International Conference on Lightning Protection
33rd International Conference on Lightning Protection
25 - 30 September 2016
Estoril, Portugal

Lightning Fatalities and Injuries in Malaysia from 2008 to 2015

Maryam Hajikhani[1*], Mohd Zainal Abidin Ab Kadir[1], Mahdi Izadi[1], Chandima Gomes[1], Mary Ann Cooper[2]
[1] Centre for Electromagnetic and Lightning Protection Research (CELP), University Putra Malaysia
[2]African Centres for Lightning and Electromagnetics Network
Email: [1*]maryamhajikhani@yahoo.com

***Abstract*—This study examined the risk of lightning-related deaths and injuries in Malaysia between January of 2008 to July 2015. The majority of lightning-related injuries and fatalities occurred during the months of April and May. Most lightning related casualties reported in the statistics since 2008 occurred in the states of Melaka and Selangor in the western coastal belt. The majority of victims, were engaged in outdoor and sports activities when injured or killed by lightning incidents.**

Keywords- lightning fatalities, injuries, lightning flash density, lightning casualties

I.INTRODUCTION

Tropical regions tend to have the highest lightning density [1, 2]. Located at 2˚30' N and 112˚30' E, Malaysia has one of the highest lightning densities in the world. However, there is a lack of knowledge and awareness among both the general public and the engineering/technical communities in Malaysia on lightning safety and protection. Kadir et al., (2012) reported lightning accidents which have led to deaths, injuries, property damage and service disruption [3]. Each year in Malaysia, lightning strikes affect electrical/communication networks, disrupt essential services, damage buildings, start many bushfires, and injure or kill a number of people. These causing large financial losses to the country both directly and indirectly [3]. It has been reported that casualties associated with lightning are high in Malaysia both due to lack of awareness and misconceptions spread by vendors that sell unscientific systems and techniques [4]. In order to increase the general awareness of the danger of lightning to determine whether there are any trends and if particular groups are more at risk, statistics of lightning fatalities and injuries in the country has been compiled. Most lightning injury statistics in Malaysia are based on newspaper reports and medical records. The number of fatalities may be significantly higher than reported as injuries and deaths in rural areas may not spread beyond the individual village where they occurred. Deaths are generally better reported than injuries [5] partly because there is no registry or compulsory recording of lightning injury [6]. In addition, many injuries may not involve a hospital admission and this will affect the accuracy of the database that relies on the reports [7]. This present research used lightning flash density profile provided by the Lightning Detection Network managed by Lightning Detection System Laboratory, TNB Research Sdn. Bhd.

II. DATA AND METHODOLOGY

Most studies in this area have been conducted in the world mainly depends on historical data and newspaper articles, the latter is the dominant source in this matter [8]. Similarly most lightning injury and death statistics in Malaysia are based on newspaper reports and medical records. The real number may be significantly greater than what is reported. In rural areas information on death and injured people who admitted to hospital, rarely spread beyond the village and generally deaths are better reported than injuries [5]. In this study, source of data was kilat malaysia which is a governmental office collecting the information of lightning related deaths and injuries throughout the Malaysia. The website reports are generally based on media reports, newspaper reports, personal anecdotes and hospital admissions [3].

III. LIGHTNING FLASH DENSITY

Lightning flash density is a critical factor for evaluating the effects of lightning on buildings, structures and electrical networks. In order to consider the distribution of lightning events in a country, a lightning flash density map is usually used by designers to set proper protection levels according to a set of objectives. Figure 1 illustrates the lightning flash density of for Malaysia from 2004 to 2012. The West of Malaysia has the highest values of lightning flash density compared to the other areas.

