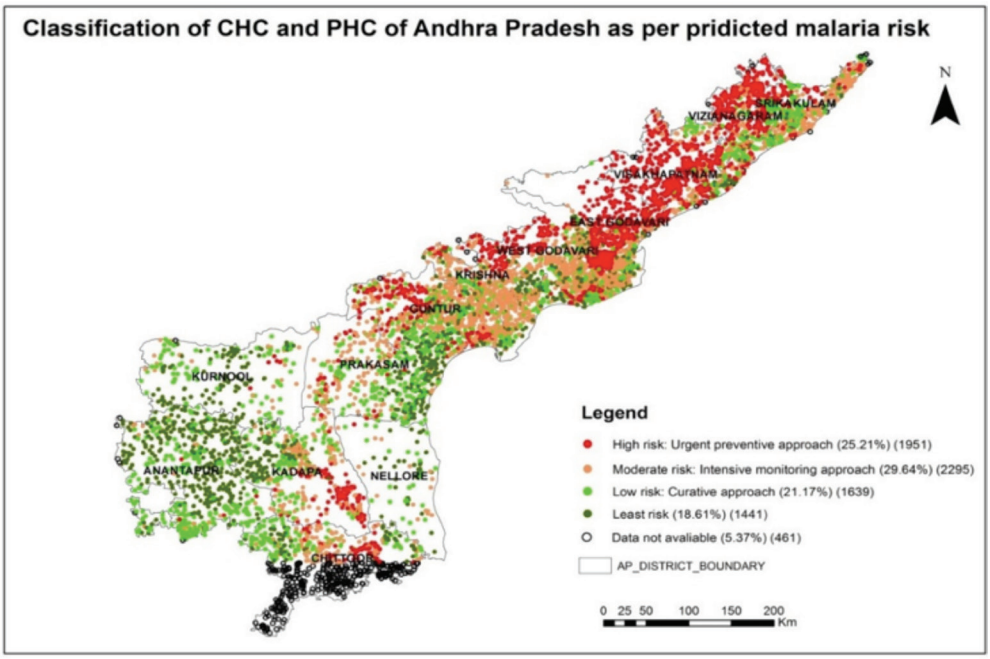


Figure 5. Classification of Primary Heath Care (PHC) and Community Health Care (CHC) centers according to malaria risk

5. DISCUSSION

Malaria is closely linked with climate variabilityas the threat of global climate change is expected to change the spatial and temporal windows of malaria transmission. The findings of the present study would serve as an evidence to predict the alterations in malaria incidenceusing spatial toolsby identifying factors which can be used as malaria indicators as done in other studies. The results of the present study are consistent with other studies conducted in Delhi (Kumar et al., 2014) and Vishakhapatnam (Srimath-Tirumula-Peddinti et al., 2015) in identifying rainfall as the significant meteorological variable and NDVI as the most significant physical variable (Ferrao et al., 2018; Gaudart et. al., 2008).

This analysis helped in classifying Andhra Pradesh into four risk zones of malaria transmission. The high-risk zones are clustered spatially in Vishakhapatnam, East Godavari and Vizianagaram districts while the districts of Kurnool and Anantpur showed low-risk. This district wise risk classification and identification

of malaria hotspots will help in policy planning along with the variables needing urgent attention i.e. NDVI and rainfall.This analysis further helps in combating malaria based on the identification of PHCs and CHCs within high-risk categories through targeted interventions. Globally, studies have been done to study the effectiveness of spatial analysisin predicting the malaria risk and mapping vulnerable areas based on climate variability (Tanser et. al., 2003; Canelas et. al., 2016).The spatial modelling for high-risk areas isused as proxy for understanding and outlining strategies under national control programs to eliminate malaria (Ranjbar et. al., 2016).

Malaria occurrence data was collated from Integrated Disease Surveillance Program (IDSP) for the year 2014-16 and mapped to identify the intensity of the malaria across Andhra Pradesh districts.The findings of the spatial risk zonation were further validated with the malaria occurrence data and astatistically significant correlation of 0.68 was obtained.This predictive malaria risk map is in line with malaria incidences across districts (as shown in Figure 6) so it can be used to provide insights on malaria endemicity and for targeted monitoring of progression of malaria outbreak and control actions across the state.

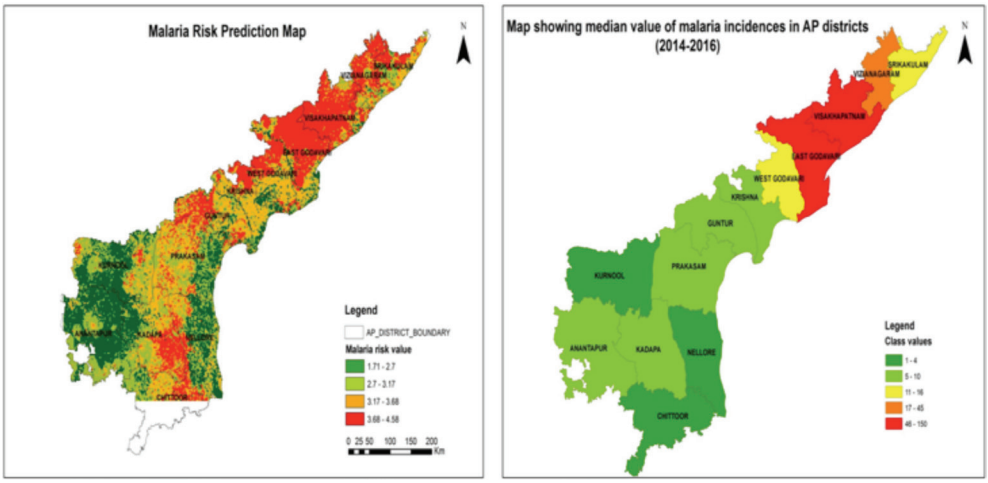


Figure 6. Spatial validation of malaria risk prediction map with map showing malaria incidences in AP reported by IDSP data

6. CONCLUSION

The spatial modelling based on multi-criteria analysis using AHP in a GIS environment has effectively predicted the malaria risk zones at the district level in Andhra Pradesh. The ability to accurately identify areas at higher risk will help in utilizing the limited resources of India in an effective and efficient manner. Malaria risk map and predictive risk stratification based on relevant information provides a targeted cost-effective method in terms of preparedness

and early warning system. Various variables govern the level of risk with respect to this disease and GIS provide necessary technology for identifying and combining these different variables, while remote sensing provides the necessary environmental information. The district wise malaria risk map using GIS-based technologies help decision-makers to generate information for policy planningforimproved health resilience in Andhra Pradesh.

7. LIMITATIONS

One of the limitations with the present data is that better resolution of meteorological data (hourly data) is possible. More variables such as soil, forest coverage, land use/ land cover, socioeconomic factors etc. could be integrated in the present model for better prediction. And, for all these variables optimum range needs to be generated for each district as there is a large geographical and climatic variation found in the state. Lastly, the study assumes a two-dimensional approach with no inherent interaction and associations among the variables taken into consideration.

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Chapter 20

INTRICACIES OF WATER-HEALTH SYSTEMS AND STRENGTHENING WATER UTILITIES UNDER CLIMATE VARIABILITY

Chitresh Saraswat

ABSTRACT

Traditionally, water sector research was focused on minimizing human health and ecosystem risks, but recent focus on climate variability added another dimension of water-health complexities. Consequently, significant progress has been made in understanding the intricacies of water-health system in a changing climate. The consequences of climate variability and induced water insecurity will be more severe for water sustainability and health risks. In this background, water utilities of the future need to develop the capabilities and foster innovation to deal with the magnitudes of climate variability. Academic research highlighted the significance of sustainability of drinking water service provisioning and recommend water safety plan (WSP) to achieve the goal. However, little attention was paid to the capabilities and innovation required to achieve integrated WSP and to deal with the intricacies of water-health systems under climate variability, specifically in developing countries such as India. The Indian water utilities are struggling with the lack of capabilities to deal with inefficient management, inter-institutional coordination, engaging stakeholders, achieving financial stability, and holistic implementation of strategies. To investigate such limitations, the case-study approach is adopted to understand the complexity of the water-health system and capabilities required for implementing climate integrated WSP in the Indian context. The study showed that performance-based public-private partnership was effective in identifying and assessing risks at earlier stages and improving the capabilities to integrate climate variability in planning. The rationale and illustration calls for engaging expertise, collaboration, and technology diffusion in Indian water utilities to achieve Sustainable Development Goal 6.

Keywords: *Water Utilities, Water-Health System, Health Risks, Innovations, Capabilities, Public-Private Partnerships.*

Chitresh Saraswat✉
The Fenner School of Environment & Society, Australian National University, Canberra, ACT, Australia
saraswat.chitresh@gmail.com

Around the world, more than 10% of the world's population lacks access to adequate and safe water; hence, more than 750 million are at severe health risk. Mostly, research in the water sector is motivated by the primary concern of improving human wellbeing and highlights the complex interactions and linkages between water-health (Charles et al., 2019). Climate change is impacting global water resources and posing significant threats to human wellbeing, health, and ecosystem (Vörösmarty et al., 2010). Water resources have socio-economical value for humans and are considered as one of the vital resources for maintaining the ecosystem balance. The climate change aggravated the variability of frequency and intensity of precipitation, which affects socio-environmental determinants of health (Setti et al., 2016). The intensified and variable precipitation disrupts water cycle, which impacts on drinking water supplies, leads to sporadic contamination of surface water sources. Water-related disasters leads to degradation of water supply infrastructure (WHO, 2017; Moore et al., 2008). The contamination of drinking water sources by intensified precipitation with pathogens or chemical pollutants could be the source of cyanobacterial blooms, which causes health issues (Frey et al., 2015). The climate variability comprises of precipitation, temperature, and evaporation changes. There are growing evidences that climate variability is impacting water resources in the form of increasing frequency of floods and drought occurrences, inducing uncertainties in potable water supply, reducing environmental river flows, hence endangering the overall water security (Moore et al., 2008; Bartram, 2009). Overall, the water insecurity will have dire impacts on human health, livelihoods, communities, and ecosystem wellbeing.

The gravity of water insecurity is highlighted by the fact that the annual increase in global freshwater demand is continuously growing by 64 billion m3 per year, in last five decade the demand of water is tripled worldwide (McDonald et al., 2014). The Asian Development Bank (ADB) report evaluated that the water demand will increase more than 50% by 2050 globally (ADB, 2016). The reason is the current population growth rate of 1.09%, adding approximately 83 million people every year, increasing economic conditions, and increasing energy demands exacerbates the current rate of water use. By 2040 the major parts of USA, Australia, Africa and South America will face the water stress situation (high ratio of freshwater withdrawal to supply of 40%-80%) and the major parts of Asia experiencing extremely high-water stress with >80% of ratio of freshwater withdrawal to supply (World Bank, 2018), which is exacerbating due to climate variability.

The consequences of climate variability and induced water insecurity will be more severe for developing countries (Mirza, 2003). The developing countries are already facing challenges of rapid urbanization, uncontrolled population growth, and limited technical and institutional capabilities to adapt, which induces the uncertainty of availability of safe and adequate quality of water, specifically in the South Asian region. In the region, there is a strong

correlation between water consumption rates and the pace of urbanization and economic growth. Increasing economic activities and rapid urbanization is increasing water consumption rates that exert persistent pressure on available water resources, infrastructures, and supply provisioning capabilities of water utilities (Saraswat et al., 2016). The Asian Development Bank report ranked the South Asian region in last place in the analysis of water security situation in the Asia-Pacific region (ADB AWDO, 2016). The National Institution for Transforming India (NITI Aayog), a government think tank, estimated that at least 21 cities in India would have no potable water by 2030, and groundwater level subsides to zero by 2020 (Aayog NITI, 2018). In the capital city of Nepal, Kathmandu valley, due to the intermittent supply of water and scarcity, waiting queues for hours to obtain drinking water from stone waterspouts has become a common sight (Saraswat et al., 2017). In Dhaka, Bangladesh, water shortage is prevalent in the backdrop of increased salinity of water and arsenic contamination problems (Pinchoff et al., 2019). These stresses have caused a decrease in the per capita water availability that leads to water scarcity and the degradation of the water quality, therefore affecting human health and ecosystem in the South Asia region. It is evident that operating under the business-as-usual scenario, and developing countries will face intensification of complex challenges in effectively managing the water-health system.

Complexity of water-health system challenges also hampers the United Nations recognized goals to achieve sustainable development by 2030. Passing the resolution in the form of commonly agreed Sustainable Development Goals (SDG's) provides a pathway to the developing countries to formulate policies to achieve sustainability. Importance of linkages between water and health is reflected in SDG 6, which recognized the universal access to safe and affordable drinking water and adequate sanitation for all by 2030 (Hall et al., 2016). In comparison to previous global goals, SDG's recognized the shift in emphasis from infrastructure/technological approaches towards more holistic water service provision, including health as a significant factor. SDG 6 focus on improving holistic water-related service provisions is especially relevant to the water-health interrelationships. Ensuring water quality, sanitation and health, and 'water for all' in the long-term requires continuous improvement in management practices/strategies, and verifying water safety measures (Charles et al., 2019). Nevertheless, it is acknowledged that developing countries lack in capabilities for drinking water service provisioning under climate variability (Munasinghe, 2019). It is predicted that the water-related health risks are continuing to rise in the South Asian region due to the constraints in drinking water service provisions (Munasinghe, 2019; AWDO, 2016). The reason behind increment in risk is bad water quality, lack of piped water access, water infrastructure, and governance issues, which are exacerbated by the intensity of climate change/variability.

