ISSN: 2320-5407 Int. J. Adv. Res. 10(08), 912-920

Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/15250
DOI URL: http://dx.doi.org/10.21474/IJAR01/15250

RESEARCH ARTICLE

MORTALITY OF LIGHTNING HAZARD AND ITS MANAGEMENT IN INDIA

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Manuscript Info

Manuscript History
Received: 26 June 2022
Final Accepted: 28 July 2022
Published: August 2022

Key words:-
Lightning, Thunderstorm, Hazard, Disaster, Extreme Weather Events

Abstract

India is the most disaster - prone country in the world. Nearly 85% geographical area and more than 50 million people of India are in vulnerable state by one or multiple hazard. Lightning, an extreme event, has emerged as a major weather-related hazard with changing climatic conditions of tropical and sub-tropical countries. It is a massive electrostatic discharge caused by the circulation of warm moisture-filled air through unbalanced electric field in the atmosphere, accompanied by the loud sound of thunder. It is hazardous which affects lives, livelihoods and property. Every year more than 2,500 people in our country die due to lightning. In this paper an attempt has been made to analyse the spatio-temporal variations of lightning mortality in Indian context for last five decades. Assessment of lightning-mortality statistics and its comparison with other major natural disasters reveal that lightning ranks number one amongst all natural disasters in India. On the basis of available secondary data, the geographical distribution of lightning incidents along with the States which have the most lightning casualties have been identified in this study. Though lightning is a widespread disaster in India in terms of mortality and losses, but it has drawn a little attention. In this paper, I have tried to highlight the neglected dimensions of disaster compensation acts and rules related to lightning. This is the high time for reorientation of perceptions on disaster insurances, government funding and management for the people affected by lightning. The findings of this study will help such unnoticed and unrecognised problems.

Introduction:-

Extreme weather events are increasing day by day in our changing climate due to increase in greenhouse gases and environmental degradation. Among them lightning has been recognised as one of the most powerful, spectacular and all-pervasive climatic hazards that mankind has encountered throughout history. Simply lightning is a flash of light in the atmosphere, occurring during a thunderstorm and caused by a discharge of electricity, either between clouds or between a cloud and the ground. It is common phenomena in tropical and in subtropical regions and results in numerous deaths every year throughout the globe. A global estimate is about 6,000 to 24,000 fatalities per year. The people struck by lightning may survive with different medical problems such as lifetime injuries, temporary disabilities and psychological trauma. The affected sectors include health, property, insurance, forestry, electricity (generation, transmission and distribution), agriculture, telecommunication, transportation, tourism and recreation.

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Surprisingly, there has been little systematic collection of information on lightning deaths in many regions of the world including India making it difficult to estimate the annual rates of lightning fatalities either globally or nationally. Government initiatives for lightning hazard management have got momentum very recently in India and different issues of compensation are not covered till now.

Objectives:-

The objectives of this present study are – 1. to assess the lightning-mortality events and its comparison with other major natural disasters in India. 2. to find out the spatial distribution and temporal change of lightning events among the different states of India. 3. to suggest the prevention, preparedness & mitigation strategies along with public awareness and safety campaign of lightning hazard. 4. to highlight the neglected dimensions of disaster compensation acts and rules related to lightning.

Materials & Methods:-

Available secondary data has been used in this study in order to portray the real scenario of lightning event in India. In this present study different extreme weather events (EWEs) were analysed, both at the national and state level based on 50 years' data (1970–2019) of India Meteorological Department in terms of mortality rates. Various statistical analyses were carried out and the result has been presented in a meaningful way using tabulated form. The study period for this present study is 1970 to 2019. Both qualitative and quantitative approaches have been used from the view point of management approach. The time series analysis was done based on different periods, i.e. annual, decadal, twenty-year and fifty-year slice periods.

Spatio-Temporal Variations:-

Lightning, hazard accounted for about 33 percent of deaths that resulted from natural disasters in India from 1967 to 2019. Table 1 shows the scenario of casualty by different natural hazards in Indian sub-continent during the above motioned time period.

Table 1:- Natural Hazard Casualty in India, 1967-2019.

Lightning	Flood	Sunstroke	Cold	Landslide	Cyclone	Earthquake	Epidemic
33%	14%	12%	10%	10%	9%	9%	3%

Source: Lightning resilience India Campaign, 2019

The share of lightning event in the country was about 35.6% in relation to other extreme weather events (EWEs) in the past 50 years (1970–2019). Among the EWEs, the flood was most frequent followed by lightning and heat waves. These 2,517 events caused 8,862 deaths, with an average of 3.5 deaths per event. Lightning had the lowest mortality of 6.3% among various EWEs (Table 2).

