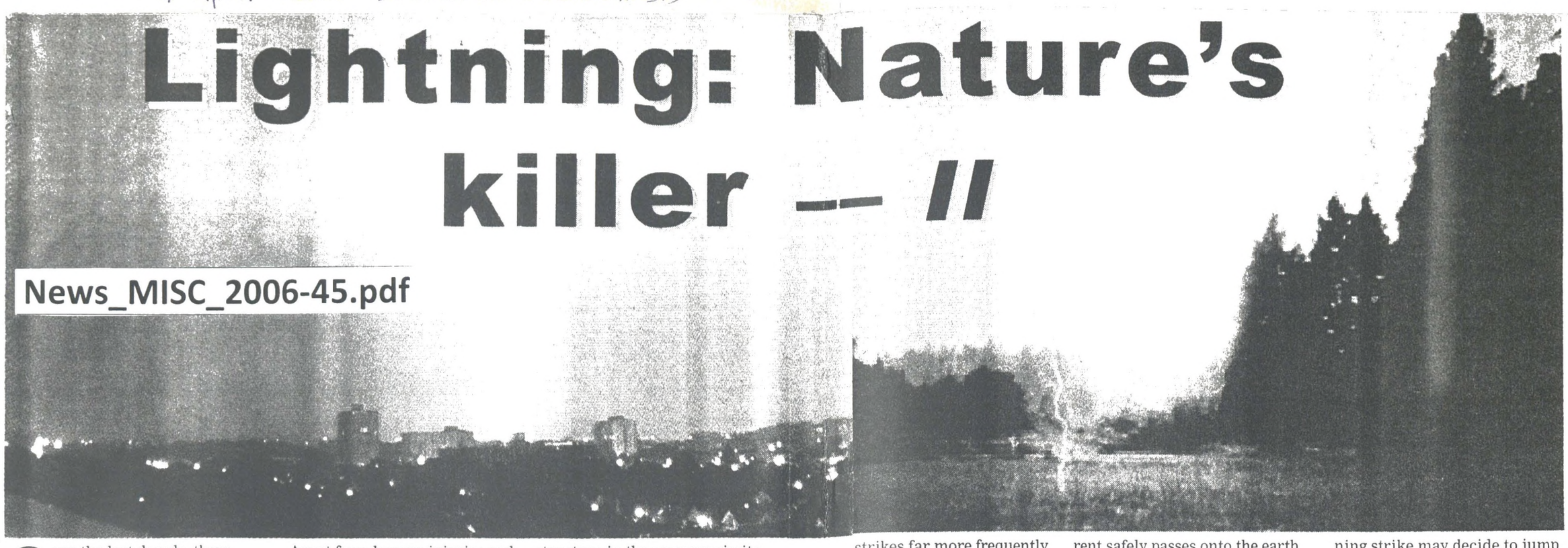
4th April 2006 Island (Science & Technology Wip)

Lightning: Nature's killer — II



Over the last decade, there has been an increase in the effects of lightning in Sri Lanka. Most importantly, lightning causes human casualties. Lightning ignites fires that may bring an entire building down or reduce a house to ashes. At a lower degree of damage, the lightning current may destroy electrical, electronic and communication equipment. However, one of the most significant losses that lightning may cause, as far as industries are concerned, is the downturn. A standstill of normal operations for a couple of hours or a loss of important data stored in a computer may cause a company an economic loss of several millions. A country that is rapidly industrialising, unavoidably becomes vulnerable to lightning related hazards due to several reasons.

In Sri Lanka property worth more than 2.5 million USD is damaged in the power, communication and industrial sectors and at domestic level, during the two lightning seasons of the year. This does not take into account the billions of indirect losses due to the downturn caused by damaged and malfunctioning equipment and loss of data in microprocessors. The first lightning season starts in mid-March and extends to the end of April. The second lightning season starts in October and lasts for nearly one and a half months. However, in recent years, we have observed intense lightning activities even beyond this period.

Damage to equipment has been on the increase for the last few decades, most probably due to the widespread use of electronics, extension of the national power grid to rural areas and the modification of the environment due to high rise buildings, communication towers and artificial activities. This type of unacceptably high economic loss due to a natural hazard is a very unhealthy situation for a country seeking NIC status. As we have observed, such damage could be avoided or at least minimized with a proper engineering knowledge of lightning protection and safety among the general public and technical communities.