To deliver SDG 6, the causal relationships and complexities of water-health system interactions are critical in policy designing and decision-making. To improve the water-health system, developing countries requires enhancing the water services capabilities and fostering innovation. In this background, the chapter investigates the complex interactions between climate variability and drinking water service provisioning in improving the water-health system. Also, the chapter examines the role of water utilities in enhancing capabilities and foster innovations to implement climate-resilient drinking water services provisioning as a driver of the effective water-health system in India. The study is based on the secondary data, annual government and water utility reports and interview with experts during 2019-20. In this chapter, the first section covers the role of drinking water service provisioning under climate variability. In the next sections, the role of water utilities implementing water safety plan is discussed, followed by how improved capabilities and innovation paving path for climate-resilient[1] water services provisioning under Public-Private-Partnership (case study from Nagpur city, India). The final section discussed the innovation and capabilities to overcome water-health problems in an uncertain future.

2. COMPLEX INTERACTIONS OF WATER-HEALTH SYSTEM UNDER CLIMATE VARIABILITY

Climate variability[2] is altering the water cycle and increasing intensity of weather-related events, which is impacting the drinking water service provisions. As a result, degradation of water quality, limited access to safe water, and reduced affordability are affecting human and ecosystem health. Higher intensity of precipitation causes stormwater runoff or flash floods and contributes in contaminations of near water source. In urban areas, stormwater runoff discharge pollutes the nearby water sources as it carries elevated levels of microbial and chemical contaminants. The stormwater discharge contaminants contaminate the drinking water supplies, recreation, irrigation, and food services as well. The agencies or water utilities responsible for drinking water services generally tap the near-surface water sources/river or lake as an only water supply source. In the case of untreated or improper treatment, these contaminants can harm human health and exacerbate the problem of environmental pollution. Potable use of contaminated chemical water can cause long-term chronic health problems and short-term acute health risks.

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[1]*Climate resilient services are the service which are user-centric, collaborative and effectively harness the power of IT and innovation under changes of temperature and precipitation.*

[2]*Climate Variability is defined as variations in the mean state and other statistics of the climate on all temporal and spatial scales, beyond individual weather events.*

The chemical and microbial contaminated stormwater runoff washes into the river and more abundant water bodies and resulted growth of algae. This impacts on aquatic lifecycle and reduce the oxygen in water. Toxins from algae bloom are dangerous for aquatic and human life in case of ingestion and difficult to remove during purification processes makes water unfit for any potable use. Moreover, non-potable use of polluted water in irrigation and other activities such as swimming can cause serious health risks. Various Scholars showed that extreme drought periods hamper the water quality, accessibility, and damage the water infrastructure (REF). Settee presented the fact that dry soil cervices allow contamination and growth of pathogens, which poses serious risks to human wellbeing and contamination related health issues in a few European countries (settee et al., 2018). In the coastal region, saltwater intrusion due to sea-level rise is responsible for groundwater contamination, and in other places, illegal abstraction of water due to the increase in water demand is reducing the water table.

On the other hand, varying frequency of precipitation introduces the uncertainty in water management and water accessibility. Access to piped water to the households is considered to be beneficial to human health (Komarulzaman, 2017), and it influences health positively in comparison to public water connections (Baum and Bartram, 2017). Water accessibility using piped connection is considered safer as adequate water quality can be transmitted to the households, and proper treatment of water reduces the health risks. Nevertheless, it is argued in the literature that to reduce the human health related risks, effective treatment of water is essential not only before supplying the water to consumer but at different stagess : water collection, storage, and distribution through the pipes. Generally water contamination occurs due to improper handling at different stages of water supply system (Shields et al., 2015). Thus, improving drinking water service provisioning reduces the health risks. To achieve a higher level of drinking water service provisions, the World Health Organization (WHO) recommended WSP, particularly in the developing countries. The WSP is an inclusive approach to risk assessment and management for drinking water service provisioning (WHO, 2017). It comprises of the water service provisioning from point-source (catchment) to destination (local communities) to effective management to ensure the safe drinking supplies. Under climate variability, effective management of WSP should integrate resilient climate planning[3]. Many authors argued that 'soft and nature-based approaches[4]' are sustainable in comparison to hard measures of building concrete infrastructure in water safety planning (Howard et al., 2010).

[3]*Holistic planning is the process of pursuing life goals through the proper management of your resources.*

[4]*The approaches which are based on integrating nature as form of solution rather than completely focusing on the engineering or technical solution, for example, use of wetlands as a filtration technique.*

Water utilities of the future, operating under diverse modes of governance, need to consider management approaches and build capabilities to become resilient.

3. WATER UTILITIES AND CLIMATE VARIABILITY INTEGRATED WATER SAFETY PLAN: CAPABILITIES AND INNOVATION

Worldwide, water utilities operate under diverse modes of governance (e.g., Public, Private, Community-Led, and Public-Private-Partnerships). They are responsible for water service provisioning, waste water management, maintenance of infrastructure, based on the contracts or responsibilities assigned, which varies in different settings. Water utilities are regulated by government policies to ensure supplying safe, equal, and adequate water distribution to community and environmental flow[5]. Also, water utilities are widely accepted as the most effective means of managing water resources and efficiently assessing the future risk. The local health agencies are typically responsible for surveillance of health-related consequences of drinking water supply. However, along with other government agencies, water utilities are also responsible for achieving health-related targets in the community. Implementing WSP to minimize the health risk and managing water supply systems in urban and rural areas is one of the essential responsibilities of water utilities, which increases the significance of water utilities in the water-health system (Charles et al, 2019).

The water utilities are playing a significant role by implementing WSP and integrating climate change impact to deal with future uncertainties. The WSP approach helps to implement robust drinking water service provisions in a inclusive and incremental process. The WHO recommends the successful implementation of WSP, composed of a comprehensive risk assessment, prevention-focused operations, risk management, and monitoring practices (WHO, 2017). This enables water utilities to strategies to mitigate risk in every step of the water supply process. These principles are uniform across the size and shape of water utilities to improve the water service provisions. The implementation of WSP is essential for water utilities to develop strategies to manage significant risks and improve the sustainability of the drinking water supply system (Bartram, 2009).

Climate variability integrated WSP, provides tools to water utilities to anticipate climate risks at every step of WSP procedure, effectively plan, efficiently manage risks, and enhance capabilities to strengthen the water-health system (Ferrero et al., 2019; Bartram et al., 2018). It is recognized that water utilities in the South Asian region lacks capabilities (ADB AWDO, 2016) to achieve

[5]*Government policies are to ensure that water required for maintaining the environmental activities/flow must be supplied to the rivers, lakes and ponds*

sustainability. In response, water utilities and policymakers focus on building new infrastructures for water supply system. In this background, here I argue that under increasing adverse impacts of climate variability, water utilities need to enhance capabilities to achieve demand management, productive stakeholder engagement, partnerships and collaborations, and research & development (REF). Also, I assert that innovation can play a crucial role in organizational support (management strategies), holistic implementation, and financing models. Climate variability integrated WSP offers a pathway to develop required capabilities and foster innovation.

Water utility's capabilities can be defined as the capacity of utilities to deliver efficient water services, manage risk, and achieve long term goals (UNDP, 2010). The capabilities can be extended as a multidimensional concept as the capacity to effectively manage human, financial, implementation, organizational and enabling environment to influence policies (Ringwood, 2017; String and Lantagne, 2016; WHO, 2017). Capability building and fostering innovation are multi-level learning process and to implement climate variability integrated WSP, water utilities needs, capabilities to assess the effectiveness of current measures, potential risk, and prioritizing risks with climate hazards. The focus should be on supporting hard measures along with non-infrastructural (soft) measures such as management strategies. These strategies comprise of clear communication protocol, alternative plans, and clear roles and responsibilities. Including water-health modeling capabilities to accurately predict future events and inform decision making is critical. Innovation in water management are water treatment plants at point of use (in the community to reduce the chances of contamination), new systems for improving water quality, and managing water demand effectively using technology required capabilities, which recognizes community & stakeholder engagement and can help create partnerships across the discipline. The capabilities of in-house research & development increase operational efficiency and having a multidisciplinary team on board provides space to different perspective and inform decision-making (Ferrero et al., 2019). Training for operational staff and encouraging innovation to increase the efficiency of water supply service provisioning is important.

4. WATER UTILITIES OF FUTURE: FIRST-EVER CITYWIDE PUBLIC-PRIVATE PARTNERSHIP IN WATER SERVICE PROVISIONING: NAGPUR INDIA

Nagpur city is known as the second capital of the state of Maharashtra and one of the fastest-growing cities of India. With a population of approximately 2.5 million people living in an area of 218 sq. km., Nagpur is home to several federal government agencies and research think-tank such as National Environmental Engineering and Research Institute (NEERI). The Nagpur Municipal Corporation

(NMC) is mandated to manage drinking water service provisioning, wastewater collection, treatment, and disposal as also municipal solid waste management. In 2005, NMC undertook a water audit, which highlighted the ineffectiveness and inefficiency of water supply system and water service provisioning in the city with more than 62% of Non-Revenue water (losses), intermittent and low-quality supply impact public health. In this background, NMC took measures to augment water availability and reduce technical losses. It started a project under JnNURM to replace canal supply with piped supply, improving treatment capacity and providing 24*7 uninterrupted, safe and adequate drinking water supply using the piped connection to community. Also, focusing on reducing water losses by the early leak detection to supplement its water supply and improving service level benchmark. Overall, improvement in drinking water service provisioning by targeting improving water quality of Indian government and WHO standards, 24X7 uninterrupted water supply, 100% coverage and metering, cost recovery, enhancing customer service and engagement to urban poor population.

To strengthen the water service and SDG6 under climate variability, in 2011, NMC and its subsidiary, NESL (Nagpur Environmental Services Ltd.), entered into a performance-based public-private-partnership (PPP) agreement with Orange City Water Ltd (OCWL). OCWL is a joint venture of Veolia Water India Pvt. Ltd., a globally recognized business firm in the water sector and an Indian infrastructure development company (Vishwaraj Environment Ltd.) to offer end-to-end solution (water treatment, supply, collect billing for NMC). The joint venture is considered as successful as the first-ever citywide privatization of water service provisioning in India. The private sector is known for fostering innovation and enhancing capabilities to improve the performance of an organization to seek profit and increasing the consumer base by providing customer-oriented services. The primary focus of public water utility is to provide equitable and good quality water to the community is the objective of PPP based system (OCWL) as well, which can achieve by fostering innovation in providing services and enhancing capabilities.

The water safety plans have informed the performance-based PPP (OCWL) to design an end to end plan solution from collecting water from source, treating water, distributing to community by enhancing capabilities, and fostering innovation (Nijhawan et al., 2014). First, developing human capability by building an interdisciplinary team to identify the risks and hazardous events for the utility water service provisioning. The team discovered the risks of contamination in Nagpur catchment, from nearby coal energy plant and animal activities in nearby areas. Minimizing health risks and improving overall performance requires the standard operating procedures. WSP procedures informed the utility to invest in a systematic training program to build informed human resources skills (Ferrero et al., 2019). The control measures are enacted for risk assessment and management. For example, at the treatment plant

stage, algae in raw water and poor maintenance and operation are identified as hazardous or a risk to entire supply system. To minimize the risks, control measures of pre-chlorination with proper dose and regular cleaning for algae removal and monthly preventive maintenance contract established for equipments and malfunction reported and addressed immediately.

The next step was to set up an improvement and upgrade plan, which includes identifying storage servicing, leakage detection, and repair to manage water quantity. This includes building technical and managerial capabilities for defining the monitoring of control measures and developing management procedures. The skills improved on GIS (Geographical Information System) mapping and risk assessment, pressure and pipe break detection, regular water quality testing at various locations with collaboration with research institutes such as NEERI, Nagpur. At the community level, reducing the Non-revenue water (NRW) and improving customer-oriented services showed improvement in water service provisioning in Nagpur city. According to Nagpur municipal corporation report, the OCW (public-private partnership) is able to reduce the non-revenue water to 35% from 62% (reference).

5. DISCUSSION

In developing countries, the water utilities are struggling with aging infrastructure, massive amount of NRW, water losses, negative impacts of climate change. Together, water quality and quantity issues, intermittent water supplies, and poor governance causing risks associated to ecosystem and the community. Strengthening water utilities under climate variability depends on tackling the complexities of the water-health system by switching a reactive approach to manage the system for developing capabilities and fostering innovation. There is considerable uncertainty regarding the magnitude of the impacts of climate on water sustainability and health risks associated. Under climate variability, it is essential to devise resilient water service provisioning strategies to adapt uncertainties in the future.

The SDG 6, explicitly recognized the importance of continuous supply of adequate quality drinking water in reducing health risks. The goal focused on improving holistic water-related service provisions are especially relevant to the water-health interrelationships (Bartram et al., 2018). Ensuring water quality, sanitation and health, and water for all in longer-term requires continuous improvement in management practices/strategies, and verifying water safety measures (Charles et al., 2019). The WSP provides a blueprint to address water challenges in an incremental process in water utilities. However, integration of climate variability in WSP is of utmost importance under changing climate. The WSP is vital in encouraging effective water governance as an incremental approach by fostering innovation.