Table 2:- Mortality of Lightning and other Extreme Weather Events (EWEs) 1970 – 2019.

Category	Events (Number)	Share (%) of each EWE	Mortalities (Number)	Share (%) of each EWE	Mortality per event
Lightning	2,517	35.6	8,862	6.3	3.5
Heat waves	706	10.0	17,362	12.3	24.6
Cold waves	548	7.8	9,596	6.8	17.5
Floods	3,175	45.0	65,130	46.1	20.5
Tropical cyclones	117	1.7	40,358	28.6	344.9
Total	7,063	100.0	1,41,308	100.0	20.0

Source: Weather and Climate Extremes 32 (2021)

Table 3 presented here in order to exhibit the comparative picture of mortality rates among different EWEs during two 20-year periods, i.e., 1980–1999 and 2000–2019. The lightning event has a significant positive change in means between the two twenty-year periods for all parameters. Lightning event per year between the two twenty-year periods increased about 3 times. It showed an increase of 193% in lightning in the last twenty years, compared to the previous twenty years. Similarly, the mortality per event, due to lightning, was 2.64 in 1980–1999, which enlarged by 37.9 % to 3.64 in 2000–2019. Similarly the mortality rates per million for lightning had increased by 52.8%. Lightning had a mortality rate of 0.189 during 1980–1999 and it enlarged to 0.289 during 2000–2019. Mortality rate has a negative trend for all EWEs, except for Cold waves and lightning.

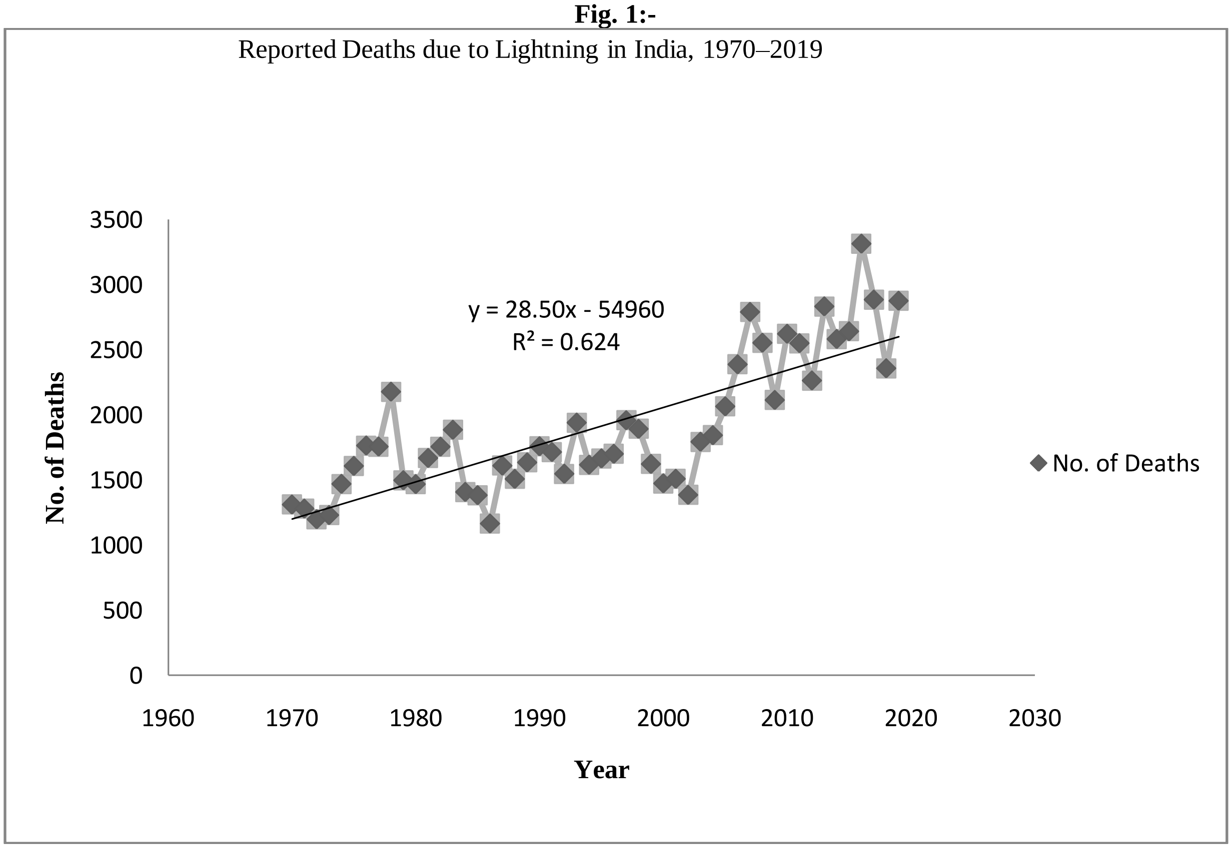
Table 3:- Comparison of Mortality Rates due to various EWEs.