In Sri Lanka, over 50 deaths per year are reported due to lightning. The entire South Asian region is well known for multiple deaths related to lightning. To give a few examples, in Chapainawabgonj, a remote village in Bangladesh on 12th July 2005, eight people died and about forty people were injured as lightning struck an unsafe shelter. Furthermore, in February, seventeen people were killed and twenty-three injured in a similar incident in Bangladesh. In Sri Lanka, on 5th April 2002, five women working in a farm in Moneragala were killed on the spot as the tree they were sheltering under to escape from a thin drizzle was struck by lightning. The lives of these people could have been saved if they had been properly educated in lightning protection.

Apart from human injuries and deaths, another matter of concern is the innumerable deaths of animals caused by lightning every year. On 13th April 2001, a thirty-year-old elephant, Seetha Menike, belonging to the Temple of Sacred Tooth Relic, Sri Lanka was killed when struck by lightning. There are many other incidents of deaths of such animals due to lightning strikes in South Asia.

A strong momentary current

Lightning originates inside a cloud, several kilometres above the ground level. Except for a ball of lightning, a very rare phenomenon that we will discuss later, lightning is simply an electric spark between a cloud and ground, between two clouds or between two parts of a cloud. The spark that jumps between the ends of two wires connected to the terminals of a car battery, is a very basic form of lightning.

In the first stage of the lightning strike, a channel of charge flows towards the ground from the cloud. When this channel is about 50-100 metres above, earth-bound objects in the vicinity (e.g. trees, buildings, human beings, animals etc.) start sending upward channels of opposite charge to meet the downward channel from the cloud. One of these upward channels succeeds in meeting the downward channel first. Subsequently a large current will flow through the object that sent that upward channel. Then we say that the object has been struck by lightning. In a single lightning flash more than one current pulse may flow to the earth through the object that has been struck by lightning. This is what gives the flickering effect to the lightning channel.

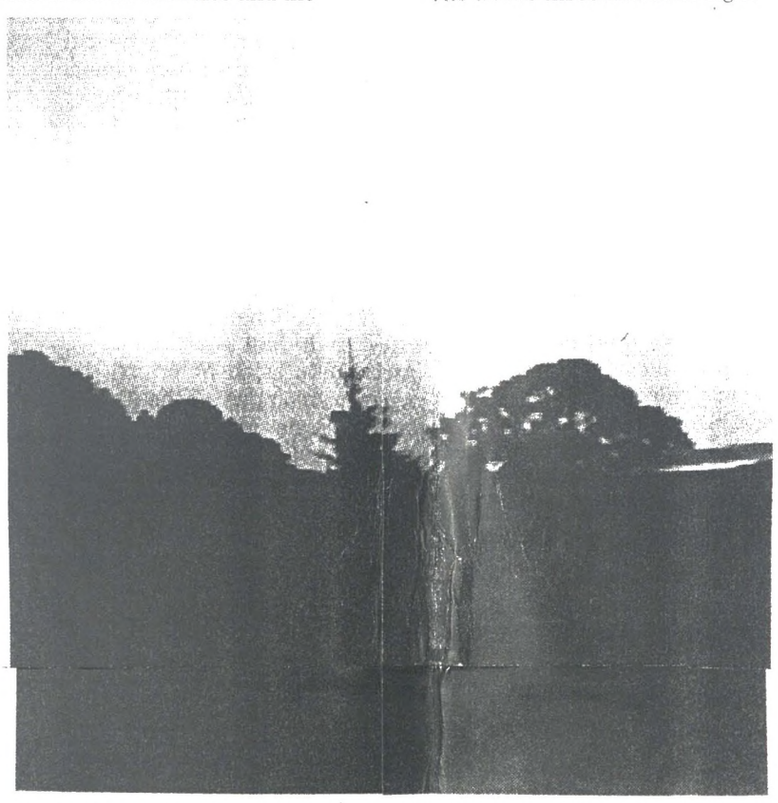
As lightning flows through an earth-bound object sparks may fly onto nearby objects due to the high resistance of the object through which the current flows. This is termed side flashing. Direct lightning strikes and side flashes are equally important for consideration.