In India, to achieve the sustainable water service provision, the first citywide performance-based PPP agreement between NMC, NESL, and OCWL was established in the year 2011. The PPP based water utility was informed by WSP to design an end-to-end solution from 'water source, treatment plant, distribution, and customer-oriented services' by enhancing capabilities and fostering innovation (Hastak et al., 2017). This enables the local water utility advancing capabilities of implementation of enabling environment by advancing appropriate policies (Baum and Bartram, 2018). Also, fostering innovation in organisational management to integrate WSP in processes. Holistic Implementation of WSP focuses on enhancing staff capacity via training and learning. The capabilities developed from front end to the back end of water utility such as building multi-disciplinary team, tools and training for hazard identification and risk assessment, planning, innovation processes for management, monitoring, and review audits (Ferrero et al., 2019). Also, it enables the utility on enhancing the capacity of identification of stakeholders such as consumers, regulators, catchment, and health authorities and engagement programs to utilize their input in decision and policymaking. The capabilities for limiting financial barriers were shaped using government and privately funded project to achieve the goal.

As a result, OWCL water utility is continuously enhancing capabilities along with implementing programs such as WSP. This is helping utility to achieve its target of 100% coverage and metering, distributing 150 liters of water per person, reducing NRW less than 20%, improving water quality, uninterrupted 24*7 drinking water supply, effective customer services and providing services to urban poor (Hastak et al., 2017).

6. CONCLUSION

Indian government hailed the performance-based PPP in the water sector as a successful experiment to improve urban water service provisioning. In a particular way, introducing WSP in local water utilities was successful in enhancing the capabilities and fostering innovation to manage risks, including health risks. WSP enables utilities to upgrade water quality and quantity protection, develop capabilities as standard operating procedure and systematic training to improve skills, foster innovation in managing service provisioning and health risks, and distribute revenues to provide financial stability. This helped the Nagpur water utility to manage an NRW project to create a more cost-effective water supply (Hastak et al., 2017). However, there are significant gaps identified in the integration of climate variability in strategies and planning. There is no specific procedure developed for dealing with the future water situation and hazardous events, which requires specific capability building. Integrating climate variability in WSP is not only the requirement and is an integral part of water utilities for the future. PPP form of water governance is capable of building capacities and fostering innovation.

Water utilities of the future in India require engaging broader expertise to integrate climate variability. The holistic implementation needs expertise from technology (new tool, technical experts), society (health risk identification, demand management, and engagement in decision making) and environment (disaster risk reduction experts and knowledge transfer from developed countries) system (Ferrero et al., 2019). This will help water utilities to capture the intricacies of water-health system and interactions between technology, society, and environment. In response to the growing challenges of climate change, it is also essential to integrate plans to develop significant capabilities to support and strengthen the involvement of local decision-makers (Bartram et al., 2018). The discussed case study of Nagpur city, showed the relevance of WSP, and PPP mode of governance in understanding intricacies of water-health system and improving water and health risk situation, while developing required capabilities. However, it is identified that the integration of climate variability in WSP was not reflected in the vision strategies of the water utility (OCW, 2018). The chapter recommend that to improve the water management practices at state and national level, there is a need of significant improvement of the Indian national water policy directives (NWP, 2018). The improved directives should focus on enhancing the collaboration, partnerships and innovation in Indian water management system to reduce the health related risks and improving overall efficiency of water management system.

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Chapter 21

DEVELOPING VULNERABILITY INDEX TO ASSESS CLIMATE RELATED HEALTH IMPACTS IN ANDHRA PRADESH

Vidhu Gupta, Mahima Uttreja and Meena Sehgal

ABSTRACT

Climate change impacts human health directly and indirectly and thus climate associated health indicators can be used to identify vulnerable populations for targeted interventions. Our aim was to develop a composite health vulnerability index for climate change in Andhra Pradesh to compare the existing differences between the districts. The data for the indicators of vulnerability index was used from the National Family Health Survey (NFHS-4; 2015-16), District Level Household Survey (DLHS-4; 2012-13), Population Census (2011) and Government of Andhra Pradesh (2015-16). A composite score was obtained for each district of Andhra Pradesh using equal weights method and was then sorted from lowest to highest. The lowest score (most vulnerable) gets a rank of 1 for that district. The performance of districts showed wide variation under different components of vulnerability index. Vizianagram and East Godavari were the most vulnerable districts in Andhra Pradesh while the least vulnerable districts included Chittoor and Prakasham. The developed index enables formulating a targeted approach based on gaps identified in climate-based health vulnerability of each district and strengthen the healthcare system.

Keywords: *Climate change, Health, Vulnerability Index, Andhra Pradesh, Districts.*

Vidhu Gupta✉
Associate Fellow, The Energy and Resources Institute (TERI), New Delhi, India
Vidhu.Gupta@teriindia.onmicrosoft.com

Mahima Uttreja
Research Associate, The Energy and Resources Institute (TERI), New Delhi, India

Meena Sehgal
Senior Fellow, The Energy and Resources Institute (TERI), New Delhi, India

1. INTRODUCTION

Climate change adversely affects human health by increasing exposure and vulnerability to climate- related stresses and decreasing capacity of health systems. The fifth assessment report of the International Panel on Climate Change (IPCC) concluded that climate-related extremes will lead to greater risks of disruption of food production, morbidity and mortality, damage to infrastructure, consequences of mental health and human well-being. Vulnerability and exposure vary over time and across geographic contexts. These differences in vulnerability arise from non-climatic factors and multidimensional inequalities such as poverty, socio-economic status, ethnic composition, existing health status, and governance (Field et al., 2014).

According to the fourth assessment report of IPCC, vulnerability to climate change is defined as "the degree, to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Parry et al., 2007). India is a diverse country and thus, some regions and states are highly susceptible to climate variability and climate change (Panda, 2009). The major climate- related health impacts in India include vector-borne and water-borne diseases, air-borne diseases, extreme weather events like cyclones, floods, droughts etc., heat waves and food insecurity. Thus, developing countries like India will be one of those least able to cope without assistance to prepare and respond as the severity and frequency of health problems with the increased climate change impacts (National Health Portal-India, 2019).

As per the United Nations Sustainable Development Goals (SDGs), we have to take urgent action to combat climate change and its impacts (SDG 13). While SDG 3 has 13 targets covering many diseases as well as ensuring universal health coverage (UNDP, 2017). Although monitored globally, it is important to use these SDGs sub-nationally to drive policies and programs.

Health vulnerability is a complex and multidimensional concept (Watts et al., 2015). Vulnerability encompasses individual biophysical characteristics, as well as population- based socio-economic-environmental characteristics. Incorporating multidimensional data can present a comprehensive characterization of vulnerability. Given the considerable intra- country and intra- state variations, it is prudent to use this characterized vulnerability to identify communities in need of prioritized and focused interventions (Azhar et al., 2017). Also, the knowledge of vulnerability of the system is essential to assess the risk and thus, risk- impact assessment is the next step to vulnerability assessment (Sharma et al., 2018).

The main challenge of vulnerability assessment is in integrating components, dimensions and methodologies within different disciplines. Rana and Routray (2018) reported that there has been no clear- cut and standardized methodology available for measuring the multidimensional aspects of vulnerability. Therefore, our study is an attempt to develop a methodology for vulnerability assessment in a diverse developing country like India.

The climate- linked health indicators are potentially useful for tracking and predicting the adverse public health effects due to its direct and indirect effects by identifying vulnerable populations and monitoring interventions.

Andhra Pradesh, a state in southern India (Box 1) has begun a process of evaluation of the implementation of the SDGs at both state and district-level using various indicators which culminate into implementing a health vulnerability assessment due to climate change.

Box 1. Description of Andhra Pradesh

- Population density of Andhra Pradesh districts varies from 188 per sq km in Cudappah to 518 per km^2 in Krishna (Population Census, 2011)
- Approximately 2.9 million people are vulnerable to cyclones out of 31.57 million people from coastal districts of Andhra Pradesh (EPTRI, 2011)
- Major climate change issues are due to changing patterns of rainfall, temperature and humidity which are increasing the cases of vector-borne diseases (VBDs); excess of air pollution in towns is increasing the respiratory problems and lung infection cases; and health problems due to extreme hot and cold climate across districts of the State (EPTRI, 2011).
- Districts like Visakhapatnam, East Godavari, West Godavari and Krishna have high exposure to floods and cyclones due to their geographic location (EPTRI, 2011).
- VBDs are more prevalent in Prakasam, Kadapa and East Godavari (EPTRI, 2011)
- Chittoor and Kadapa are more prone to droughts compared to other districts (EPTRI, 2011).

The Andhra Pradesh vulnerability index approach is to assess the health vulnerability of various districts of the state in relation to climate change.

Therefore, the present study aimed to evaluate the health vulnerability to climate change at district level in Andhra Pradesh and identify the hotspots for targeted interventions and adaptation strategies.

2. OBJECTIVE

The purpose of this study was to compare the health vulnerability for climate change between districts of Andhra Pradesh by developing a composite health vulnerability index. This district- level analysis would highlight areas within Andhra Pradesh needing targeted preparedness; resource allocation and health adaptation and resilience strategies, besides providing critical guidance for reducing preventable deaths and diseases. This index includes multi-dimensional indicators to assess composite vulnerability of climate change on health. The study has been designed to meet a collective vision for a healthier state and support the development of targeted interventions to expedite the progress of the SDGs.

3. METHODOLOGY

3.1 Integrated indicator- based approach for Vulnerability Index.

The most common method of measuring vulnerability is by using indicators which act as proxies for the multi-dimensional impacts associated with vulnerability. The indicators are quantitative measures intended to represent a characteristic using a single value which are able to provide information regarding the exposure, susceptibility, coping capacity and resilience of a risk element like extreme weather event such as flood, cyclone and drought etc. (Cutter et al., 2006).

The IPCC 2007 definition has been most commonly used and thus, the conceptual framework of the vulnerability index based on various theories (Sharma et al., 2018; Monterroso et al., 2014, Hahn et al., 2009; Ahumada- Cervantes et al., 2017) is shown in figure 1.

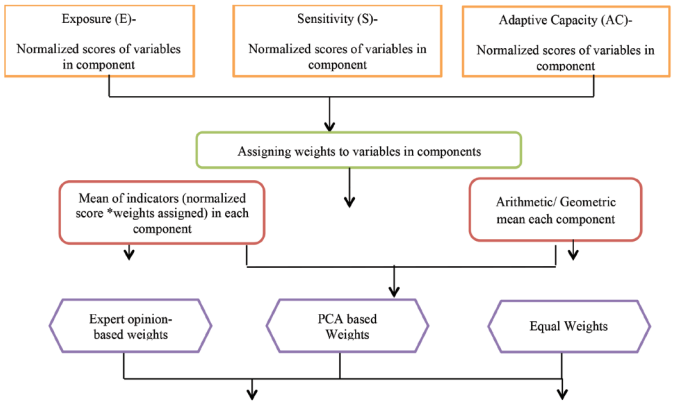


Figure 1 Conceptual framework of the relationship of Vulnerability Index based on a number of popular theories

The parameters selected represented the three components of vulnerability. A total of 25 indicators (may influence directly or indirectly) with coverage of key socio- economic, health, demographic, governance and climate domains were selected based on literature search and the expert advice (Table 1). The decisions were made jointly by the study investigators over multiple sessions.

Vulnerability

Vulnerability Index (VI) = $(AI_E + AI_S) - AI_{AC}$ (Monterroso et al., 2014)

OR

LVI- $IPCC_d = (e_d - a_d) * s_d$ (Hahn et al., 2009)

OR

$V = [E + S + (1 - AC)]/3$ (Ahumada- Cervantes et al., 2017)

Category	Indicator	Year of Data	Source of Data	Type	Rationale for functional relationship	Functional Relationship to vulnerability	Empirical studies
Exposure (E)	Maximum Temperature, summer months ^{0}C)	2015	IMD	Meteorology	Higher temperature during summer months increases the susceptibility to heat	↑	McMichael et al., 2003b; Pandey et al., 2011
	Relative Humidity (%)	2015	IMD	Meteorology	Higher humidity, higher the exposure to VBDs	↑	McMichael et al., 2003b; Pandey et al., 2011
	Rainfall (mm^2)	2015	IMD	Meteorology	More rain, more is the exposure to VBDs	↑	McMichael et al., 2003b; Pandey et al., 2011
	Malaria (ratio of cases)	2015- 16	Govt. of AP	Climate-sensitive illness	Higher the cases, higher is the vulnerability	↑	Bhattacharya et al., 2006; Shukla et al., 2003
	Dengue (ratio of cases)	2015- 16	Govt. of AP	Climate-sensitive illness	Higher the cases, higher is the vulnerability	↑	Shukla et al., 2003
	Heat Stroke (ratio of cases)	2015- 16	Govt. of AP	Climate-sensitive illness	Higher the cases, higher is the vulnerability	↑	Pandey et al., 2011; Vittal H et al., 2020
	Percentage forest cover	2015- 16	Govt. of AP	Environment	Increases the exposure to climate change impacts due to low forest cover	↓	Pandey et al., 2011; Vittal H et al., 2020
Sensitivity (S)	Women age 15- 49 years who were already mothers or pregnant at the time of survey (%)	2015- 16	NFHS-4	Maternal Health	More vulnerable to climate change health impacts	↑	Ebi et al., 2018
	Anaemia: all women 15-49 years of age (total, %)	2015- 16	NFHS-4	Maternal Health	Low nutritional status increases the vulnerability	↑	Ebi et al., 2018