Category	Number of Events per year			Mortality per event			Mortality Rate		
	1980–1999	2000–2019	Change (%)	1980–1999	2000–2019	Change (%)	1980–1999	2000–2019	Change (%)
Lightning	31.85	93.40	193.2	2.64	3.64	37.9	0.189	0.289	52.8
Heat waves	11.25	14.10	25.3	15.21	27.36	79.9	0.262	0.217	-17.1
Cold waves	9.90	23.55	137.9	19.46	23.54	21.0	0.252	0.409	62.2
Floods	64.25	82.50	28.4	26.21	17.15 5	- 34.6.	2.281	1.174	- 48
Tropical cyclones	2.35	1.90	-19.1	353.48	38.13	- 89.2	0.877	0.050	- 9
Total	119.6	215.35	80.1	23.59	12.14	- 48.6	3.862	2.140	- 44.6

Source: Weather and Climate Extremes 32 (2021)

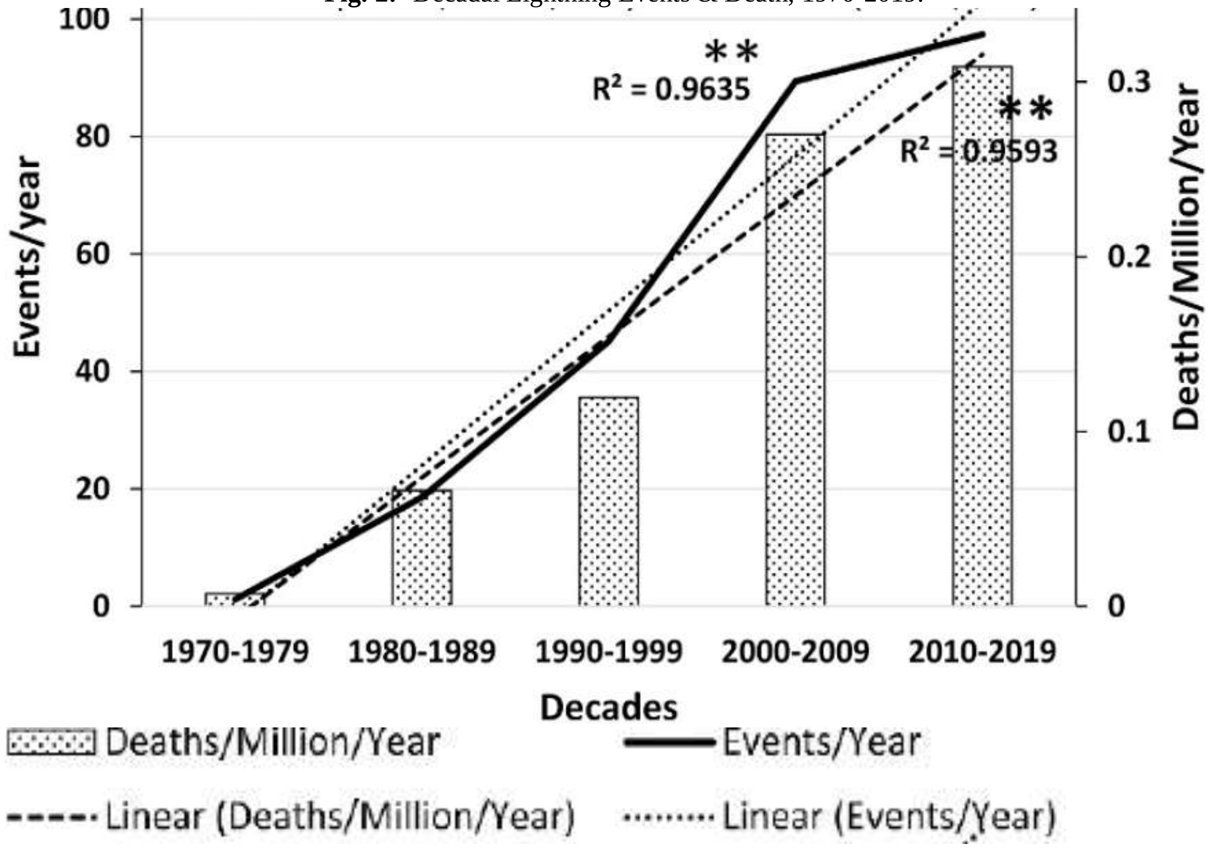
Fig. 1 clearly depicts the trend of reported death due to lightning in the past five decades in India (1970-2019). Nearly one lakh population (94,973) died due to lightning strike during last fifty years with an average of about 1,900 deaths per year. The maximum and minimum deaths were reported in the year of 2016 (3,315) and 1986 (1,163) respectively. Mortality due to lightning showed a significant increasing trend, over the years. There is a significant strong positive relationship (r =0.78) between time and reported death due to lightning in India. The lightning death in India over last decade (2010-2019) varied from 2,263 to 3,315 with an average of 2,692death/year.