At the point of striking the ground the electric potential (voltage) rises to a very high value (sometimes millions of volts). Therefore, a person, animal or any other object in the vicinity will be subjected to a large potential difference between the parts of body in contact with the ground. This is called step potential.

Deaths, injury and damages

If a person or animal is subjected to a direct lightning current or side flash he may undergo internal and external burns, ventricular fibrillation (heart failure) or stop breathing. If the lightning current flows through an external path through the body there may only be external burns in the body. If a person is subjected to step potential he may be paralysed, or even die due to the shock.

Lightning may damage buildings and equipment in three ways. When your building attracts a downward lightning leader (direct strike) or attracts a part of a lightning flash that hit another structure in the near proximity (side flash) you will get the maximum damage. The lightning current reaches a maximum value of about 30,000 amperes on average but currents in the range of 300,000 amperes are also reported. Simply compare this value with the current drawn by your refrigerator, which is about 10 amperes. The lightning current heats its path to a temperature of about 40,000°C. Compare this value with the temperature on the surface of the sun, which is about 5000°C. The enormous current of the lightning flash may destroy the entire power and communication networks in your building including all the equipment connected to the networks. The high temperature resulted by both the current that flows in the lines and the



sparks that jump in between different parts of the building may trigger fires that will completely burn out your installation. Direct lightning (or side flashes) causes damage at a very rapid rate so that once your building is struck by lightning it is very unlikely that you can prevent damage to equipment and human injuries (you could still prevent the fire from spreading by acting quickly).

The second mode of getting lightning currents into your installation is through the service lines such as power, communication and cable TV. Once lightning strikes a service line, fractions of the lightning current enter all the nearby buildings and may destroy all equipment that is plugged into the system. The lightning current may also injure the users of equipment connected to service lines.

This mode of intrusion of the lightning current causes much damage and a standstill to operations of institutions as service lines are subjected to lightning strikes far more frequently than the buildings themselves.

The lightning current that flows from cloud to ground is a good emitter of electromagnetic radiation. Thus once lightning hits a nearby object (say at 500m) even your building is exposed to a strong dose of electromagnetic radiation. When this radiation passes through electronic equipment such as computers, medical equipment, military equipment etc. their more sensitive parts could be destroyed. This may happen even when equipment is unplugged from service lines. However, the chances of ordinary electrical equipment being damaged due to such radiation are very slim.

Protection of structures

The above three modes of lightning threats can be eliminated by three types of lightning protection systems. A person who seeks protection from lightning should clearly understand this difference.

By Dr. Chandima Gomes

Chartered Engineer and Senior Lecturer in Physics, University of Colombo, Advisor to the National Lightning Safety Institution, USA

In commercial jargon a building protection system is referred to as a network that is meant to protect a building from direct lightning strikes and side flashes. An ordinary building protection system consists of one or several sharp pointed rods (or a mesh of metal strips/wires) installed at the roof of the building (called air termination), several metal stripes or metal wires from roof to base (down conductors) and one or several conducting rods buried in the ground (earth conductors). The down conductor system connects the air termination to the earth conductors. When a downward channel comes from a cloud, the air termination sends an upward channel much faster than the other parts of the building thus the lightning is attracted to one of the rods (or to the metallic mesh). Then the lightning current safely passes onto the earth through the rest of the system. Thus, instead of repelling a lightning channel, a lightning protection system attracts that. However, as the lightning current is safely driven onto the earth the building will not be damaged. The above system is called the "Franklin Rod System", named after Benjamin Franklin who first proposed lightning rods in 1749. Whatever building protection you select for your installation you have to make sure that the system follows certain standards. You may follow the Sri Lankan standards published by SLSI or any other recognised standard such as International Standards (IEC), British Standards (BS), Australian National Standards (AS), American Standards (NFPA 780/ANSI) etc.

For protection against lightning effects coming through service lines, protective devices should be connected at various points of a building starting from the service entrance. The location, number of devices and their rating should be determined by taking into account the safety level required for the building.