Sensitivity (S)	Women age 15- 49 years who were already mothers or pregnant at the time of survey (%)	2015- 16	NFHS-4	Maternal Health	More vulnerable to climate change health impacts	↑	Ebi et al., 2018
	Anaemia: all women 15- 49 years of age (total, %)	2015- 16	NFHS-4	Maternal Health	Low nutritional status increases the vulnerability	↑	Ebi et al., 2018
	Women with BMI below normal (<18.5kg/m2) (%)	2015- 16	NFHS-4	Maternal Health	Low nutritional status increases vulnerability	↑	Ebi et al., 2018
	Anaemia: 6- 59 months old; <11.0mg/dl (%)	2015- 16	NFHS-4	Child Health	Low nutritional status increases vulnerability	↑	Ebi et al., 2018
	Underweight (weight for age) (%)	2015- 16	NFHS-4	Child Health	Low nutritional status increases vulnerability	↑	Ebi et al., 2018
	Wasting (weight for height) (%)	2015- 16	NFHS-4	Child Health	Low nutritional status increases vulnerability	↑	Ebi et al., 2018
	Stunting (height for age) (%)	2015- 16	NFHS-4	Child Health	Low nutritional status increases vulnerability	↑	Ebi et al., 2018
	Population Density (persons/ sq km)	2015- 16	Govt. of AP	Demographic	Higher population density translates to higher sensitivity	↑	Vittal H et. al., 2020; Debabrata M., 2013
	District GDP per capita (in Rs. Cr)	2015- 16	Govt. of AP	Demographic	Increases the sensitivity of climate change impact	↓	Guveria et. al., 2019
	Fully immunized children (%)	2015- 16	Govt. of AP	Child Health	Low immunization increases vulnerability	↓	Chan et. al., 2019
Adaptive Capacity(AC)	Literacy rate (%)	2015- 16	Govt. of AP	Demographic	Lower literacy relates to lower capacity to adapt	↓	Vittal H et. al., 2020; Debabrata M., 2013
	Urban areas/ slums/ villages with Sub- health centres within 3 km (%)	2012- 13	DLHS-4	Governance	Absence of such centre decreases adaptive capacity	↓	Quintao et al., 2017

	Urban areas/ slums/ villages with Primary health centres within 10 km (%)	2012- 13	DLHS-4	Governance	Absence of such centre decreases adaptive capacity	↓	Quintao et al., 2017
	PHCs functioning on a 24 x 7 basis (%)	2015- 16	Govt. of AP	Governance	Presence of such PHC increases adaptive capacity	↓	Quintao et al., 2017
	Mobile medical services (%)	2015- 16	Govt. of AP	Governance	Increases the adaptive capacity	↓	Vittal H et. al., 2020
	HHs with improved drinking water source (%)	2015- 16	NFHS-4	Environment	Higher percentage indicates higher adaptive capacity	↓	Pandey et. al., 2011
	HHs with improved sanitation facility (%)	2015- 16	NFHS-4	Environment	Higher percentage indicates higher adaptive capacity	↓	Vittal H et. al., 2020
	HHs with clean fuel for cooking (%)	2015- 16	NFHS-4	Environment	Higher percentage indicates higher adaptive capacity	↓	Guveria et. al., 2019

DLHS- District Level Household and Facility Survey, NFHS- National Family Health Survey, IMD- Indian Meteorological Department; ↑- positive relationship i.e. higher the indicator value, higher is the vulnerability; ↓- negative relationship

Table 1 Indicators selected for components of vulnerability and their functional relationship with vulnerability

3.2 Data Collection

Data collected by the National Family Health Survey (NFHS), 2015-16 and District Level Household Survey (DLHS), 2012-13, Statistics and Program Implementation, and from the Andhra Pradesh government have been used in the study. NFHS provides state and national information on fertility, infant and child mortality, nutrition, utilization and quality of health and family planning services. DLHS provides information on reproductive health of women, utilization of maternal and child healthcare services at the district-level. The Health department of Andhra Pradesh provided the data on climate-sensitive illnesses and governance indicators.

3.3 Data Analysis

3.3.1 Normalization of indicators

The process of construction of vulnerability index involves normalization as different indicators have different units of measurement so they cannot be added or aggregated directly. The normalization enables aggregation of indicators by converting all the values into dimensionless units. The normalized values of indicators lie between 0 and 1. Normalization is done based on the functional relationship of an indicator to climate variability. If an indicator has negative functional relationship, i.e. vulnerability increases with decrease in the value of the indicator, the below formula is used:

$$x^{n}ij = Max\ i\ \{X_{ij}\} - X_{ij} / (Max\ i\ \{X_{ij}\} - Min\ i\ \{X_{ij}\})$$

Similarly, if an indicator has a positive functional relationship, i.e. vulnerability increases with increase in the value of the indicator, the following formula is used:

$$x^{p}ij = X_{ij} - Min\ i\ \{X_{ij}\} / (Max\ i\ \{X_{ij}\} - Min\ i\ \{X_{ij}\})$$

where Xij is the variable that is being normalized of jth indicator for ith district and xp/nij is the normalized value (Sharma et al., 2018).

3.3.2 Assigning weights to indicators

Since different indicators have different impact, the indicators are given weights to reflect their comparative importance or contribution to the total vulnerability of the system or communities. The three ways to assign weights to indicators according to the literature include equal weights, Principal Component based, and expert opinion.

The large number of indicators considered is given equal weights in the present study. Three indices for sensitivity, exposure and adaptive capacity were constructed by obtaining an arithmetic mean of the normalized values of indicators. The arithmetic index (AI) for exposure and sensitivity indicate

higher vulnerability with high index value but for adaptive capacity indicates higher vulnerability with low index value and vice-versa.

Based on the equation by Monterroso et al. (2014), the vulnerability index was calculated using the following formula:

Vulnerability Index (VI) = (AI exposure + AI sensitivity) - AI adaptive capacity

Higher values of the index indicate higher vulnerability and vice- versa. The districts were then ranked based on their vulnerability index. This is helpful in targeting and prioritization of regions for adaptation.

4. Results

The analysis showcases the vulnerability of health to climate change for the three components i.e. exposure, sensitivity and adaptive capacity and overall vulnerability index (Table 2).

District	AI (E)	E Rank	AI (S)	S Rank	AI (AC)	AC Rank	Over all VI	VI Rank
Prakasham	0.2920	10	0.3597	12	0.5787	13	0.0730	13
Chittoor	0.2804	11	0.3994	10	0.5138	9	0.1660	12
Anantapur	0.2220	13	0.3888	11	0.4215	5	0.1894	11
West Godavari	0.3344	9	0.3073	13	0.3318	3	0.3098	10
Nellore	0.4776	2	0.4128	8	0.5533	11	0.3371	9
YSR Kadapa	0.3607	8	0.4310	7	0.4441	6	0.3477	8
Krishna	0.4181	5	0.3995	9	0.4627	8	0.3549	7
Kurnool	0.2795	12	0.5686	3	0.4532	7	0.3949	6
Srikakulam	0.4086	7	0.6001	2	0.5714	12	0.4374	5
Visakhapatnam	0.4579	4	0.5084	4	0.4007	4	0.5656	4
Guntur	0.4093	6	0.4868	5	0.3270	2	0.5691	3
East Godavari	0.4605	3	0.4386	6	0.3064	1	0.5927	2
Vizianagram	0.4891	1	0.8080	1	0.5209	10	0.7762	1

E= Exposure, S= Sensitivity, AC= Adaptive Capacity; higher the VI value, more is the vulnerability.

Table 2 Arithmetic Index (AI) of each vulnerability component and rank along with overall Vulnerability Index (VI) with district rank

The district- level analysis of exposure indicators showed Vizianagram (Rank 1st) and Nellore (Rank 2nd) as the most vulnerable for variables of meteorology and climate-sensitive illnesses. The least vulnerable districts included Kurnool (Rank 12th) and Anantapur (Rank 13th). The performance of districts for sensitivity component showed Vizianagram and Srikakulam as the most vulnerable districts while the least vulnerable districts were Prakasham and West Godavari. Similarly, for adaptive capacity East Godavari and Guntur were the most vulnerable districts and the least vulnerable were Srikakulam and Prakasham.

Vizianagram and East Godavari were the most vulnerable districts considering overall vulnerability index while the least vulnerable districts included Chittoor and Prakasham. A positive correlation was observed with exposure (0.77) and sensitivity (0.74) whereas adaptive capacity showed a negative correlation with vulnerability (-0.33). This indicates that an increase in exposure (such as meteorological variables) and sensitivity tends to increase vulnerability of a district of Andhra Pradesh. A similar relationship was observed by Monterroso et al. (2014) in Mexico.

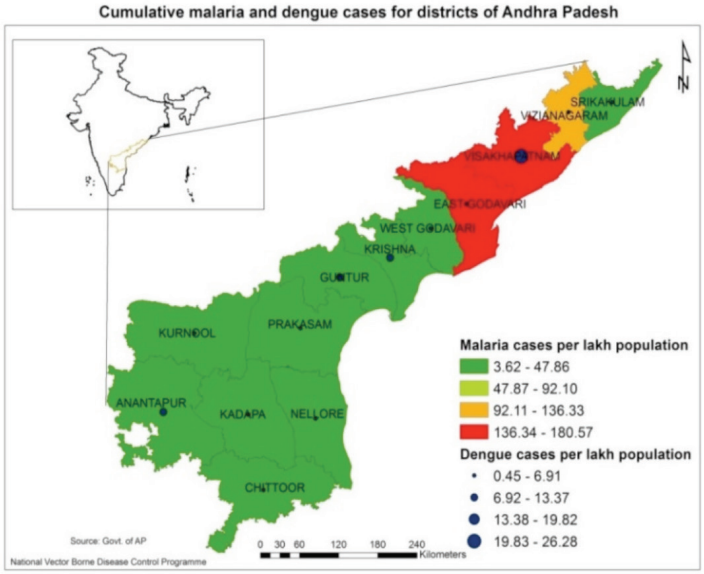


Figure 2. Map showing reported cases of malaria and dengue in districts of Andhra Pradesh

The vulnerability has been categorized as 'very less vulnerability', 'less vulnerability', 'moderate vulnerability', 'high vulnerability' and 'very high vulnerability' based on the arithmetic means of the components i.e. exposure, sensitivity and adaptive capacity and composite score of overall vulnerability as shown in Figure 3.

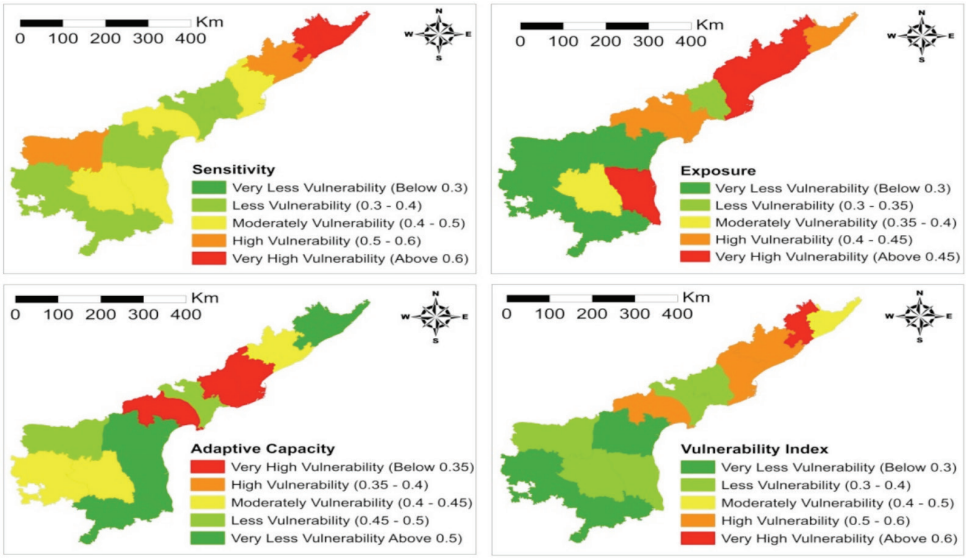


Figure 3. Variation in vulnerability and its components across Andhra Pradesh districts

5. DISCUSSION

Vulnerability is useful in investigating the causes and understanding the linkages between different indicators and their impact on health; identification of hotspots and prioritisation of adaptation measures. These assessments are significant in informing the development of policies that reduce the risks associated with climate change (Fussel and Klein, 2006). Previous studies have shown vulnerability assessment to agriculture in India (Ahumada-Cervantes et al., 2017; Monterroso et al., 2014); for cyclones (Sharma U & Patwardhan A, 2008); and to heat waves (Azhar et al., 2017). Globally, studies have been conducted in Georgia (Binita et al., 2015); Brazil (Quintao et al., 2017); Pakistan (Rana and Routray 2018) and others. All of these studies have integrated indicators of exposure, sensitivity and adaptive capacity components of vulnerability as in present study. The exposure component was represented by the climate-sensitive illnesses and meteorological parameters since they increase the susceptibility to health. The adaptive capacity indicators consider the capacity of the local governments to provide public services to the population which are important for adaptation. On the other hand, the sensitivity component included epidemiological indicators reflecting the health status of the population (Quintao et al., 2017). The livelihood vulnerability index was also developed using health along with other factors to understand the climate vulnerability in Mozambique (Hahn et al., 2009).

Broadly, the vulnerability rankings show that assessing at small area (districts) can help classify them into distinct groups. First group, the districts which

still need to focus on action plans for climate change and primary care due to high vulnerability for exposure and sensitivity indicators such as Vizianagram. The second group, these districts have undergone epidemiological transition, which score high on women's and child health, environment and governance i.e. adaptive capacity indicators such as Prakasham. Thus, ranking supports identifying hotspots in the state and building evidence for policy making and identify collaborations with other departments.