Fig. 1:-



The decadal analysis of lightning events/year and corresponding mortality rates/million/year shows a highly significant increasing trend over the decades, with the last decade having the highest number of events and death rates (Fig. 2).

Fig. 2:- Decadal Lightning Events & Death, 1970-2019.



Source: Weather and Climate Extremes 32 (2021).

The EWE wise major five states, according to the total mortalities reported during 1970–2019 are listed in Table 4. The highest mortality due to lightning was found in Maharashtra state. Mortality due to lightning was very high in the state of Maharashtra, Orissa, West Bengal, Karnataka and Madhya Pradesh. However, among all the states, Andhra Pradesh, Bihar, Orissa, Uttar Pradesh and West Bengal had reported high mortality due to multiple disasters and needed special attention for disaster management. Similarly top 5 States of lightning mortality for 2019-20 and 2020-21 presented by Table 5.

Table 4:- Mortality of Top 5 States for EWEs, 1970–2019.

EWE	Top 5 States
Lightning	Maharashtra, Orissa, West Bengal, Karnataka, Madhya Pradesh
Cold wave	Bihar, Uttar Pradesh, Jharkhand, West Bengal, Rajasthan
Heat Wave	Andhra Pradesh, Rajasthan, Uttar Pradesh, Bihar, Orissa
Floods	Uttar Pradesh, Maharashtra, Uttarakhand, Andhra Pradesh, Bihar
Tropical Cyclone	Orissa, Andhra Pradesh, West Bengal, Gujarat, Tamil Nadu
Total	Andhra Pradesh, Orissa, Uttar Pradesh, West Bengal, Bihar

Source: Weather and Climate Extremes 32 (2021)

Table 5:- Mortality of Lightning, 2019-20 & 2020-21.

Year	Top 5 States of Lightning Mortality
2020-21	Bihar(401),UttarPradesh (238),MadhyaPradesh(228),Orissa (156),Jharkhand(132)
2019-20	UttarPradesh(293), MadhyaPradesh(248),Bihar(221),Orissa (200),Jharkhand(172)

Source: Annual Lightning Report 2020-21

The comparisons of the mortality rates based on the recent twenty years (2000–2019) and the past fifty years (1970–2019) for some of the most affected states are presented in Table 6.

Table 6:- Comparisons of Mortality Rate for the past 50 years (1970–2019) and recent 20 years (2000–2019) for some major affected states.

States	Mortality Rate (per year per million population)									
	Lightning		Floods		Heat wave		Cold wave		Tropical cyclones	
	1970–2019	2000–19	1970–2019	2000–19	1970–2019	2000–19	1970–2019	2000–19	1970–2019	2000–19
Andhra Pradesh	0.0	0.07	0.25	1.65	0.12	4.39	3.3	0.0	0.0	0.07
Bihar	0.11	0.17	1.19	1.09	0.0	0.0	0.96	0.75	0.11	0.17
Gujarat	0.03	0.04	2.43	1.50	0.89	0.0	0.05	0.0	0.03	0.04
Kerala	0.3	0.43	1.48	1.95	0.09	0.0	0.0	0.0	0.3	0.43
Maharashtra	0.53	0.72	1.72	1.4	0.01	0.0	0.01	0.01	0.53	0.72
Orissa	0.62	1.0	1.66	0.79	9.74	0.25	0.11	0.19	0.62	1.0
Assam	0.12	0.17	2.63	2.4	0.0	0.0	0.0	0.0	0.12	0.17
West Bengal	0.27	0.31	1.21	1.06	1.9	0.15	0.11	0.04	0.27	0.31