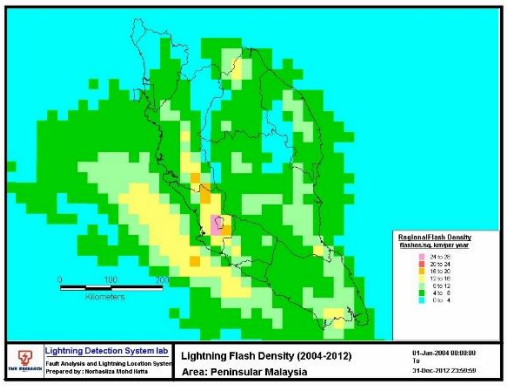

Figure 1. Malaysia Cloud to Ground lightning flash densities in 2004- 2012 (from TNB research Malaysia)

IV. LIGHTNING FATALITIES

Lightning casualties range from one death over 40 years in Northern Ireland to over 20,000 fatalities reported in the United States between 1900 and 1991 [9, 10]. Based on the reports, fatality rates in most developed countries over the past 30 years have been decreased considerably [8, 11, 12]. Based on Elsom (2001) there have been fewer lightning causalities in England and Wales over the past decades [13]. He suggested it was likely due to the fewer people working outdoors in open fields, improved weather forecasts that have enabled people to plan activities that avoid being outside during a thunderstorm, the expansion of urban areas, and improved responses by medical staff. Holle (2005) has reported a considerable reduction in the rate of lightning-caused deaths over the last century in the United States [14]. In this case, this reduction has been assumed to be the result of a shrinkage in the percentage of the population living in rural areas and modifications in construction (e.g., heating, plumbing and electrical systems that effectively ground structures). A brief comparison of rate of the lightning fatalities reported in the past studies (from Mills, 2008) is shown in Table I.

Table I. Summary of published estimates of lightning fatalities

Author	Time frame	Location	Fatalities	Death, injury rates per million, per year
Ferrett and Ojala (1992)	1959–1987	Michigan	81 deaths, 527 injuries	236
Groubiere (1999)	1979–1996	France	180 deaths	17
Hornstein (1961, 1962)	1939–1958	Canada	320 deaths	110
Lopez and Holle(1996)	1959–1990	United States	2983 deaths	41
Lopez and Holle (1998)	1900–1991	United States	20758deaths, 8233injuries	630
Lopez et al.(1993)	1980–1991	Colorado	36–51 deaths, 46–82 injuries	345
Lopez et al.(1995)	1950–1991	Colorado	103 deaths, 299 injuries	251
Nguyen et al.(2004)	1991–1996	Canada	5 deaths, 9 injuries	6.8
Baker (1984)	1941–1980	England	263 deaths	11
Baker (1984)	1951–1980	Scotland	9 deaths	6
Baker (1984)	1954–1969	Ireland	7 deaths	15
Baker (1984)	1941–1980	Northern Ireland	1 death	1.6
Coates et al.(1993)	1824–1991	Australia	650 deaths	22.7
Curran et al.(2000)	1959–1994	United States	3239 deaths, 9818 injuries	160.1
Duclos et al.(1990)	1978–1987	Florida	101 deaths, 44 injuries	148.7
Ten Duis (1998)	1910–1995	Netherlands	602 deaths	49
Elsom (1993)	1975–1990	England and Wales	56 deaths	6.1
Elsom(2001)	1993–1999	United Kingdom	22 deaths, 34 1injuries	13.7
Pakiam et al.(1981)	1956–1979	Singapore	80 deaths	160.7
Kadir et al. (2012)	2008- 2012	Malaysia	131 deaths and injuries	92
Mills et al. (2008)	1986- 2005	Canada	53 deaths, 277 injuries	53

V. LIGHTNING POTENTIAL TO CAUSE INJURIES

Lightning may injure people in several different ways [15-17]:

- Direct strike, often to the head, causing the serious injuries, and generally occurs to people standing out in the open.
- Contact voltage (touch potential), occurs when current goes into the body through objects struck by lightning that an individual is touching (e.g., golf club, phone, umbrella)
- Splash or flashover voltage from a nearby object, e.g. tree, post, where lightning strikes an object and then a portion arcs to a nearby person.
- Upward streamer, can cause hair to stand on end or objects to buzz or crackle, also a streamer from a person's head could cause injury
- Step voltage effect (ground current) caused by lightning strike several meters away. This involves current striking the surface through the ground. In this case, the path of least resistance may take the current from the ground through a human body nearby to cause injury. It also depends on the environmental conditions, the orientation of an individual, and distance from the strike.
- Pressure or shock wave, causing blunt trauma injuries, when a person is thrown to the ground by the force of the shock wave due to the lightning or by muscle contraction caused by the current [18].