Through this methodology, several critical pathways could be pursued for improving population health. For instance, the district of Visakhapatnam would need to establish early warning systems for climate- sensitive illnesses such as malaria to face local challenges. Therefore, such tools help in monitoring and implementation of SDGs at district level to strategize interventions.

Two features set apart our approach of indexing health vulnerability to climate change, first is the indicator-based approach, climate change impact is viewed in different components, from an intervention perspective which needs targeted approach requiring local planning and mitigation measures. Ranking along each component distinctly shows the stage of epidemiological transition of the district. Second, the health- related climate change impact components are ranked separately; this helps both in identifying the vulnerable areas and the preventive measures which need to be prioritized and strengthened such as early warning systems, innovative farm resources management techniques and many more (Manangan et al., 2019).

Through these bench marking approaches, the state is enhancing the health system by building technical and knowledge partnerships with medical, climate and environment institutes. Enhance outreach of health care services through community health volunteers, Sunday clinics, mobile medical units, free bus passes and rural emergency health transport scheme (National Health Portal-India, 2019).

6. CONCLUSION

We developed a composite index of health vulnerability to climate change that aggregates multidimensional indicators for districts of Andhra Pradesh. This index makes data more relevant, differences more visible and actions intuitive. It is designed and implemented at a local level and thus helps to address local concerns. It is a simple, easy to use method and can be employed by health and climate professionals. The two key policy messages that can be gathered from this study are –

1) Large difference in ranking of the same district on different climate- based impacts can be noted. This assessment of small area approach helps design need-based targeted interventions to build resilience against the health effects related to climate change.

2) There is a need to identify and track climate- linked health determining indicators to inform non-health sectors to undertake mitigation measures to promote health. This is critical as health continues to be affected by exposures/ risks beyond the control of the health sector (but are key determinants of health) such as air quality, weather variations, vegetation, environmental contamination and city development.

The study highlights the need for pro-active information systems for identifying parameters for emerging problems, for instance, environmental features of urban cities triggering chronic morbidities, tracking existing indicators, and analysing both climate- sensitive health determinants and outcomes for transforming health of the population. This also showcases need for galvanizing public- private partnerships to bring health equity across districts.

7. LIMITATIONS

The availability and reliability of data on some indicators has been a major limitation. For instance, health outcome indicators like disability, mental health, mortality in extreme events, are missing from the calculations. Similarly, exposure indicators, air pollutants, droughts, vegetation, low lying areas, have not been included. Since the vulnerability varies across spatial scales, our methods can be modified to develop rural and urban indices.

Likewise, reliable climate prediction data for districts are not available. Therefore, this vulnerability assessment does not consider future threats and hazards but only focuses on utilizing the system's current available resources.

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Chapter 22

GENDER DIFFERENTIATED IMPACT OF 2013 FLASH FLOOD ON HEALTH AND LIVELIHOOD IN RUDRAPRAYAG

Neha Yadav

ABSTRACT

The paper aims to evaluate a climate-induced natural disaster event to analyze the differential impact it had on women's health and livelihood practices. Based on theoretical evidence of the impact that disasters have on food security, market linkages and livelihood opportunities. The empirical study was based in two villages in Rudrapyarag district, Uttarakhand, which combined household survey and ethnographic techniques for collecting field data.The findings suggest, 13.1% of women households (N=46) were sufficient in self-production whereas 60.9% were dependent on market for grainsfor their daily consumption.The disaster event severely influenced the dissemination of livelihood capitals of vulnerable women and adversely affect their health and nutrition. 78.3% took reduction in the amount /number of meals/day to avoid food instability, 54.3 % suffered post-disaster stress and 74% faced hygiene and sanitation issues. The study stresses the need for a gendered perspectiveto understand women' svulnerability and their ability to recover and cope with disasters.

Keywords: *Natural Calamity, Livelihood, Food Security, Healthcare, Women.*

Neha Yadav
Doctoral Candidate, Centre of Social Medicine & Community Health, Jawaharlal Nehru University, New Delhi
nehayadav44444@gmail.com

1. INTRODUCTION

On 16-17 June 2013 Uttarakhand was devastated by cloud burst followed by flash floods and landslides, Rudraprayag was one of the adversely affected districts. The disaster happened during peak pilgrimage season (Chardham Yatra), the state economy majorly reliant on the tourism sector collapsed, thousands of people crumbled, and lakhs lost their employment. Flash floods incurred a massive loss of human lives, livestock, infrastructure, and property and heightened the challenges faced by the economically vulnerable agrarian groups and even expanded the pace of out migration. Consequently, a scenario of food insufficiency emerged at the community level.

As per Rudraprayag District Census 2011, 95.50 percent population resides in rural villages; agriculture, tourism, and unorganized sector labourprovide occupation to a significant part of the population (District Census Handbook Rudraprayag, 2014). The district has a favourable sex ratio of 1,114, and women are the significant contributor in various economic activities, primarily in agricultural-based activities,livestock rearing, and crop production. Land holdings are characteristically small in size and segmented; the production is not sufficient for a household for the whole year. The tourism-based activities provide alternate livelihood opportunities mainly during the Yatra season, andthe male members work as hotel staff, porter, horse/pony wala, taxi driver, and tourist guide. The women work independently or with Self Help Groups to knit shawls and sweaters to be sold in several markets on the way to Kedarnath. As well as, they sell livestock products, milk, and vegetables to the hotels and dhabas and handmade crafts in the local market.

The flood destroyed the houses, ruined the standing crops and washed away land and stored grain reserves, eventually culminating in a decline in food production. Loss of income further reduced their ability to purchase food. Access to healthcare facilities, clean drinking water, and sanitation becomes challenging. Women had to travel miles in the hilly terrain to collect fuel, fodder, and drinking water. Food crises resulted as a consequence of the breakdown of the transportation and disintegration of the market system. Roads have been damaged,the foot over bridge connecting Chandrapuri to National Highways 109 collapsed, and the village remains inaccessible for nearly two months. Women have to climb 3-4 km to access the health camps and collect relief supplies provided by the government and humanitarian organizations. Once the respite phase got over (3-4 months); the households had to purchase essential commodities, the market prices have gone up by four to five times. The women who had lost their land, earning members or livelihoods, were expected to face the greatest threat of food insecurity.

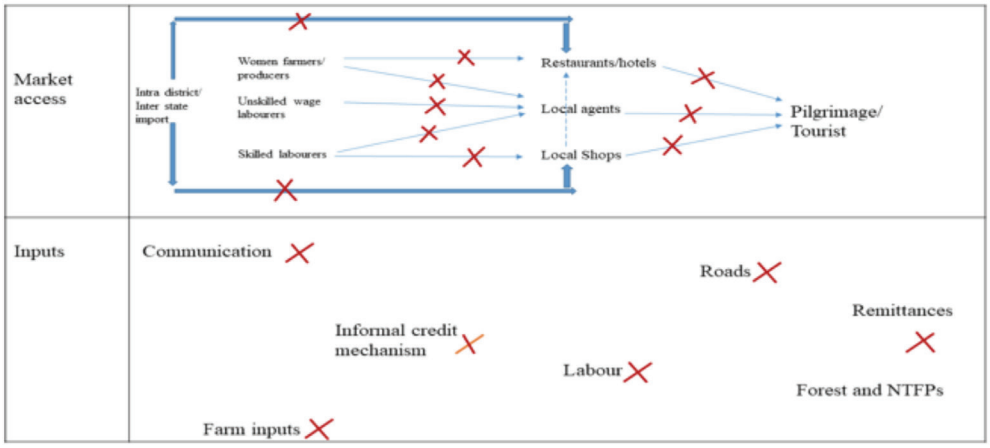


Figure 1. Disintegrated Market System for Small and Marginalized Livelihoods for Women Based on Tourism

Source: Adapted from (Emergency Market Mapping and Analysis (EMMA) in Uttarakhand post floods of June 2013)

Many studies have been conducted examining the impact of climate change on women, still rarely addresses the vulnerabilities caused due to a sudden disaster event. The paper addresses this absence by exploring the consequences of a natural calamityon women's health, food security, and livelihood practices. The study was conducted in two disaster-affected villages in Rudraprayag district, investigating the structure of women's lives, vulnerabilities, and coping capacity.

2. Literature Review

Borrows and De Bruin (2006) specified that among natural calamities, flooding hasthe potential to claim more lives than any other natural disaster (Carey, 2005) argues that certain circumstances such as geographical location, mode of subsistence generation, or income level decide the degree to which natural hazards can cause adverse consequences on people's households and livelihoods. Predominantly, hazard like a flash flood can cause high losses for rural communities as most of the destruction is absorbed by the agriculture sector (Smith, 1998). The study conducted by the (International Flood Initiative, 2003) regarding the emotional behaviour of flood victims was distressing. The follow-up studies suggest the hazardand its secondary effect caused severe emotional trauma. A case study on rural communities of southern Punjab, Pakistan, which faced massive floods in 2010 reveals flood situation made the local community food deficit and food insecure. Agriculture was the primary source of livelihood, and natural capital (land, irrigation facilities, and livestock) was affected adversely. The combination of government, private sector alongside NGOs and funding agencies supported to gain resilience during the initial period,

but in the long-run capacity building of victims was supportive in coping with disaster (Ashraf, 2013). Disasters affect gender differently because of the different roles and responsibilities given to men and women in the society and possibly because of dissimilarities in their needs, capacities and vulnerabilities (Ariyabandu, 2005).

According to Food and Agriculture Organization (FAO) statistics, majority women in the least developed countries practice agriculture and livestock rearing as their principal economic activity (Doss, 2011). Women are more likely to give a significant share of their income generated through labour and non-labour activities to their families (Hopkins, 1994) and (Hoddinott, 1995). Gender inequality might thus have considerable effects on household food access. Women face various challenges in their health and livelihoods, comprising vulnerability to their income, assets (house, land, livestock), food security, water sources and sanitation because of ongoing climate change impacts (Momtaz, 2018). Hasan Mansoor asserted disasters left the worst impact on women's psychological and reproductive health. Natural calamities resulted in poor agriculture yield for the next year; it increased issues of food insecurity and adversely impacted women's health. Moreover, in rural areas, women's health revived slowly as government health facilities lacked services. Women's economic recovery gets delayed in the absence of resources and the lack of alternative livelihoods skills (Mansoor, 2016).

3. METHODOLOGY

The study is based on the mixed method of data collection.The primary data was collected through a household survey conducted in two villages; Vijaynagar and Chandrapuri in Augustmuni block, Rudraprayag.

Study area

Augustmuni was one of the adversely affected blocks, the majority population is engaged in subsistence agriculture, informal labour, and during the Yatra season (May-Oct), the leading livelihood alternative is tourism. The block consists of women as asignificant workforce, out of 48,999 employed individuals, female workers outnumber the male workers. Among them, 21,346 workers rely on agriculture, women working as agricultural labourers and cultivators are double in number than male workers.

Methods

There were three criteria for selection of villages a) proportion of disaster-hit population in the village b) source of subsistence generation c) access to humanitarian aids and health facilities. Following the purposive sampling, two villages were selected for the study. Community stakeholders, village pradhan, Anganwadi workers, and officers from Community Health Centre

(CHC) and Block Development Office Augustmuni were consulted to identify the households which incurred asset and livelihood losses, death and, health issues during the disaster. A random sampling method was used to select 25 percent households out of a total of 182 households affected by a disaster in both the villages. A total of 46 female participants of two age groups (18-35 and above 35) were involved in the study for capturing the wide range of possible experience and opinion.

Table 1. Socio-economic profile of women respondent households

Characteristic	Frequency (n 46)
Average HH size of respondent	5.4 members
Average age of respondent	46.8 years
Respondents with education of more than 10 years	17.2%
Respondents with education of 10 years	28.0%
Respondents with education of 5 years or less	24.3%
Mean annual household income, including contributions of women	INR 98,560 ± 3442.4 (approx. USD 1292.7)[1]
Mean annual household income, without contribution of women	INR 70,010 ± 301.4 (approx. USD 918.2)[1]
Average landholding size (range: 0.0–5.14 ha per household)	0.40 ± 0.01 ha per household

[1]*At the time of writing, USD 1= INR 76.245*

The study was conducted three years ofpost-disaster event in November 2016. The quantitative data comprisea structured schedule for the household survey to identify primary sources of acquiring food pre-disaster and post-disaster change in consumption pattern & coping strategies—access to healthcare services, government & humanitarian supplies, and WASH sources. The qualitative study was conducted through various ethnographic methods to complement the survey questionnaires. In-depth interviews were done with women household respondents, community leaders, Self Help Groups leader, Block Development Officer (BDO), Chief Medical Officer (CMO) and, Anganwadi workers in order to gain information on health issues, community support, government intervention, change in livelihood and coping strategies adopted by the womenafter the loss of the crop, food reserves and source of livelihood.

4. RESULTS & DISCUSSION

A total of 46 women from both the villages were interviewed for a household survey. About 40 percent have a nuclear family, others live in a joint family with an average family size of 5.4 persons. The majority of the woman respondents maintain a livelihood strategy that includes a combination of subsistence agriculture, livestock rearing, natural resource extraction and marginal tourism-based employment.

Table 2. Women respondent main occupation (reported for all participants of surveyed households)

Occupation % of total (n =46)	
Agriculture (including horticulture)	60.8
Poultry production	8.9
Dairy production	4.2
Government job	6.5
Private sector (mainly tourism-related)	10.4
Livestock rearing	0.9
(Goats, sheep, horse, ponies)	
Other sources of income	8.3
(Includesdaily wage labour and sale of NTFPs)	

Source: Primary data

4.1 The Implication of Disaster on Women's Food Security and Livelihood

For a household economy majorly dependent on subsistence agriculture and the small & marginal service sector under tourism, the disaster had a significant adverse impact on crop production and other livelihood opportunities.