Source: Weather and Climate Extremes 32 (2021)

Among the major states (Population >15 million) of the country, Andhra Pradesh, Assam, Bihar, Kerala, Maharashtra, and Orissa had the highest mortality rates of around 2–4.5 human deaths per year per million population caused by EWEs. The mortality rates due to lightning have increased in most of the vulnerable states with the highest increase of 61% in Orissa in the last two decades. Among all the EWEs, the mortality rate decrease was statistically significant for floods, and the increase was significant for lightning.

State wise average lightning death between 2001and 2020 has been depicted by Fig-3. Madhya Pradesh was the topper followed by Maharashtra and Orissa as far as average lightning death in India is concerned.

Fig. 3:-

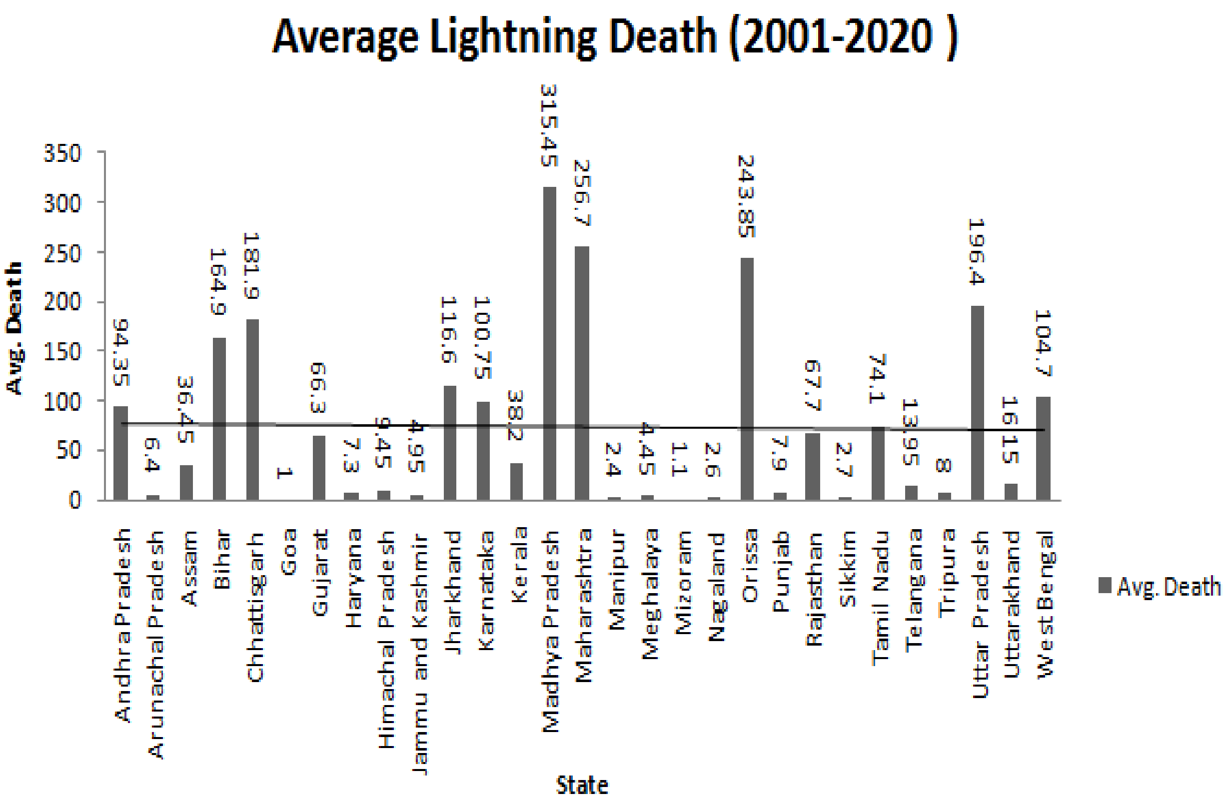
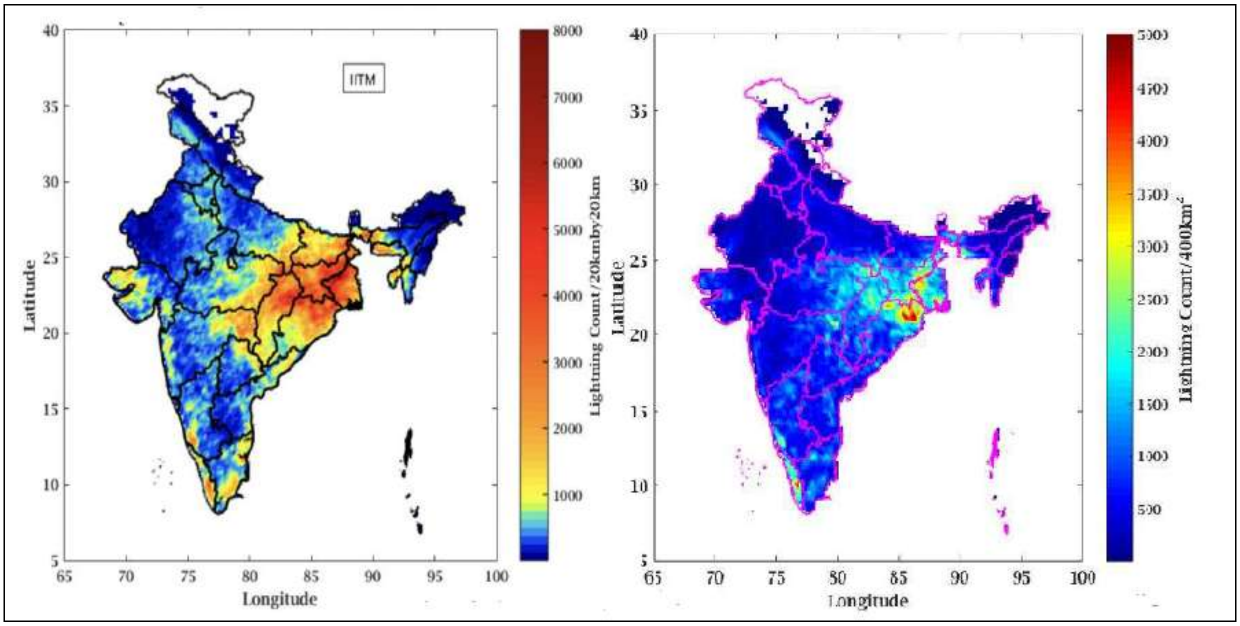