If you are seeking protection for a large building, it is strongly recommended to engage a knowledgeable consultant to address lightning related issues before calling vendors for quotations. You may engage the services of the consultant to evaluate the quotations and specifications of equipment and technologies offered by the vendors. In this way you may be able to get a good system and service at a lower price.

Safety of human beings

Postpone outdoor activities. If you notice overcast conditions postpone your outdoor activities. If you have already started a picnic, game of golf or any other outdoor activity, quickly go inside a completely enclosed building, not a car port, open garage or covered patio. If no enclosed building is convenient, get inside a hard-topped all-metal vehicle. A cave is a good option outside but move as far as possible from the cave entrance.

Be at the lowest possible point. If you are a tall protrusion in a particular landscape your body may be the unfortunate object that sends the first upward channel that meets the downward stream of charge from the cloud. Thus in thunderstorm conditions it is very advisable to avoid standing in playgrounds, seashores, paddy fields, open boats on waterways, roads with no structures on the sides or swimming in open waters etc.

One should also refrain from hiking, working on roofs, on the top of ....., on telecommunication towers, radio and television towers (even if the structures are lightning protected), riding bicycles, leaning against metal objects etc.

If you cannot get to a shelter, stay away from trees. The large current that flows along the trunk of a tree because of a lightning strike may decide to jump onto your head and reach the ground through your body when you stand nearby. This is termed a side flash. A majority of lightning victims have been struck while sheltering under trees. Thus, we may say that the number one rule of lightning protection of living beings is not to shelter under trees or any other tall structures when lightning strikes.

Get out of the water. It's a great conductor of electricity. Stay off the beach and out of small boats or canoes. If caught in a boat, crouch down in the centre of the boat away from metal hardware. Swimming, wading, and scuba diving are NOT safe. Lightning can strike the water and travel some distance beneath and away from its point of contact. Don't stand in puddles of water, even if wearing rubber boots.

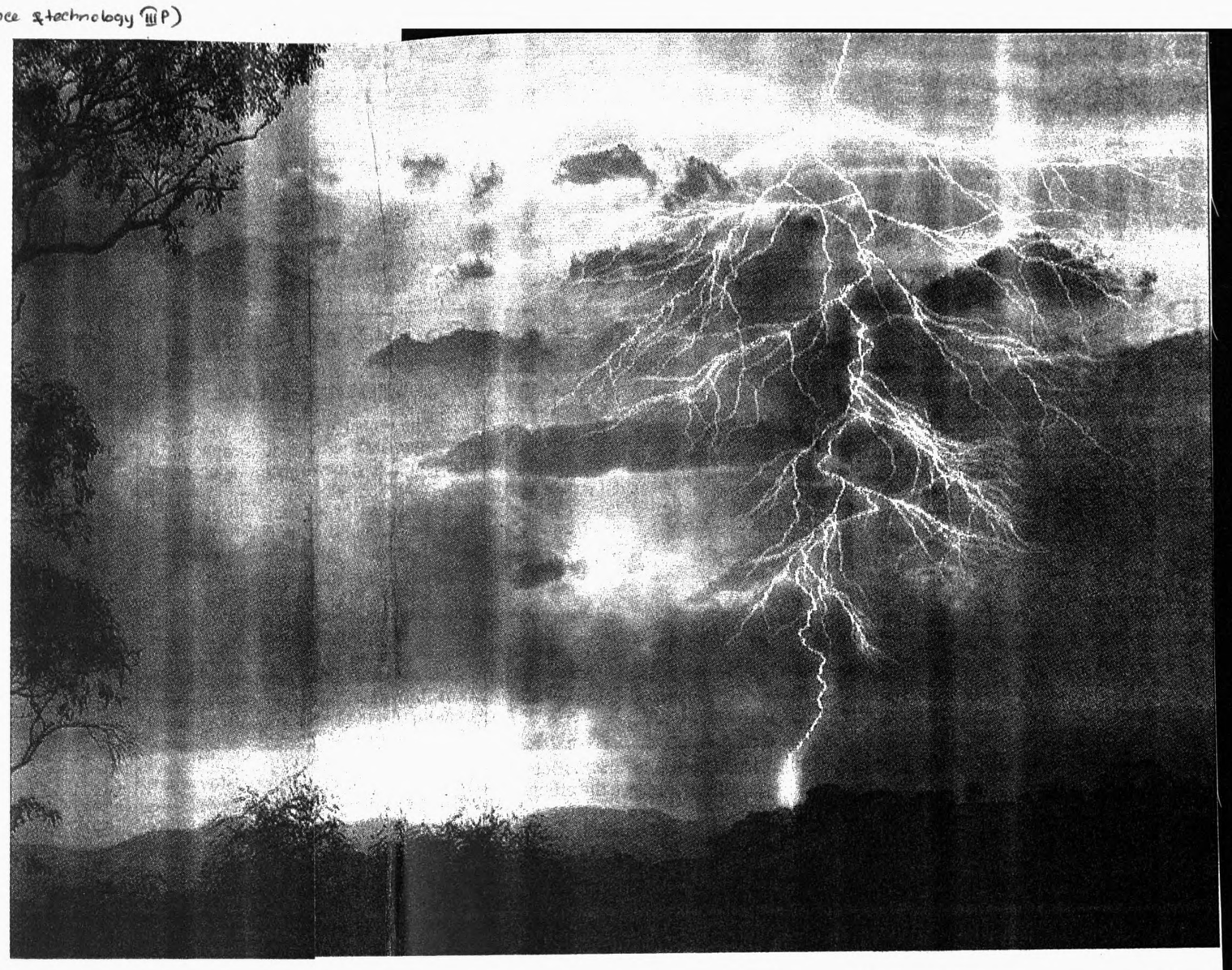
Avoid metals. Drop metal backpacks, stay away from clotheslines, fences, exposed sheds and electrically conductive elevated objects. Don't hold on to metal items such golf clubs, fishing rods, tennis rackets or tools. Large metal objects can conduct lightning. Small metal objects can cause burns.