Table 3. Household distribution according to the consumption and primary source of acquiring food pre-disaster

Household dependence on source for daily consumption	Household composition of daily meal		
	Grains*	Vegetables	Oil/ghee
Self-cultivated/ produced	6 (13.1)	14 (30.4)	12(26)
Market	28(60.9)	28(60.9)	34(74)
Forest gathering	0(0)	4(8.7)	0(0)
PDS	12 (26.1)	0(0)	0(0)

(Source: Primary source) **includes both cereals and pulses*

Table 3 shows the self-cultivated/produced products are not sufficient for the majority of the households for consumption on a daily basis; therefore, women respondents (60.9%) were majorly dependent on a market purchase. 26.1 percenthouseholds; Below Poverty Line (BPL) and Above Poverty Line (APL) were partially dependent on fair price shops for grain supplies through Public Distribution System (PDS). Rice is a staple crop, and the production is sufficient for 3-4 months of consumption, during the Yatra season respondents earns substantially for the consumption throughout the year.

Table 4. Coping strategy adopted by women respondents to avoid food

Coping strategy	N=46
Reduction in amount/number of meals per day	36 (78.3)
Reduction in expenses other than food	38 (82.6)
Depend on gathering from forest	30 (65.2)
Move out to relative's place	18 (39.1)
Borrow grains	25 (54.3)
Mortgage (land, livestock)	7 (15.2)
Sale of assets (land, house, livestock)	11(24)
Loan	13 (28.3)

(Source: primary data) Note") Denotes cell percentage to N

Table 4 shows the coping strategy adopted by women respondents to avoid food instability during the post-disaster period. The destruction of infrastructure and connectivity disintegrated the market linkages and resulted inan altered supply of grains in the local market and fair price shops. The disaster occurred during mid of June, relief services provided by the humanitarian organizations becomes short after 3-4 months and almost stopped with the start of winter. As a coping strategy, 78.3 percent of women respondents adapted for a reduction in the amount /number of meals per day. The loss of livelihood reduces the purchasing power, 82.6 percent women respondents prefer to reduce expenses other than food, whereas 65.2 percent was dependent on forest products for food. For 39 percent of respondents, social networks were significant sources to assist in responding to a crisis in the short and medium-term.

Table 5. Different source of income for the women respondent households

Share of contribution to household income	Women respondent major sources of income	Situation before the disaster	Situation after the disaster
Saving approx. 12,000 per crop season	Agriculture crop production	Cultivated paddy/wheat crop, production lasts for around 3-4 months for self-consumption	Standing crop was washed away; agriculture land was wiped off or silted
6,000 per month	Milk production + Poultry	During the Yatra season, 4-5 liters of milk and poultry products were sold to hotel/restaurant/guest house amounting to around INR 200 per day.	Sale was almost insignificant due to non-availability of market. People used milk and poultry products for self-consumption.
6000 per month	Petty shops; Vegetables and fruit vending	Earned around INR 200 per day	Standing vegetable and horticulture crop has been damaged and even market has been destroyed.
3,900 per month	Working for Self Help Groups(Spices, weaving, stitching)	Earned around INR 150 per day	Product is not able to reach the markets in neighboring or far-flung towns
21,000 (consolidated for 6 months)	Household dependent on the cattle herders for sale of wool for making traditional woolen clothes.	During the Yatra season, the average earning per month was around INR 3,500	The demand for woolen clothes has gone down substantially with the insignificant flow of tourist.
3,000 per month	Sale of NTFPs	Earned around INR 100 per day	The forest either becomes inaccessible due to landslides or risky to access due to rockfall and mud sludge.
	Remittance; majority migrating members send remittance to their home.	In majority cases, remittance varies between INR 1,000 to 5,000 per month	Due to destruction and loss of communication and infrastructure systems, this has reduced drastically. Banks and Post-Offices remains closed.

(Source: Primary source)

Table 5 suggests that women were responsible for household food production and distribution along with that involved in weaving, sale of non-timber forest products (NTFPs), agriculture, horticulture and, poultry& animal products. Some of them were associated with Self Help Groups working with wool and spice industries. The total monthly income of the householdis approx. INR 8,000

and contribution by the women workers with in the household is approx. INR 2,000. The income varies, it is highest during the tourist season (May-June and Sep-Oct) and lowest during the winter season (Nov- Feb). Remittances made an essential partof annual income for the women's household. On average, every third respondent household has at least one member of the family working outside and sending money on a monthly or quarterly basis.

4.2. The Implication of Disaster on Women's Health

Women's health was impacted directly by the disaster event, through physical injury as well as emotional stress, and indirect impacts like violence and increase in their work load causeda long-lasting impacton health and well-being. They faced adverse health conditions like water-borne infections, due to limited access to clean water and ill-health linked to poor nutrition concerning lack of access or income to purchase food. Given their lower social status in the family, they also face particular health issues related to their sex.

Table 6. Implication of disaster event on women health

Effect of disaster on women health	
Health issues	N= 46
Domestic violence	11 (24)
Injury & ill health	19 (41.3)
Reproductive health issues	18 (39.1)
Hygiene and sanitation issues	34 (74)
Post-disaster stress	25 (54.3)

(Source: Primary source)

Table 6 Post-disaster, the burden of securing food, falls on women as their male counter part started moving out of villages to ensure income by daily wages work. Along with the routine work, a woman has to collect relief supplies, walking kilometers through a forest, and rough terrain, 41.3 percent respondents reported being injured due to sudden rockfall or wild animal attack. 24 percent women respondents disclosed the incidence of physical violence inflicted by their spouse citing frustration, mental stress, or with drawal symptoms of alcohol and post-disaster woman increased dependency on male income. The majority of the respondents who spent days in the relief camp had their needs unfulfilled for personal hygiene and sanitation and became prone to infections resulting in fever and malaise. 54 percent of the respondents hademotionaldistresswho facedthe death of family members or complete loss of assets or livelihood. For the majority of them, it was stressful to bear the scene of destruction, death, and injuries. Due to old age health risks and socio-economic limitations, older women have affected more adversely than younger ones. The calamity lowered

the access of pregnant females to a health facility for pre and post-natal care. During pregnancy, many face fear ofobstetrics complicationsin the absence of skilled assistance, the majority of them delivered at home, and a few suffered from postpartum infections. As services under ICDS were hampered, lactating mothers became susceptible to malnutrition; this further leads to morbidity.

4.3 Impact of Disaster on Women: Realities for Mountain State

One of the serious consequences of the 2013 disaster was people lost their land, livestock and livelihood and unexpectedly became unemployed. In the absence of other employment opportunities or skills faced financial distress and food insecurity. It was evident that women in hills are self-employed and not wholly dependent on their male counterpart for economic well-being. Never the less, they experience the utmost stress due to their several daily works and inferior social status.

4.3.1 Post-disaster nutritional and health risks

A School teacher in Vijayanagar told, the supply through PDS and humanitarian organizations was not sufficient; women were expected to serve male members of the family first. It might result in post-disaster nutritional risks for women. Poor personal hygiene and sanitation services made them prone to infectious diseases. Less number of women attended the health camps as they find it challenging to take out time to access health care facilities.

"When food was scarce, females were expected to serve male members first. Their need for healthcare, personal hygiene and sanitation were not fulfilled, even they didn't get time to visit a health facility."

4.3.2 Post-disaster stress syndrome

The wounds of the 2013 disaster were still fresh in her mind as she reacted in tears, a 52-year-old woman in Chandrapuri, who lost his son during flash floods. It took around four months for her to speak. Now, she has come to terms with life but couldn't forget the scene of the havoc; drowning of cattle, dead bodies, broken houses. Initially, she didn't allow her daughter-in-law to claim the compensation for his deceased spouse, later older people at the village counsel her for the same. She still believes his son will return home one day.

I lost my son in the floods…. couldn't forget the scene of the havoc that occurred in 2013. Initially, I didn't allow claiming compensation considering my son as dead but…. I feel he will come back home someday.

4.3.3 Disruption of Routes to Anganwadis

A 28-year-old Asha worker told, services sponsored under ICDS; supplementary nutrition to children, pregnant women, and lactating mothers were hampered

as Anganwadi remains non-functional. The flash floods and landslides raised danger of life and property; working staff was not available for weeks to restart the services. Later immunization and health check-up were arranged at different places other than Anganwadis.

"The services provided under ICDS were stopped as Anganwadi remains non-functional for weeks. Later a few services were arranged at different places in both the villages."

4.3.4 Unfulfilled promises for livelihood assistance

A 29-year-old woman lost her husband in the flash floods leaving her as the sole caretaker of three children. One leading NGO paid a monthly amount, 2000 each for children. Since it was promised for five years, the NGO will stop paying by 2018. She didn't have a job, even though the government had promised jobs for widows.

"I don't have a job….the government had promised jobs for widows, but it never happened."

4.3.5 Livelihood securitywas not provided

A 32-year-old employee at Block Development Office, Augustymunitold, the Rudraprayag district administration has been awarded for the effective implementation of MNREGA for the year 2013-14, it provided work for six months. As there is little hopefulness of revival of pilgrimage or tourism in the near future the male members migrated to the cities and the burden to sustain the household fell on women.

"Rudraprayag districthas been awarded for effective implementation of MNREGA…. what about the long term livelihood security of the villagers?"

4.3.6 Living life with adequate means

A 38 years old village Pradhan told post-disaster the women get engaged in agricultural activities and petty shops, which provides economic stability. Compensation was given by the government for the death of spouse and loss of assets and livestock. This allowed them to sustain their families with the second source of income.

" Many of the women started working in the agriculture fields or managed a small shop. The government swiftly released the compensation….atleast they become able to sustain their families."

5. CONCLUSION

Natural disasters are capable of disjointing the social and administrative coping mechanism and can cause food insecurity that may results in malnutrition and adverse health outcomes. Women faced 'double burden' of disaster as they typically juggled roles; reproductive and productive. They had to manage rearing responsibilities, domestic tasks as well as income generation. Along with the material and asset loss,women respondents experienced more intangible losses; the loss of health and well-being. Along with the direct impacts they were subjected to several indirect impacts, including violence and emotional trauma, an increase in workload, poor nutrition, health and sanitation. The root causes of women vulnerability were the lack of access to the resources that can allow them to cope with disaster events, such as income, education and social and market networks. Respondents faced multiple barriers to financial recovery due to less income and lower savings base, compounded by barriers to asset holding and income production, which exist because of women's socially constructed gender role and inferior status in the society.

6. Limitation of the study

The outcomes of the study cannot be generalized to any other disaster-hit rural village located in a different set-up with a completely different geographical location.

- The respondent faced difficulty in reporting exact details of income sources, food consumption, and healthissues during pre and post-disaster phases. The researcher acknowledged that recall biases might influence the responses.
- Best attempts were made to check data regarding ICDS center, government schools, fair price shops and birth, mortality and morbidity data. However, the register showed missing or scanty records for months following the disaster.

THREE YEARS POST-DISASTER



Figure 1 A damaged house in need of reconstruction at Chandrapuri



Figure 2 A poly-fiber house constructed by a NGO



Figure 3 SaraswatiShishu Mandir school temporarily constructed post-disaster



Figure 4 Ringal basket for sale at local market, Vijaynagar

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Chapter 23

HEALTH RESPONSE DURING EMERGENCIES: A CASE STUDY OF YAMUNA FLOOD

Shweta Bhardwaj, Thinles Chondol and Anil Kumar Gupta

ABSTRACT

Flooding of the settlements in floodplains of Yamuna River in Delhi is an event that occurs every year. It is not a natural disaster but caused due to the release of water from upstream barrage affecting communities living on the Yamuna riverbank in illegal settlements. With timely dissemination of early warning, District Disaster Management Authority evacuates the settlements to nearby elevated locations. This study was conducted at three different sites affected by rise in Yamuna water level- Ranney well, Vijay Ghat and Gaspur colony. With the help of this study, an attempt has been made to assess the physical and mental health impact of this annual flood event on communities residing in the affected areas and the study the relief and response post flooding, using key informant interviews and focused group discussions. The key parameters influencing health safety and hygiene during disaster relief and response including physical health, mental health, sanitation and hygiene, food & water and solid waste management are studied. The outcomes of the study highlight the influence of social and economic vulnerabilities of communities in aggregating the hazards risk. Further, it was found that the quality and quantity of relief operations varied in different flood affected locations.

Keywords: *Yamuna Flood, health, livelihood, recue and relief, WASH.*

Shweta Bhardwaj
Junior Research Fellow, ECDRM Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi

Thinles Chondol✉
Young Professional, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi
thinleschondol@gmail.com

Anil Kumar Gupta
Professor & Head, ECDRM Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi

1. INTRODUCTION

Delhi experiences floods almost every year. According to the report by Delhi District Management Authority (DDMA), 2015, major floods occurred in the year in 1924, 1947, 1976, 1978, 1988, 1995, 1998, 2010 and 2013. The water level of Yamuna River crosses its danger level of 204.83 m due to the release of excess water from barrages upstream which often lead to submerging of the settlements and agricultural fields in these areas, thus damaging the agriculture produces and source of livelihood.