Fig 4:- Cloud to ground Lightning Strikes over India.

Apr 2020- Mar 2021	Apr 2019- Mar 2020



Source: Annual Lightning Report 2020-21

A comparative regional scenario of Cloud to Ground lightning strikes over India presented through Fig.-4. Eastern part of India is the most vulnerable in terms of Cloud to Ground lightning strikes. Table 7 highlights the top five states of India with relation to lightning strikes & lightning death. Spatial variations of lightning density and lightning strike per thousand populations have been presented by Table 8 and Table 9 respectively.

Table 7:- Lightning Strikes & Lightning Death, 2020- 2021.

Lightning	Top 5 States
Strikes	Orissa, Madhya Pradesh, Chhattisgarh, West Bengal, Jharkhand
Death	Bihar, Uttar Pradesh, Madhya Pradesh, , Jharkhand

Source: Annual Lightning Report 2020-21

Table 8:- Lightning Density 2020- 2021.

Lightning **Density** (No. of Lightning Strike per sq.km)	States/UT
High (>10)	Lakshadweep, Kerala, Jharkhand
Medium (5-10)	Orissa, West Bengal, Goa, Chhattisgarh, Tripura, Meghalaya, Bihar
Law (<5)	Karnataka, Madhya Pradesh, Delhi, Tamil Nadu, Uttar Pradesh, Telangana, Andhra Pradesh, Maharashtra, Haryana, Dadra & N Haveli, Gujarat, Chandigarhh, Puducherry, Rajasthan, Mijoram, Assam, Punjab, Uttarakhand. Daman & Diu, Himachal Pradesh, Jammu and Kashmir, Manipur

Source: Annual Lightning Report 2020-21

Table 9:- Lightning Strike per thousand population 2020-21.