Move away from groups of people and crouch down. If you hear thunder very close to you when outdoors, stay several meters away from other people. Don't share a bleacher bench or huddle in a group. Crouch down, keeping the feet as close to each other as possible. Close your ears with your hands. Never sleep or lay down flat under thunderstorm conditions. Rubber slippers or shoes will not save you from direct lightning strikes or side flashes. However, in the case of exposure to step potential, rubber or any other insulating footwear will help you to minimise the effects.

Wet clothes may be better than dry clothes. If the person is struck by lightning then wet clothes will give him some protection. The lightning current always takes the best conducting (least resistive) path. When a person is wet his external body becomes a good conductor. Thus if he is struck by lightning the current will prefer to flow outside the body instead of flowing internally. Thus you will escape with some skin burns instead of damaging vital organs inside the body.

Avoid using land phones. There is a high chance of lightning striking telephone and power lines that run for miles over open fields. Once lightning strikes the telephone network, a person who uses the telephone may be injured or even killed by the large current that is transmitted. However, use of cordless phones or mobile phones will not increase the risk of lightning unless they are connected to the main power for charging.

More next week



Lightning: Nature's killer - II

By Dr. Chandima Gomes
Chartered Engineer and Senior Lecturer in Physics, University of Colombo,Advisor to the National Lightning Safety Institution, USA

(Continued from last week)

Protection of archaeological and religious sites

With a history of over 2500 years, Sri Lanka is full of sites of archaeological interest. Many archaeological sites are religious, so that in addition to site-seeing visitors, a large number of devotees also gather regularly at these places. Therefore, a single lightning strike may not only destroy a thousand-year-old monument but also kill and injure several people. Although we do not have a historical record of lightning attacks in such sites, recent trends in the escalation of lightning density, enhancement of the number of visitors and improper structural modifications, it is high time necessary action is taken to safeguard such structures and visitors from possible lightning hazards.

The common lightning related risks and hazards at archaeological sites are discussed below.

Dagobas in Anuradhapura and Polonnaruwa

Almost all dagobas are tall and pointed. In many cases the dagoba is the sole protrusion in a flat terrain. Therefore the structures need an external Lightning Protection System (LPS) unless an internal system had been installed at the time of construction (a separate research is required in this regard). The requirement of a sound LPS is greatly felt at some locations due to the mass gathering of devotees on a regular basis (e.g. Ruvanveli Maha Seya). It has also been noticed that at some locations the lightning protection systems, that have been installed, are either partially or completely destroyed due to the lack of maintenance. Furthermore, it is regularly seen that metal scaffoldings are placed around the dagobas for various purposes. Usually, these temporary structures are not properly grounded thus the dagoba and people around it are exposed to a high risk of lightning hazards. Catholic shrines and Cathedrals along the coastal belt and open lands also have a similar requirement of lightning protection (e.g. Madhu Church, churches in Mannar and Negombo).