The floods in these areas is not a natural disaster but caused due to the release of excess water from the barrages upstream and irresponsibility of the concerned authorities that has caused the mushrooming of informal settlements with non-planned and poor housing structures on the banks of Yamuna (Gupta, 2017). Yamuna flood plains are delineated on each side of the river by 800 meters in 1986 which was reduced to 300 meters in 2014 because of which new settlements and construction activities begun in these fragile and vulnerable areas. According to a report by DDMA (2015), there are about 15,000 families and 75,000 individuals residing in these areas with annual risk of inundation of their houses and livelihood sources. These settlements get inundated every year under the increased water level and evacuation camps are set up by the government at safer locations. The same report mentioned that almost 5% (74 sq. Km.) of the banks are protected by earthen embankments and bunds. The water released from upstream headwork takes about 2 days to reach Delhi causing rise in Yamuna water level. The flooding due to rise in Yamuna water level generally affects areas of North Delhi on the west bank and the entire trans-Yamuna area on the east bank. Early warning for the rise in water level is disseminated from district administration and evacuation operations for shifting people residing in flood prone areas to safer locations in temporary shelters are carried by concerned authorities.

1.1 Health impact during emergencies

Disasters are accompanied by physical, psychological, social and economic impacts. The health consequences majorly depend on the adversity of the flood, effectiveness of early warning system and socioeconomic capacities of the victims. Everyone is affected differently by flood events depending on the vulnerability of the individuals/families/communities. Vulnerable sections of the communities including children, women, elderly, individuals with medical conditions and disability are at higher risk because of lack of their ability to access healthcare systems. The evacuation and relocation before as well as post disaster have serious health consequences. In temporary shelters, displaced population generally become more vulnerable towards malnutrition due to poor diet, overcrowded and unhygienic shelters increasing the risks of vector borne diseases and outbreaks such as urticaria (nettle-rash), scabies,

skin infections due to bacteria and fungus, gastrointestinal sickness, dysentery and enterovirus infection (Mohamed et al., 2017). Some of the major concerns during emergency situations like floods include contaminated water sources which might aggravate the occurrence of waterborne diseases and also can provide favourable breeding grounds for mosquitoes, parasites and other disease causing pathogens. During emergencies, effective management of relief and response operation particularly relief camps are essential to minimise the health risk. The overcrowded relief camps setup with poor solid waste, wastewater and sanitation management can enhance post disaster health risks due to poor hygiene. Inadequate Water, Sanitation and Hygiene (WaSH) systems leave communities more vulnerable during disasters. Direct contact with faecal matter can contaminate food, water and utensils may cause gastrointestinal infection, cholera, typhoid, diarrhoea, dengue and chikungunya etc which when left untreated might become fatal (WMO, 2015). Relief camps can also attract rodents causing diseases like leptospirosis, which is generally transmitted when there is direct contact with host's urine (WMO, 2015). Apart from direct and visible consequences on physical assets, environment and health, disasters/ emergencies can also have psychosocial and mental health impacts on victims wherein they may suffer from post disaster anxiety, depression and stress due to loss of property, asset and life. All of these risks can be real challenges to public health and in this scenario rapid recovery and restoration of basic and fundamental services (food, water, sanitation and healthcare systems) can be really helpful in substantially reducing exposure of affected communities of these risks.

2. STUDY AREA PROFILE

The topography of Delhi is divided into three types- Ridge, Yamuna floodplain and the plain. The Yamuna flood plains are low-lying areas, which had remained uninhabited for a long time, but due to migration of people from different regions in search of job and livelihood opportunities, these areas have now become home to approximately 30 percent of the total Delhi's population. The study was carried along the bank of Yamuna River in Delhi across three districts viz. East, Central and South-East Districts at Ranney Well (Yamuna Bank), Vijay Ghat (Bela Estate), Gaspur colony (Nizzamudin) relief camps respectively, set up by the concerned district authorities as a response to flooding of Yamuna` River in Delhi.



Figure 1: Delhi district map (Source: Maps of India)

In this case study an attempt has been made to assess the health impact of flood event on communities residing near

Yamuna river bank and study the emergency response and relief interventions taken by government authorities during the flood event in the city. The flooding in city is an annual event which is witnessed every year however, like most of the disasters of present times what makes the flooding of river Yamuna in Delhi, an unnatural and complex event, are the physical, social, economic and political vulnerabilities of the communities; these vulnerabilities play an important role in defining the impact of these floods.

The communities residing in the floodplains of river Yamuna in Delhi mostly comprising of the people living in these communities have migrated from nearby states of Uttar Pradesh and Bihar primarily in search of jobs. Most of them are daily wage labourers working as farmers, rickshaw pullers and construction workers etc. Their average income usually varies somewhere from Rs. 200-250 per day. Women in these communities are primarily engaged in household work; however, some of them work as daily wage agriculture labourers in nearby agricultural fields or nurseries. Some of the households in these communities own agricultural fields on the banks of the river, however majority of agricultural land and nurseries in these areas are owned by big framers who lives in other parts of the city. Majority of children in these communities are school drop outs who have attended school at most till 10th grade after which young boys become bread earners and contributors to family income; whereas girls takes care of household chores and become caretaker for younger siblings in the family usually when parents are out for work or are married at very young age. The flooding of their agricultural fields and evacuation to temporary shelters is an every year's story for them.

These communities lack access to basic amenities such as clean drinking water, electricity, healthcare system, roads and most importantly safe and hygiene environment for living. The reasons for this are deeply rooted in socio-economic circumstances of the people living in these areas, which actually ends up making them more vulnerable and exposed towards extreme events like flooding. As a relief and response measures, district authorities provide the affected communities with essential amenities which include tent, electricity supply, drinking water, food and healthcare facilities. However, these relief and response interventions vary largely in quality and quantity at different locations.

2.1 Methodology

The study is based on cross-sectional research design utilising a mixed approach where in both qualitative and quantitative data was collected. The primary data for the study was collected through focussed group discussion and key informant interviews. Whereas, the secondary data were taken from government reports on past and recent flood events in Delhi. Focussed group discussions were used to get a general insight of relief response provided by government as well as helped in gathering information on flood-health linkages. The focussed group

constituted of 10 people; in total three FGDs were conducted, one at each site. The samples were characterized based on the respondents' age and gender (Figure 1 and Figure 2).

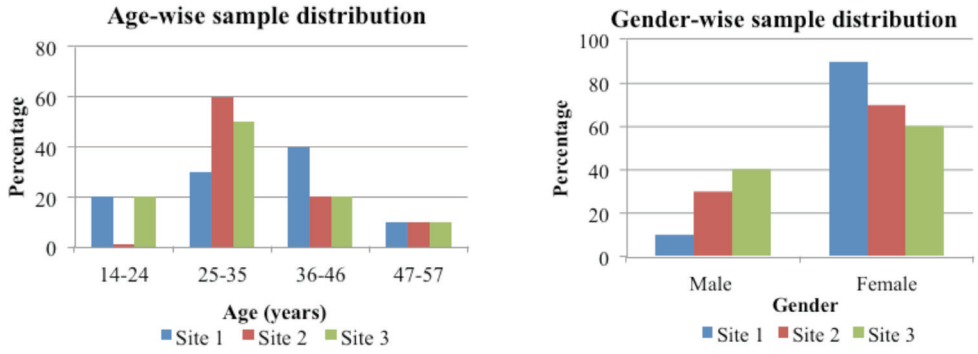


Figure 2: Sample characterization based on the respondents' age & gender

The key informants' interviews were based on a questionnaire consisting of open-ended questions that were formulated prior to visiting the site. Descriptive statistical techniques which included measurement of frequency through total and percentages were used to assess the primary data obtained by interviews and summarised as outcome of the study. The focused group discussion helped in identifying the key thematic areas pertaining to health and the parameters influencing these areas during disaster relief and response phase. The key parameters included physical health, mental health, sanitation and hygiene, food and water and solid waste management (Figure 3). The table 1 summarises the details of the relief and response undertaken at different study locations across five selected parameters. All these parameters have strong linkage to public health particularly during emergencies. Later on, descriptive statistics was used to evaluate some of quantifiable parameters across these thematic areas.

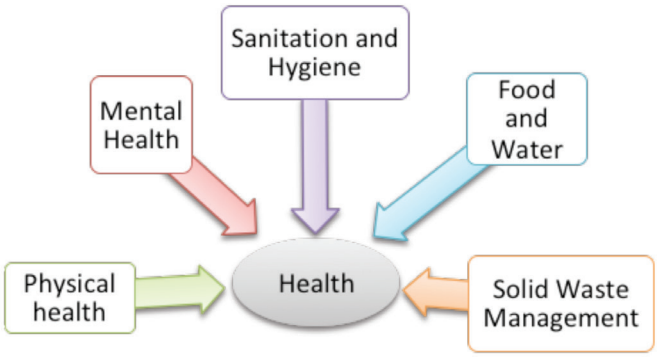


Figure 3: Sample characterization based on respondents' gender

Table 1: Parameter wise relief and response at different study locations

Parameters	Ranney Well	Vijay Ghat	Gaspur Colony
Physical Health	• Few children suffering from fever/ loss of appetite/ nausea • No women specific intervention • First-aid and healthcare facility available	• Few children/elderly suffering from ever/ loss of appetite/ nausea • No women specific intervention • Power connection (only in few) • No first-aid and healthcare facility available • Snakebite	• No women specific intervention • No first-aid and healthcare facility available • Sometimes doctor visited for checkups • Fumigation to prevent mosquito breeding
Mental Health	• Anxiety and stress due to loss of their livelihood source • Risk of theft and robbery	• Anxiety and stress due to loss of their livelihood source • Risk of thieves and robbery • Stress/worry for women and child safety	• Anxiety and stress due to loss of their livelihood source • Risk of thieves and robbery • Stress/worry for women and child safety
Sanitation & Hygiene	• Mobile toilet facility provided but not timely cleaned • Open-defecation • Washing utensils and clothes near the tents • No bathing area	• No toilet facility • Open-defecation • Washing utensils and clothes near the tents • No bathing area	• Mobile toilet facility provided but not timely cleaned • Open-defecation • Washing utensils and clothes near the tents • No bathing area
Food & Water	• Water source: Ranney well and water tankers • Inequitable and no systematic food distribution mechanism adopted	• Water Source: water tanker and supply water from another colony not affected by flood • Insufficient number of water tanker • No provision of food	• Sufficient water supply from tankers • Sufficient food is prepared on the site for everyone (Three meals a day)
Solid Waste Management	• No solid waste collection/disposal facility	• No solid waste collection/disposal facility	• No solid waste collection/ disposal facility

3. RESULTS

3.1 Physical Health

According to the results, 50% of the respondents reported physical health problems which included loss of appetite, snakebite, nausea and vomiting, headache and light-headedness (mainly due to lack of sleep) and loose motions post flood events. Majority of the respondents complained about loss of appetite (26.67%) and headache/ light-headedness (26.67%). Some also reported incidents of snakebites (20%) along with nausea and vomiting (13.33%) and loose motions (13.33%). The problems pertaining to physical health showed close association with the displacement to temporary shelters (relief camps) post flooding.

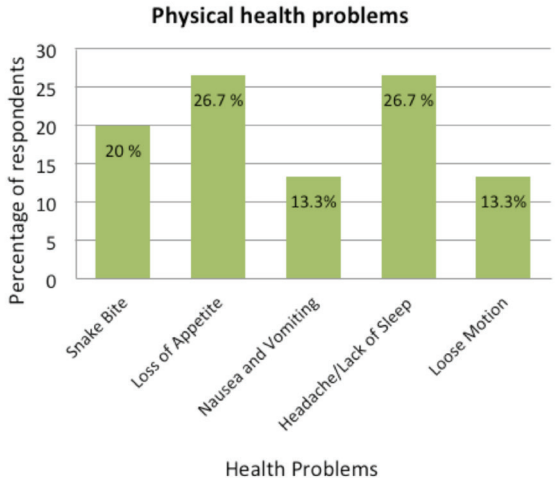


Figure 4: Various physical health problems reported by the respondents

Most of the people stated that there was timely flood warning due to which they could safely pack their valuables and necessary assets while some claimed that the warning was provided late. Mainly children and elderly suffered from loss of appetite, nausea, vomiting, fever, etc. At site 1 (Ranney Well) cases of minor cuts during the evacuation process and at site 2 (Vijay Ghat) cases of snake bite were reported. Healthcare services like first aid and basic health checkups were available at site 1 (Ranney well) and site 3 (Gaspur Colony) only.

3.2 Mental Health

Disasters can have a number of consequences on mental health and well being of individuals exposed to such events. Due to disruption and displacement to relief camp during flooding, people can experience Post Traumatic Stress Disorder (PTSD), anxiety, depression, grief and other such psychological problems. Primary stressors such as injuries and death etc are inherent in most of the disaster events and have close association with mental health of affected people; however, secondary stressors such as loss of livelihood, lack of access to basic services and infrastructure etc can aggravate the impact of disasters

particularly on mental health and well being of affected people. Diagnosis of most of these psychological problems requires expert interventions; however, Focused Group Discussion and Key Informant Interviews were used in this study helped in indentifying some the key stressors across the affected communities. These stressors include loss of livelihood, safety of women and Children in relief camps, threat of theft and loss of assets. Majority of the respondents (42.31%) reported feeling of stress due to loss of their livelihood after the floods. Shifting to relief camps left them worried about safety of women and children as well as threat of theft/robbery, which was reported by significant number of respondents. Loss of assets was another significant stressor reported by 11.54% of respondents.