Lightning Strike per thousand population	States/UT
High (>500)	Chandigarh, Delhi, Puducherry
Medium (100-500)	Andaman & Nicobar, Dadra & N Haveli, Punjab, Sikkim, Assam, Nagaland, Manipur, Arunachal Pradesh, Haryana, , Himachal Pradesh, Uttarakhand, Andhra Pradesh, Jammu and Kashmir, Tamil Nadu, Gujarat, West Bengal
Law (<100)	Daman & Diu, Rajasthan, Kerala, Telangana, Karnataka, Goa, Tripura, Madhya Pradesh, Jharkhand, Lakshadweep, Chhattisgarh,

Source: Annual Lightning Report 2020-21

Protection, Prevention, Preparedness & Mitigation:-

Indian Institute of Tropical Meteorology (IITM), Pune, under the Ministry of Earth Sciences, Govt. Of India, has taken a project to study the characteristics of lightning by using Lightning Location Network (LLN). This network is able to detect the exact location of occurrence of a lightning strike and forewarn the public at least 1-2 hours before the occurrence of a thunderstorm. Considering the severity of the damages caused due to lightning in Maharashtra, a 20-sensor network has been established with the Central Processing Station at IITM, Pune, on an experimental basis. Each sensor has coverage of about 200 km. This network is complemented with a mobile app that not only shows the ongoing lightning event but also send out warnings in the form of Short Messaging Services (SMSes) to people. The major failures of early warning systems over recent times have largely been of institutions rather than science. Very recently thunderstorm and lightning forecast service has started in India from April, 2019. A mobile application named Damini for lightning prediction has been developed to disseminate the information,

National Disaster Management Authority, Government of India has prepared guidelines for preparation of Action Plan (2018) to prevent and manage Thunderstorm and Lightning hazard. Strategic plan has been formulated considering the short, medium and long-term management. In order to minimize the impact of this hazard the adopted key strategies are - i) Establishment of qualitative and effective Early Warning System ii) Inter-agency coordination and communication iii) Developing advanced preparedness, mitigation and response plan iv) Preparedness at the local level for effective incidence response plan v) Capacity building and training vi) Public awareness and community outreach vii) Collaboration with Non Government Organisations and civil society vii) Assessing the impact – getting feedback for reviewing and updating the plan.

The occurrence Lightning cannot be impeded. But its harmful effects can be minimized through a number of preventive measures. Among them Hazard and Vulnerability Assessment is most important one. The first and foremost need is awareness generation among policy makers, administrators, engineers, architects, general public as well as the farming community. Public awareness and education will be helpful in improving the disaster resilience of masses. Lightning shields are the most commonly employed structural protection measure for buildings and other structures. A lightning shield consists of installation of a lightning conductor at a suitably high location at the top of the structure. The conductor is grounded using a metal strip. The grounding of the conductor is also specially designed to ensure rapid dissipation of the electrical charge of lightning strike into the ground. Lightning shields are not foolproof in their effectiveness. The ability of lightning shields to complete the cloud-to-ground circuit depends on several variables such as the height of the conductor, the shape and size of adjoining structures or natural conductors. However, following actions are helpful at before, during and after lightning event.

Before Thunderstorm and Lightning

As a part of preparedness of thunderstorm or lightning hazard one can do the following: i) Do remember that vivid and frequent lightning indicates the probability of a strong thunderstorm. ii) You should build an emergency kit and make a family communication plan. iii) Remove dead or rotting trees and branches that could fall and cause injury or damage during a severe thunderstorm. iv) Postpone outdoor activities. v) Remember the 30/30 Lightning Safety Rule: Go indoors if, after seeing lightning, you cannot count to 30 before hearing thunder. Stay indoors for 30 minutes after hearing the last clap of thunder. vi) Secure outdoor objects that could blow away or cause damage. vii) Get inside a home, building, or hard top automobile (not a convertible). Although you may be injured if lightning strikes your car, you are much safer inside a vehicle than outside. vii) Remember, rubber-soled shoes and rubber tires provide no protection from lightning. However, the steel frame of a hard-topped vehicle provides increased protection if you are not touching metal. viii) Unplug appliances and other electrical items such as computers and turn off air conditioners. Power surges from lightning can cause serious damage. ix) Shut windows and outside doors. If shutters are not available, close window blinds, shades or curtains. x) Unplug any electronic equipment well before the storm arrives.