In addition, lightning can cause injuries and death indirectly. In this case, less direct but still relevant are the injuries associated with fires started by lightning. Moreover, individuals may be injured by falling roofing or stone, hit by flying bark after a tree is struck, suffer burns in a fire caused by lightning, suffer an accident when the driver of a vehicle is shocked by a lightning strike near the vehicle, hurt by an animal shocked by lightning, or being shocked after observing the damages to their home due to the lightning [8, 13].

VI. FACTORS INFLUENCING EXPOSURE

Previous studies have recognized a number of reasons associated with situational and population factors that influence exposure. These characteristics have been distinguished through studies on those injured or killed and give insight regarding the ''when, where and what'' characteristics of lightning fatality events. A person's risk of being struck by lightning has been indicated to vary by time of day, week and season. In mid-latitude locations, summer is the peak season for lightning incidence, and is also the time that most lightning-related fatalities take place [8]. Moreover, nearly 70% of the lightning strike incidents in the United Kingdom [13] occur in the months of June to August, while in Australia most lightning mortalities occur between November and February [19]. In this sense, in the United States, lightning fatalities occur generally between May and August with a maximum in July [20, 21]. According to Curran et al. (2000), in the United States 24% more lightning deaths occur on Sunday than on any other day of the week. Also, regarding the time of day, most of the fatalities in the United States occur during the afternoon and early evening [20]. Socio-demographic and geographic factors influencing exposure are interrelated at a variety of scales. The frequency of Cloud to Ground (CG) lightning and the population density in particular

regions are the macro level factors that play a critical role on exposure. In specific areas, more people and more lightning events associate with a greater potential for an individual to be struck by lightning [8]. As illustrated in Figure 1, in Malaysia, the CG lightning flash densities are greatest in the states of Selangor and Perak. With regard to demographic attributes of those struck by lightning, a number of research studies have observed a pattern in this matter including age and gender. Generally, younger men account for the majority of lightning strike victims [8]. As Elsom (2001) reported, in the UK males were struck more than women (65% male compared to 35% female). Moreover, among the 27 lightning fatalities reported in Canada, men of 15–50 years were more likely to be killed [22]. In addition, past studies indicate that the majority of fatal incidents in developed countries occur in outdoor environments [13, 14, 23-25]. In this context, it is reported that different outdoor activities are associated with different levels of risk. In a study by Curran et al. 2000, the activities that individuals engaged in while struck by lightning were in open fields, ballparks, and playgrounds; under trees; water-related activities (fishing, boating, swimming); golfing; operating tractors, farm equipment, and heavy road equipment; on the telephone; and touching a radio, transmitter or antenna.

VII. Empirical Analysis of Malaysian Data

An empirical analysis was conducted to evaluate the casualty and injury risks associated with lightning in Malaysia. Locations and activity are coded to six classes of indoors, outdoors, agriculture, sports, recreation, small structures as seen in Table II. This study evaluated the available source of mortality information and the results are shown in Figures 2-6. Figure 2 demonstrates that the majority of fatal incidents occur during outdoor activities (130 out of 224) (2008-2015), sport, agriculture, recreation, indoors and small structures respectively (see Figure 2). Moreover, the most lightning fatalities were occurred in outdoor areas and the sports area has the next highest rate in terms of lightning fatalities compared to the others. Therefore, thought should be given to the social training of the public in lightning safety to effectively increase the level of safety awareness.

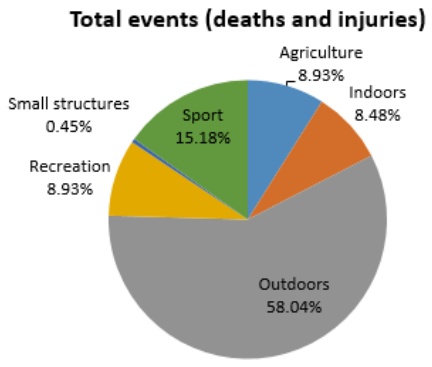

Figure 2. Distribution of fatalities by locations/activities in the Malaysia (2008 – 2015)

Table II. Types of activities, locations

Type	Description of locations and activities
Indoors	The event take place inside a building most often a house
Outdoors	The case take place in a wide variety of locations where the fatality is outside a structure but the circumstance is not related to recreation, agriculture, sports or small structures
Agriculture	The event occur in a farm or ranch, the agricultural setting is more large than a garden in the backyard of a home, It usually is where the income of a lightning victim and related family involved agriculture
Recreation	Such events involve any entertaining activity, these cases occur outside but not include group sports events
Sports	The event take place during a group sporting event including a team situation, If only one or a few people are fishing, for instance, the situation is recreation
Small structures	The case occur when the victim is in vehicle, open-sided shelter, shed, or other small isolated structure, it does not contain large structures such as homes, office buildings, or stores.