Temples on rocks

There are Buddhist temples and Catholic churches, of historical value, built on rocks in several parts of the country. Matale, Kandy, Gampola and Waskaduwa, are a few examples of areas where such sites can be found. These structures need special attention with regard to lightning protection as the attraction of lightning is more likely due to their high elevation. Unfortunately, most often, the earthing requirements at these places are pathological due to the high resistance at the locations.

Statues

There are a large number of tall statues of religious and archaeological value throughout the island. Many of these are erected over flat terrains or on rocks. These statues urgently need standard lightning protection for the safety of the monument as well as visitors. Recently, at some archaeological sites, temporary or permanent shades have been built up to safeguard the monuments from the natural elements (sun and rain). However, it has been found that these metal structures are most often not given proper lightning protection so that the lightning damage risk is enhanced.

Places of mass gathering

In addition to the above mentioned cases, there are sites of mass gathering which have a high degree of lightning risk. A few examples are Dambulla, Sigiriya, Sri Pada, Yapahuwa, and Wedasity Kanda (Katharagama). Lightning protection shelters should be installed at these places as in the event of a thunderstorm there are hardly any sturdy structures at these locations where people can seek shelter.

Other concerns of lightning

It is generally believed that once a person or structure is struck by lightning he/she or it will not be struck again. However, on rare occasions, structures and even people have been struck by lightning several times. There is no scientific reason one should get immunity to lightning after being struck once.

It is also believed that a person struck by lightning carries a charge in his or her body for several minutes and is therefore dangerous to touch immediately after being struck. The electrical charge injected into a person by a lightning current is drained into earth within a fraction of a second. Hence, the victim of lightning should be attended to immediately and first aid should be started as soon as possible.

It is also not correct that electrical equipment is safe if kept switched off during thunderstorms. The lightning current, which may be transmitted through power cables, can easily jump across the open switches and enter the equipment. Thus, it is highly advisable to disconnect (unplug) your electrical household items from the power line during thunderstorms. TV antenna cables should also be disconnected and kept outside the house. Also, disconnect fax machines and computers (email and Internet connections) from the telephone network. When you go away for a few days during the thunderstorm season, it is better to disconnect all electrical items at home.

It may be true that it is dangerous to use a sewing needle when lightning is striking nearby. Sharp and pointed metallic objects attract lightning more than blunt and smooth objects do. Thus if the house is struck by lightning, theoretically, there is a chance that the needle could get a side flash from walls, power lines etc. However, we don't know to what extent a tiny needle is capable of attracting a side flash.

Some people in our country throw out a metal rod habitually when lightning strikes. I cannot see any scientific reasoning for this. However, a metal rod kept close to the wall or especially a power line, metallic drain pipe etc. may attract a side flash if the building is struck by lightning. Such a side flash may cause fires and explosions. However, in order to get rid of such an accident you have to throw out all the metallic objects in the house, which is not practically possible.

There are certain small areas in the country that are prone to a high rate of lightning. According to information from several sources, there are several pockets in the country that have a very high density of lightning. Many of these pockets are not located in specific geographical conditions that favour a high rate of lightning strikes (located at high altitude, isolated hills etc.). Horana, Avissawella, Bulathsinghala, Matugama, Kalutara, Yatiyanthota, Malabe, Waliveriya, Nittambuwa, Negombo, etc. are a few of them. However, we need to conduct a thorough research in order to give reasons for this observation, as our current knowledge does not help in giving a reasonable explanation.

There may be lightning even in the absence of rain. This is true. Rain falls from the base of the thundercloud. Sometimes, due to the high wind shear the upper part of the cloud will spread in a large region while the lower part (base) is localised in a comparatively small region.