During Thunderstorms and Lightning

Following points are to be remembered when thunderstorm and lightning are in existence over an area. i) Use your battery-operated radio/TV for updates from local officials. ii) Avoid contact with corded phones and devices including those plugged for recharging. Cordless and wireless phones not connected to wall outlets are ok to use. iii) Avoid contact with electrical equipment or cords. iv) Avoid contact with plumbing or pipes. Do not wash your hands, do not take a shower, do not wash dishes, and do not do laundry. Plumbing and bathroom fixtures can conduct electricity. v) Stay away from windows and doors, and stay off porches. vi) Do not lie on concrete floors and do not lean against concrete walls. vii) Avoid natural lightning rods such as a tall, isolated tree in an open area.

viii) Avoid hilltops, open fields, the beach or a boat on the water. ix) Take shelter in a sturdy building. Avoid isolated sheds or other small structures in open areas. x) Avoid contact with anything metal tractors, farm equipment, motorcycles, golf carts, golf clubs, and bicycles. xi) If you are driving, try to safely exit the roadway and park. Stay in the vehicle and turn on the emergency flashers until the strong rain ends. Avoid touching metal or other surfaces that conduct electricity in and outside the vehicle.

After Lightning

Medical assistance at the earliest is needed for a lightning strike people. Primarily, checking of three symptoms are required i.e. i) Breathing – If breathing has stopped, begin mouth-to-mouth resuscitation. ii) Heartbeat – If the heartbeat has stopped, administer Cardiopulmonary Resuscitation (CPR) and iii) Pulse – if the victim is breathing, look for other possible injuries. Check for burns where the lightning entered and left the body. Also be alert of nervous system damage, broken bones and loss of hearing and eyesight.

Compensation Issue:-

The initiative undertaken by Indian Government is not sufficient in terms of growing importance of lightning risk or in terms of compensation. Calamity Relief Fund (CRF) and National Calamity Contingency Fund (NCCF) of Govt. of India are the main source of financial assistance. Any state can take the advantage of CRF in advance every year to fulfil the expenditure for providing immediate relief to victims for specified calamities approved by the Finance Commission. NCCF is available when loss goes beyond the CRF of the states. CRF and NCCF have been restructured following recommendations of Thirteenth Finance Commission and two new schemes emerged as State Disaster Response Fund (SDRF) and National Disaster Response Fund (NDRF). But lightning was not included within the natural calamity compensation process due to the underestimated death, injury and damage figures. A high powered committee (HPC) on disaster management constituted by Government of India was set up in 1999. This committee identified thunder and lightning as disasters under the water and climate-related disaster group and recommended the constitution of an expert committee to review the list of items approved for incurring expenditure from the CRF. However the recommendations have not materialised while reconstituting the CRF. As lightning does not come under the guidelines of calamity relief rules, most of the lightning- affected states in India provide an ex-gratia amount of Rs one lakh to the kith and kin of the deceased person from the Chief Minister's Relief Fund (CMRF), also known as Chief Minister's Distress Relief Fund (CMDRF) in some states of India. Inclusion of lightning in the list of natural calamities under CRF may be a bold step for relief distribution and immediate assistance to the bereaved families. The Fourteenth Finance Commission, 2013 may consider lightning casualty on priority basis. The issue of Damage and Compensation due to lightning is to be studied further remembering its power of death, damage and destruction. The current financial allocation and mitigation measures in India are to be reconsidered with site-specific risk reduction measures like technological interventions along with public awareness to cope with the present lightning scenario of the country. Insurance coverage and policy amount are to be fixed logically. Intensive research work on lightning is absolutely necessary and it is the right time for government to deal with this problem technologically, financially and obviously on humanitarian ground.

Conclusion:-

This study provides an overview of deaths by lightning event in India over 50 years since 1970. About five individuals per million died due to exposure to extreme events which is about 25% of all accidental deaths due to natural causes. Lightning caused the most number of deaths, followed by extreme precipitation and extreme temperature. Lightning induced fatalities and losses have turned into a widespread disaster in India but it has received little attention probably due to the un-reporting and under-reporting of events and lower media coverage. We have no national database or platform in real sense to extract the lightning mortalities and economic damage to the limelight within the administration and disaster management set-up of the country. Lightning is treated here as undervalued disaster or underestimated disaster in India. This study will be helpful to raise the voice against the neglected dimensions of disaster compensation acts and rules especially related to lightning. It is the high time for reorientation of perceptions on disaster insurance and government funding. Lightning affected victims need due attention from societal side and relief from the government side.

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