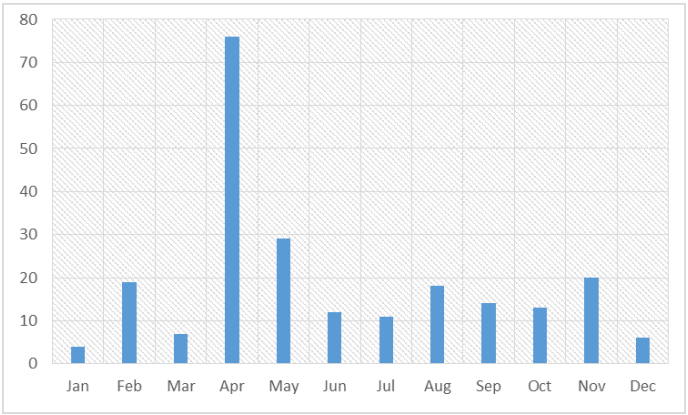

Figure 3. Distribution of lightning injuries and deaths based on month (2008-2015)(n=224)

According to the data available to the researcher of this study, in Malaysia most lightning mortalities occur in April and May (see Figure 3). Therefore, emphasis on public training specifically during these time periods may be helpful to reduce the rate of lightning fatalities in the country. Similarly, most often fatal incidents occurred in rural areas (153 cases) compared to urban (71 cases) (see Figure 4).Thus, public training through public media such as radio and television, can improve the level of lightning safety in the country.

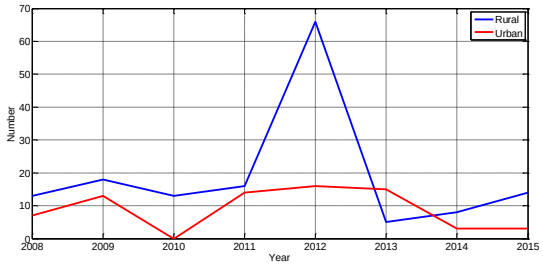

Figure 4. Distribution of lightning fatalities in rural and urban areas (2008-2015)

Moreover, most lightning related causalities reported in the statistics since 2008 occurred in the states of Melaka and Selangor (see Figure 4). As shown in Figure 1, the rate of lightning flash density in Selangor is higher than other states in Malaysia. As mentioned previously, there is a direct relationship between lightning flash density and the rate of lightning fatalities. Furthermore, Selangor is one of the major industrial states in Malaysia and creating greater public awareness of lightning safety besides the technical issues can be effective to reduce the rate of lightning fatalities, especially in the state of Selangor.

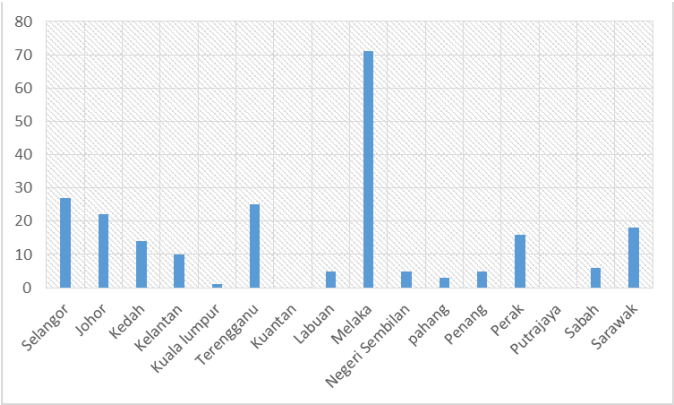

Figure 5. Distribution of lightning fatalities based on states and month from 2008 to 2015

