Environmental pollutants and aggressive climatic conditions: combination scaffolds of brain stroke

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In the present scenario, health-related complications are worsening because of escalating environmental factors. Pollution of the earth has reached alarming levels. High motorization rate and unchecked industrial wastes produce massive environmental pollutants, which are the most profound factors for aggressive climatic conditions. Heat-trapping pollutants like carbon monoxide and chlorofluorocarbons are increasingly being emitted in the atmosphere. Many toxic pollutants, viz. sulphur dioxide, nitrogen dioxide, mercury and lead have crossed their threshold levels in urban and industrial regions. These pollutants have serious consequences on human health, affecting many organs and systems. They affect our respiratory system, circulatory system and nervous system by entering the blood stream. The blood–brain barrier of the central nervous system is also being disrupted due to sustained exposure. Ischaemia and haemorrhage are the most hazardous incidences of environmental pollutants in brain. It has now become a serious cause of morbidity and mortality. Pollutants like sulphur dioxide and carbon monoxide have a tendency to produce ischaemia and clump through inflammation and arterial blockage. Almost 40% of mortality is caused due to pollution-induced brain stroke. Hence, environmental pollutants are the leading cause of cerebral stroke and somatic disabilities.

Keywords: Brain stroke, environmental pollution, disease mortality, global warming.

THE greatest threat to planet earth is the current audacious ethos of human beings which has many devastating intermediaries leading to a serious ecological damage. Our ecosystem has many biotic and abiotic components influencing each other, and the earth is an open system with regard to energy. An open system gives rise to a number of consequences. It may face the risk of global warming if the energy trapping elements are not controlled in the course of time[1,2]. The most suitable temperature on earth is 16°C, which is providentially the average temperature of earth despite many latitudinal variations. On the basis of the present climatic conditions, it is considered that human beings have entered into anthropocene epoch, where they began to substantially alter the earth's ambience and troposphere by creating an imbalance in the biotic and abiotic components of the ecosystem[3,4]. This severe and intense disturbance in the ecosystem gives rise to aggressive climatic conditions. According to a study on temperature analysis conducted by the National Aeronautics and Space Administration (NASA), USA, the average temperature of the earth has increased and it is tending towards extreme temperatures[5].

Human body follows the process of homeostasis and has the tendency to cope with extreme climatic conditions up to a certain limit. When the temperature of the ecosystem goes beyond 47°C, it results in the coagulation and denaturation of many enzymes *in vivo* as well. Our body physiology is completely dependent on enzymatic processes and almost all enzymes exhibit temperature-dependent kinetics[6]. Hence, in case of extreme climatic conditions, a cascade of disturbances will arise in our vital functions, including alteration in the functioning of the brain. The regulation of body temperature via homeostasis is carried out by the central nervous system (CNS), especially through the hypothalamus[7]. This is located below the thalamus and is the ventral part of diencephalon responsible for many autonomic activities. Various atmospheric pollutants such as sulphur dioxide, carbon monoxide, mercury, lead, etc. have severe deleterious effects on the human brain[8]. Continuous exposure to such pollutants can lead to reduction and impairment in human intelligence and in chronic conditions can also cause brain stroke[9,10].

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In this article, we examine the events of brain stroke triggered by environmental pollutants and aggressive climatic conditions.

Understanding brain stroke

Brain stroke is a consequential condition recognized by paralysis or numbness in any side/part of the body (viz. leg, arm, face, etc.). The other subsidiary symptoms are sudden loss of vision in one or both eyes, difficulty in speech and instantaneous headache. Brain stroke is an abnormal state in which blood supply to the brain is reduced or interrupted, resulting in deprival of oxygen and nutrients to the brain tissue. It can be confirmed by cerebral angiograms and hematological examinations. There are three main types of brain stroke, namely ischaemic stroke, haemorrhagic stroke and transient ischaemic attack[11] (Figure 1).

Ischaemic stroke is a condition in which the cephalic blood flow is reduced or restricted, thereby causing interruption to the nutrients and oxygen supply. It has two subtypes: thrombotic stroke and embolic stroke[12]. Thrombotic stroke is caused by a blood clot that develops inside the vessels of the brain and embolic stroke is caused by plaque debris that develops elsewhere in the body and goes to the brain via the blood stream. Haemorrhagic stroke occurs from a compromised vessel that ruptures and bleeds in the brain. The occluded blood squashes the surrounding brain tissues causing dysfunction. On the basis of occurrence, it can be intracranial haemorrhage or subarachnoid haemorrhage. Haemorrhagic stroke occurs via two mechanisms, namely aneurysm and arteriovenous malformation (AVM). Aneurysm is the ballooning of a weakened region of blood vessels due to chronic hypertensive stress and AVM is due to poorly formed blood vessels having high tendency of haemorrhage than normal vessels. Transient ischaemic attack (TIA) is also known as 'mini-stroke'. It is a temporary neurologic dysfunction characterized by weakness on one side of the body, vision problem in one or both eyes and slurred speech[13,14]. These are transient and often resolve within a day or two.

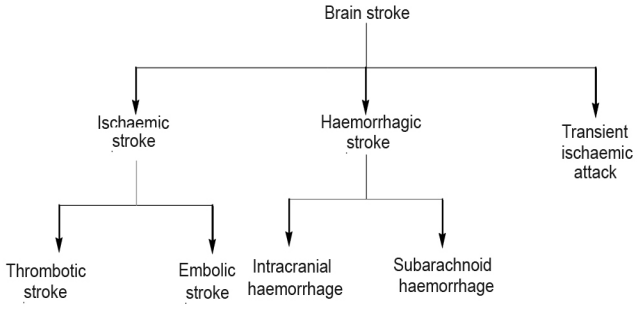

Figure 1. Types of brain stroke.