Lightning may emanate from that dispersed upper part, thus the point at which the lightning strikes ground may be tens of kilometres away from the rain. In addition, lightning may also emerge from sandstorms, dust clouds of volcanic eruptions and nuclear explosions and forest fire smoke. All these are rainless lightning.

Coconut trees are comparatively prone to a high rate of lightning strikes. This is also true, and there are a few reasons for this. Being a tall tree with leaves with sharp edges and pointed ends, a coconut tree may be the object in a certain landscape that sends the first channel to meet the down channel from the cloud. In addition, being the most abundant tree in the country, coconut trees will obviously have a high probability of being struck by lightning.

A lightning protection system repels a lightning strike that may come to your building. This is not true. An ordinary building protection system consists of one or several sharp pointed rods (or a mesh of metal strips/wires) installed on the roof of the building (called air termination), several metal stripes or metal wires from roof to base (down conductors) and one or several conducting rods buried in the ground (earth conductors). The down conductor system connects the air termination to the earth conductors. When a downward channel comes from a cloud, the air termination sends an upward channel much faster than the other parts of the building thus the lightning is attracted to one of the rods (or to the metallic mesh). Then the lightning current is safely passed onto earth through the rest of the system. Thus, instead of repelling a lightning channel, a lightning protection system attracts that. However, as the lightning current is safely driven into earth the building will not be damaged.

A lightning protection system will completely protect you from lightning. This is incorrect, with the above-described system your building is protected only from direct strikes and probably from side flashes. Still your building can be penetrated by lightning currents that propagate along service lines (power, telecommunication etc.). There are special devices (surge protectors) that prevent these current impulses from entering your building. The sophisticated electronics in your building can also be damaged by radiation, which will be emitted from the lightning flash. They propagate in free space. This radiation can be blocked from entering your building by taking measures of electromagnetic compatibility. Even with all these systems nobody can guarantee you 100 per cent protection from lightning. The company, which provides lightning protection, will give a certain level of protection (by a percentage) related to the system you buy. The cost of the system depends on the level of protection. For an example a nuclear power plant or a store of explosives and ammunitions may need a level of protection of about 99.99 per cent (a highly expensive system) while that of 75 per cent may be acceptable for an ordinary house.

I am prone to lightning when my neighbour installs a lightning protection system. This is incorrect. As I have pointed out earlier the lightning protection system attracts a downward channel from the cloud. Thus, there can be no increase in the probability of increasing lightning strikes to neighbours (it may even reduce the chance of nearby objects being struck by lightning).

Tall buildings make the lightning density high. This is not yet known. It is understandable that tall buildings get more lightning than short structures. However, we do not have evidence to say that tall buildings cause more lightning to come down due to their presence, unless they are extremely tall (e.g. Empire State Building or the CNN Tower, Canada).

During thunderstorms, fireballs may come down from the sky. This is true. Sometimes people have observed balls of fire emerging from the sky in overcast conditions. This is now termed 'ball lightning'. These fireballs are reported to be as small as a peanut or greater than a football. Their colour varies from pale yellow to glittering red. It has been seen that ball lightning moves at a walking pace and travels along transmission and power lines. Some people believe that water attracts ball lightning.

There are some cases where people have seen fireballs jump into water and vanish with a hiss. It has also been reported that when ball lightning passes over someone's body the flesh and skin along the path will be burnt to ash but the person does not feel the heat. Despite all these observations, scientists have still failed to come up with a concrete explanation for ball lightning. There are several theories put forward in this respect. At present, they are being discussed and reviewed by the scientific community.

Old temples are less likely to be subjected to lightning strikes. This maybe true. Most of our ancient temples have been built on either the flat terrain of the dry zone (thus for a large area, the only protrusion of the ground is the dagoba) or on top of hard rocks. Still there are very few reports of temples struck by lightning.

Some people say that a perfectly grounded metal rod running from top to bottom has been installed in our ancient dagobas. If it is true that full credit of the invention of the theory behind the modern day lightning protection system should go to our forefathers instead of Benjamin Franklin, the great American scientist.

It is true that lightning has a good side as well. Due to the extremely hot conditions imposed by a lightning flash Oxygen and Nitrogen combines together to form Nitrous Oxides. These nitrous compounds dissolve in rainwater, reach the ground and fertilise the soil.