Figure 6 shows a distribution of lightning injuries and deaths in Malaysia (2008- 2015) which shows that the lightning injuries in 2012 had the highest rate. In this case, the spike in injuries rate in 2012 may need to be treated as outlier. There might be specific reasons associated with this observation which needs to be more investigated. In this case, according to data available to the study, the large number of victims in the year 2012 were due to a few large groups with injuries (a few groups of students were camping in a field struck by lightning). For the mentioned reason a significant decline has been observed in the total number of victims struck by lightning from 86 people in 2012, to 17 in 2015 (by the time of this study). A comparison between Figures 4 and Figure 6 indicates that the rural area should be more targeted in terms of improving the level of knowledge on lightning safety and public media can play a significant role in this regard. It should be mentioned that the source of data is from [26].

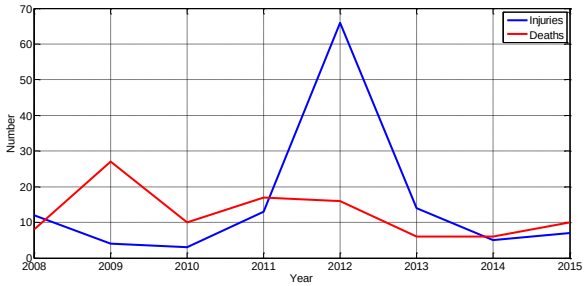

Figure 6. Distribution of lightning injuries and deaths in Malaysia (2008- 2015)

VIII. CONCLUSION

Lightning is a common hazard in Malaysia that regularly injures and kills people. Malaysian lightning-related deaths, injuries reports from 2008 to 2015 were analyzed. Different methods were used to subdivide the features of lightning causalities including urban, rural setting and activities, locations, and types of incidents were defined (i.e. agriculture, indoors, outdoors, small structures, recreation and sports). This research have used data provided by the Lightning Detection Network managed by the Lightning Detection System Laboratory, TNB Research Sdn. Bhd. of Malaysia. Based on the reports, cases of the lightning death have declined significantly over the last century. According to the data available to this study, in Malaysia most lightning mortalities occur in April and May. Moreover, most lightning related causalities reported in the statistics since 2008 have occurred in Melaka and Selangor states. The distribution of fatality locations/activities in Malaysia as reviewed by this study showed that the majority of fatal incidents occurred during activities including outdoor (130 out of 224), sports, agriculture, recreation, indoors and small structures respectively. In summary, despite the fact that the large number of events in year 2012 were due to a few groups struck by lightning, according to the Malaysia statistics a significant decline has been observed in the total number of victims from 86 people in 2012, to 17 in 2015 (by the time of this study). Although these figures could possibly be even further reduced with an appropriate public awareness campaign, especially if targeted to the rural communities in Selangor, Melaka and Perak.

REFERENCES

[1] H. J. Christian and J. Latham, "Satellite measurements of global lightning," Quarterly Journal of the Royal Meteorological Society, vol. 124, pp. 1771-1773, 1998.

[2] H. J. Christian, R. J. Blakeslee, D. J. Boccippio, W. L. Boeck, D. E. Buechler, K. T. Driscoll, et al., "Global frequency and distribution of lightning as observed from space by the Optical Transient Detector," Journal of Geophysical Research: Atmospheres (1984–2012), vol. 108, pp. ACL 4-1-ACL 4-15, 2003.

[3] M. Kadir, N. Misbah, C. Gomes, J. Jasni, W. W. Ahmad, and M. Hassan, "Recent statistics on lightning fatalities in Malaysia," in Lightning Protection (ICLP), 2012 International Conference on, 2012, pp. 1-5.

[4] C. Gomes and M. Ab Kadir, "A theoretical approach to estimate the annual lightning hazards on human beings," Atmospheric Research, vol. 101, pp. 719-725, 2011.

[5] R. E. López, R. L. Holle, T. A. Heitkamp, M. Boyson, M. Cherington, and K. Langford, "The underreporting of lightning injuries and deaths in Colorado," Bulletin of the American Meteorological Society, vol. 74, pp. 2171-2178, 1993.