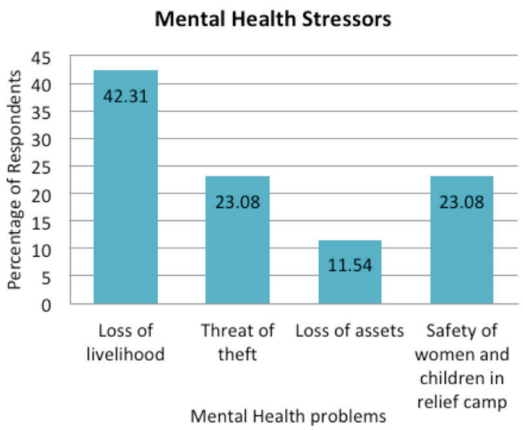


Figure 5: Various mental stressors reported by the respondents

The victims were stressed due to the loss of their livelihood since majority of them were farmers or daily wage labourers at nurseries/ farms cultivating vegetables including Fenugreek, Brinjal, Raddish, mustard, mint, etc and fruits including Custard, Apple, guava, etc. The farmers lost their investments made on the farmlands and the labourers lost their source of daily bread. They were facing constant stress and anxiety due to issues related to safety particularly of women and children in these camps on the footpaths especially during night time and they were also stressed due to the threat of stealing or robbery since all of their valuables were in these relief camps only.

3.3 Sanitations and hygiene

Sanitation and hygiene are critical components in prevention of number of vector-borne diseases and managing associated health risk. Water, sanitation and hygiene just do not impact health and well being of people but it also has wider socio-economic implications particularly on women or girls in a community. During disasters, inadequate or disrupted water supply, sanitation and hygiene systems can reduce people's accessibility to basic and fundamental sources like clean water and sanitation facilities, which can increase the risk of disease transmission, deteriorate hygiene conditions and often lead to negligence of privacy, safety and other needs of vulnerable sections of affected communities particularly women, girls, children etc. As a flood response in Delhi, temporary toilet facilities have been provided at a few sites by DUSIB

(Delhi Urban Shelter Improvement Board) but people don't prefer using them due to various reasons. Open-defecation is a common practice in these areas. People living in the camps, usually washed their utensils and clothes just near/outside their tents. No solid and liquid waste disposal and management facilities were in place in these areas during relief operation. However, focused group discussion and key informant interviews highlighted the same situation before floods as well, where these areas lacked proper sanitation, hygiene and solid-liquid waste management facilities. The discussions and interviews also highlighted the key reasons for not using the toilets facilities available at the relief camps, which included lack of cleanliness, facilities common for men and women, inaccessibility and not habituated of using toilets. Half of the respondents attributed their non-usage of toilet facilities to lack of cleanliness (50%); while others attributed it to inaccessibility due to distance of these toilets from the relief camp, no electricity in the toilets etc (25%), toilets being common for men and women (17%) and to the fact that they are not habitual of using toilets (8%).

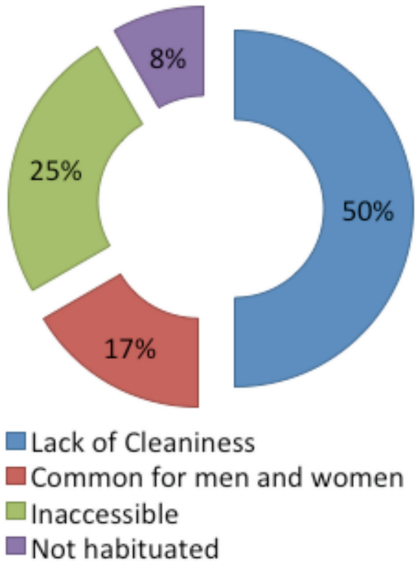


Figure 6: Reasons stated by the respondents for not using toilets

3.4 Food and water

Food in the camps waseither prepared on site or was brought 'ready to serve' by DDMA authorities. Usually, two meals were served in the camps. At site 2 i.e. Vijay Ghat, there was no provision for food. Drinking water tankers were made available by Delhi Jal Board at each of the locations. However, discussants and respondents expressed their dissatisfaction about the quantity of food and water made available to them as well as the inequitable distribution of food. The site 3 (Gaspur Colony) where food was prepared on-site, food provisioning was better managed. In case of water facilities, water was made available for drinking purpose only while there was no provision for availability of water for other purposes such as bathing, washing clothes, hand-washing etc.

3.5 Solid Waste Management

Solid waste management facilities remained majorly missing at all the sites. People were found disposing solid waste outside the tents or at nearby empty spaces.

4. CONCLUSION

Administrative response to the flooding event of 2019 varies across the spectrum wherein at site 1 (Ranney Well) the response looked relatively weak due to inefficient and ineffective management of relief and response operations; whereas at site 2 (Vijay Ghat) and site 3 (Gaspur Colony) these operations were better monitored and managed. A highly relief centric approach is employed in dealing with the annual flood events in Delhi, wherein efforts are made to provide immediate support to affected communities and restoring the basic services. However, addressing the cause of this disruption remained missing since years. The promptness of relief and response efforts made by the concerned authorities is extremely commendable but these efforts still remained inefficient due to absence of quality and quantity in the support being provided to affected communities. Providing food and shelter remain prime focus during relief operations, however, others services including health, WASH etc. were majorly neglected. Also, for ensuring an effective management of emergencies like flooding, first there is a need to address everyday challenges of these marginalised communities in urban areas. In normal scenario also, most of the households in these communities lack access to primary healthcare services as well as proper water, sanitation and hygiene (WaSH) facilities. Open defecation, poor drainage and waste management system, unsafe and unhygienic living conditions are major challenges in these marginalised urban areas, which leaves communities more vulnerable and exposed during emergencies. Ensuring fundamental services and basic infrastructure remains critical for addressing disaster vulnerabilities and risk; in this local government has an important role to play. Quantification of loss and impact of this annual flooding is also very much important since assessing losses can ensure optimization of our preparedness and relief operation for any disaster event in future; it also enables better understanding of diverse impacts of these events. The temporary settlement must be properly planned with equitable distribution of food and clean drinking water source, sanitation facilities and wastewater disposal facility. Safety and security of women and children should be a priority in emergency responses and to ensure this disaster relief responses must be sensitive to needs of vulnerable groups (children, women, elderly, already sick etc). Health response is a most critical part of any relief operation since it just not ensure faster recovery of affected/exposed population but it also protects them from prevailing health risk post disaster. That is why, it is extremely important to plan an effective health response and in doing so it would require inter-sectoral implementation and management. As seen in this case study, there are number of areas which might not directly come under the purview of health domain (such as solid waste management, food) but has a significant role to play in ensuring health, safety and hygiene of affected people particularly in post disasters conditions. Health relief response requires a more holistic and comprehensive approaches which can ensure basic health services, food security, WaSH facilities and waste management responses driven by sensitivity towards the needs of affected communities especially the vulnerable sections.



Figure 7: Field glimpses at Site 1 (Ranney well): (a) Food distribution by Civil Defence Personnel; (b) Relief camps; (c) Water Tanker made available by Delhi Jal Board on-site; (d) Relief wastes disposed on-site



Figure 8: Field glimpses at Site 2 (Vijay Ghat): (a, b) Relief Camps; (c) A woman washing utensils near the tents; (d) Discussions with the victims



Figure 9: Field glimpses at Site 3- Gaspur colony: (a) Relief camps; (b) Discussions with the victims; (c) Food being prepared on-site; (d) On-site portable toilet facility

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Chapter 24

CLIMATE CHANGE RELATED DISASTERS AND HEALTH RESILIENCE: LESSONS AND ROAD AHEAD

Anjali Barwal, Atisha Sood and Anil Kumar Gupta

ABSTRACT

Climate change and disaster are complex cross cutting issues with multi-dimensional development impacts. Climate change induced shifts in rainfall patterns can lead to unpredictable storms and flash flooding, as well as in aggravated drought-related events, such as crop failure, heat waves, drying of water reservoirs and, consequently, water scarcity, famine and loss of human and animal lives, in addition to general environmental degradation.

Disasters directly or indirectly threaten the living environment of human beings and the health of the people. Disasters are held responsible for causing substantial damage globally resulting in severe environmental and economic burden on living conditions as well as management of additional waste created by disasters. Simultaneously, it also increases the risk of many infectious diseases.

Anjali Barwal✉
Research Associate, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi, India
anjali.barwal@gmail.com

Atisha Sood
Junior Research Fellow, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi, India

Anil Kumar Gupta
Professor & Head, ECDRM Division, National Institute of Disaster Management, Ministry of Home Affairs, Government of India, New Delhi, India

This compendium is a collection of 22 case studies across India covering best practices and lessons learnt on the topic concerned with climate change, disasters and health sector. Trends, challenges, solutions and lessons are drawn from these case studies, which may serve as a guide for the design of future initiatives to be implemented under the climate change and health resilience and provide a reference for the other regions of the world. Lessons learnt from these good practices also highlight the fact that there are no magic bullets or single solutions: good-practice tools reach their full potential if implemented in the context of a comprehensive and aligned systemic approach.

Climate change may render the current flood management structures and policies inadequate and insufficient to deal with erratic rainfall. For floods, periodic forecasting and warning system is very essential during the pre-disaster period to prevent damages and save lives. Flood zoning regulations needs to be followed strictly during construction of buildings near the riverbanks. Flood proofing measures namely flood shelters, flood safe buildings are very much required in the flood prone areas. New innovative flood management guidelines to manage floods in hilly areas should be prepared. Capacity building of human resources should be done at all levels in relation to preparedness, and post-floods stage: Rescue, Relief, Recovery, Reconstruction, Rehabilitation and Research.

It has also been observed that in India, there is a lack of research and development concerning water contamination crisis and disaster management and more effective crisis management plans are required for such incidents.

During and after any disastrous event, hospitals play critical role in reducing casualties, and the emergency preparedness role of the hospital may extend beyond those hazards which could directly affect the safety of the hospital. In view of this, there is a need to transform healthcare facility infrastructure to mitigate climate change threat as well as prepare themselves to be operational during stressful climate events. Identifying issues and gaps in climate preparedness for efficient health delivery, including pre-planning and post disaster response is the key to climate change risk mitigation. The climate risk mitigation strategies should identify implementation measures for new facilities, retrofitting for existing ones, establishing dynamic link among networked health facilities for a successful transformation to a climate-smart healthcare.

Recently, the COVID-19 pandemic presents an unprecedented challenge to public health and human life. Due to pandemic induced lockdown, many people have been staying at home and indulging less in terms of social interactions and exercise, with chances of having a negative effect on physical and mental health. Further, with loss of employment and low and irregular incomes and a lack of social support, many of the workers in the informal economy have

continued working, often in unsafe conditions, thus exposing themselves and their families to additional risks. COVID-19 significantly impacts not just health of people but also services for Non-Communicable Diseases (NCDs). More than half (53%) of the countries surveyed have partially or completely disrupted services for hypertension treatment; 49% for treatment for diabetes and diabetes-related complications; 42% for cancer treatment, and 31% for cardiovascular emergencies (as per WHO). Moreover, people living with NCDs are at higher risk of severe COVID-19 related illness and death. Alternative strategies have been established in most countries to support the people at highest risk to continue receiving treatment for NCDs such as telemedicine, making use of triaging etc. We must recognize this as an opportunity to build back better and a safer world through developing our existing capacities. Also establishing partnerships between government agencies while implementing specific activities in climate change and related disaster sectors, is key to the success of integrating consideration of resilience into socio-economic developments.

ABOUT CECR AND HER-CAP PROJECT

CECR

The National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

NIDM has a dedicated division for Environment, Climate and Disaster Risk Management (ECDRM) which has been designated as a Centre of Excellence on Climate Resilience (CECR) under the National Action Plan for Climate Change and Human Health (NAPCCHH). The CECR is implementing six research projects namely Climate Adaptive Planning for Resilience and Sustainable Development in Multi-hazard Environment (CAP-RES) with support of DST-Govt of India, National Agriculture Disaster Management Plan (NADMP) funded by the Ministry of Agriculture & Farmers Welfare, Health Resilience and Capacity Building (HER-CAP) with WHO, Crisis Management Plan for Dealing with Contamination of Water Bodies (CMP-WB) funded by CPCB, Disaster Management Plan for Ministry of Environment, Forest and Climate Change (NEFC-DMP) with the support of MoEFCC and Disaster Management Plan for the Dept. of Chemicals and Petrochemicals (NCPC-DMP) supported by DCPC, MoC&F. It also collaborates with a number of international and national organizations working in the areas of climate change adaptation, resilience, disaster management and disaster risk reduction.

HER-CAP PROJECT

NIDM in collaboration with WHO India has implemented the project "Health Adaptation and Resilience: Advancing Strategic Knowledge and Capacities" (HER-CAP). Under this project, the following documents have been drafted.

- 'National Health Adaptation Plan for disasters related illnesses' for Ministry of Health and Family Welfare.
- Training Manual on 'Health Adaptation and Resilience to Climate Risks'.
- A compendium of case studies on 'Climate Change related Disasters and Health Resilience'.
- Four Policy papers on Regional Issues and Opportunities for Health System

Resilience to Climatic Disasters. (For North, East & North-East, West and South Region of India).

➢ Along with this, four thematic papers on key areas are as follows:

- Temperature related disasters: Heat and Cold Wave – Implications for health adaptation and resilience.
- Water related disasters: Floods and Drought - Implications for health adaptation and resilience.
- Air pollution and public health emergencies.
- Environmental services for health protection in disasters and emergencies.

Design & Print : kam@kamstudio.net



National Institute of Disaster Management (NIDM)
(Ministry of Home Affairs, Government of India)
Plot No. 15, Pocket 3, Block B, Sector 29, Rohini, New Delhi 110042
Website : www.nidm.gov.in