[6] M. A. Cooper and R. L. Holle, "Mechanisms of lightning injury should affect lightning safety messages," in 3rd International Lightning Meteorology Conference, 2010, pp. 19-22.

[7] M. Cherington, J. Walker, M. Boyson, R. Glancy, H. Hedegaard, and S. Clark, "Closing the gap on the actual numbers of lightning casualties and deaths," in 11th Conference on Applied Climatology, 1999, pp. 379-380.

[8] B. Mills, D. Unrau, C. Parkinson, B. Jones, J. Yessis, K. Spring, et al., "Assessment of lightning-related fatality and injury risk in Canada," Natural hazards, vol. 47, pp. 157-183, 2008.

[9] T. Baker, "Lightning deaths in Great Britain and Ireland," Weather, vol. 39, pp. 232-234, 1984.

[10] R. E. Lopez and R. L. Holle, "Changes in the number of lightning deaths in the United States during the twentieth century," Journal of climate, vol. 11, pp. 2070-2077, 1998.

[11] W. P. Roeder and F. Rockledge, "A statistic model for the inter-annual and intra-annual fatalities from lightning in the US and comparison to other storm phenomena," in International Lightning Meteorology Conference 2012, 2012, pp. 4-5.

[12] W. S. Ashley and C. W. Gilson, "A reassessment of US lightning mortality," Bulletin of the American Meteorological Society, vol. 90, pp. 1501-1518, 2009.

[13] D. Elsom, "Deaths and injuries caused by lightning in the United Kingdom: analyses of two databases," Atmospheric Research, vol. 56, pp. 325-334, 2001.

[14] R. L. Holle, R. E. López, and B. C. Navarro, "Deaths, injuries, and damages from lightning in the United States in the 1890s in comparison with the 1990s," Journal of Applied Meteorology, vol. 44, pp. 1563-1573, 2005.

[15] K. M. Walsh, B. Bennett, M. A. Cooper, R. L. Holle, R. Kithil, and R. E. Lopez, "National Athletic Trainers' Association position statement: lightning safety for athletics and recreation," Journal of Athletic Training, vol. 35, p. 471, 2000.

[16] M. Cooper, R. Holle, C. Andrews, and R. Blumenthal, "Lightning injuries in Auerbach P (ed) Wilderness medicine," ed: Elsevier Mosby, Philadelphia, 2012.

[17] V. Cooray, C. Cooray, and C. Andrews, "Lightning caused injuries in humans," Journal of electrostatics, vol. 65, pp. 386-394, 2007.

[18] K. Zafren, B. Durrer, J.-P. Herry, and H. Brugger, "Lightning injuries: prevention and on-site treatment in mountains and remote areas: official guidelines of the International Commission for Mountain Emergency Medicine and the Medical Commission of the International Mountaineering and Climbing Federation (ICAR and UIAA MEDCOM)," Resuscitation, vol. 65, pp. 369-372, 2005.

[19] L. Coates, R. Blong, and F. Siciliano, "F. 1993. Lighting fatalities in Australia, 1824-1991," Natural Hazards, vol. 8, pp. 217-233.

[20] E. B. Curran, R. L. Holle, and R. E. López, "Lightning casualties and damages in the United States from 1959 to 1994," Journal of Climate, vol. 13, pp. 3448-3464, 2000.

[21] R. E. López, R. L. Holle, and T. A. Heitkamp, "Lightning casualties and property damage in Colorado from 1950 to 1991 based on Storm Data," Weather and Forecasting, vol. 10, pp. 114-126, 1995.

[22] N. Bains and J. Hoey, "Before lightning strikes," Canadian Medical Association. Journal, vol. 159, p. 163, 1998.

[23] J. Pakiam, T. Chao, and J. Chia, "Lightning fatalities in Singapore," Meteorological Magazine, vol. 110, pp. 175-187, 1981.

[24] A. E. Ritenour, M. J. Morton, J. G. McManus, D. J. Barillo, and L. C. Cancio, "Lightning injury: a review," Burns, vol. 34, pp. 585-594, 2008.

[25] H. Ten Duis, "Lightning strikes: danger overhead," British journal of sports medicine, vol. 32, pp. 276-278, 1998.

[26] http://kilatmalaysia.blogspot.my/