Pollutants and aggressive climatic conditions

Unfavourable disturbance in an environment is called pollution and the responsible components are called pollutants. Pollutant may be a dreadful substance or energy. Everything in our ecosystem has certain limit. The malicious mixing of those components (beyond the limit) can create adverse upset. The pollutants have severe risk on human health. According to the World Health Organization (WHO), ambient environmental condition has major influence on human health[15]. By reducing the level of pollutants, human beings can enhance their quality of life as well as longevity. Toxic levels of pollutants exhibit many serious health hazards. Increased levels of pollutants can damage our vital organs and pollutants like sulphur dioxide, carbon monoxide, nitrogen dioxide, mercury derivatives and lead compounds have minacious effects[16].

Sulphur dioxide

The main source of sulphur dioxide is combustion of fossil fuels and from the exhaust of automobiles like cars, trucks, buses, etc. Sulphur dioxide dissolves the mucosal lining of internal organs, mainly circulatory vessels and respiratory tract. In an experimental study, it has also been seen to produce febrile seizures and brain damage. Sulphur dioxide is soluble in water and easily assimilates in the circulating blood. Since it has a direct effect on epithelial linings, constant exposure to this gas can cause ischaemic stroke[17].

Carbon monoxide

Carbon monoxide is a virulent gas. It does not have any colour, odour or taste. The gas is emitted by automobiles due to incomplete combustion of fossil fuels such as petroleum and natural gas. Carbon monoxide inhalation causes perilous injury to brain, heart and other vital organs. In a case study, it was observed that respiratory insufficiency due to carbon monoxide intoxication resulted in elevated levels of tropinin-I, creatine kinase-MB fraction and carboxyhaemoglobin. It has a damaging effect on brain by causing cerebral ischaemia[18,19].

Nitrogen dioxide

The source of nitrogen dioxide in our environment is from road traffic and combustion of fossil fuels. At high temperature nitrogen combines with oxygen to produce nitrogen monoxide. When nitrogen monoxide is released from vehicle exhaust system, it reacts with atmospheric oxygen to form nitrogen dioxide. The gas is also found in tobacco smoke. Long-term exposure to nitrogen dioxide even at low concentration may have noxious effect on

human health. It is one of the serious pollutants capable of causing damage to epithelial linings, haematological and metabolic disorders, coronary artery disease and stroke. Nitrogen dioxide is slightly soluble in water. It can easily diffuse through biological barriers and slowly hydrolyse into nitrous and nitric acid, leading to increase in oxidative stress. Thus, excessive exposure to this gas can also lead to methaemoglobinaemia in the blood. This causes oxygen depletion that could lead to hypoxia and stroke[20,21].

Mercury

The sources of atmospheric mercury are burning of coal and petroleum, cement, metal and paper industries, incineration of municipal and medical wastes, mining and volcanic activities. The elemental mercury has good permeation through blood–brain barrier, whereas its derivatives have poor permeation. Inhaled elemental mercury vapour is easily absorbed through mucosal membranes and causes pernicious action in many organs, including heart and brain. In the brain it has high tendency to produce multiple sclerosis and ischaemic stroke[22–26].

Lead compounds

The main source of lead in the atmosphere is combustion of leaded petrol in automobiles. Despite many adverse effects, some countries are still using lead compounds (tetraethyl lead) as anti-knocking agents in gasoline. There are also a few other sources like lead smelter and battery industries as well as incineration of industrial waste. Lead compounds are readily absorbed through biological membranes and accumulate in blood and bones. A decrease in δ-aminolevulinic acid dehydratase activity is associated with elevated blood lead levels. Acute lead poisoning is associated with disruption of blood–brain barrier and results in brain oedema with microvascular damage following ischaemic stroke[27–29].

Particulate matters

Suspended particulate matter (PM) is also noxious beyond a certain level[30]. It is classified on the basis of aerodynamic diameter. The suspended particles with diameter 2.5–10 μm (PM_{10}) are course, fine particles have diameter less than 2.5 μm ($PM_{2.5}$) and ultrafine particles have diameter less than 0.1 μm. The ultrafine particles are also known as nano-sized particles.

PM_{10} can get into the lungs, causing serious health complications. These particles are trapped in the cilia of the upper respiratory tract and excreted in the form of viscous mucous from the lung, but persistent exposure to PM_{10} can cause ciliary dyskinesia. This results in reduction in mucous clearance from the lung and leads to progressive damage of the respiratory system[31].

$PM_{2.5}$ is composed of many toxic substances (elements/ions/radicals) including sulphate, nitrate, ammonium, carbon soot, metals, lipopolysaccharides (LPS) and diesel exhaust particles. The main sources of these pollutants are road vehicles, industrial gases and firecrackers. Excessive exposure to $PM_{2.5}$ is a risk factor for cerebrovascular diseases. There is a direct relationship between $PM_{2.5}$ and stroke morbidity. $PM_{2.5}$ has been observed as an inducing agent for TIA even with relatively low pollution levels. There is a cascade of events by which $PM_{2.5}$ exposure increases the risk of cerebrovascular dysfunction. The events are acute arterial vasoconstriction, increase in blood pressure and plasma viscosity[32–34].

Concentrations of PM_1 (particulate matter of diameter less than 1 micron) recorded in ambient air can lead to many serious illnesses such as heart attack, lung cancer and cerebral dysfunction resulting in premature mortality and morbidity[35–37]. Continuous exposure to this air pollutant increases both incidence and mortality of stroke[27,38,39]. The ultrafine particles are able to penetrate the alveoli and readily assimilate into the brain. Since they are very small in size, they can cross the blood-brain barrier without any hindrance and lead to serious effects on the system. Ultrafine particles (especially those containing transition elements) have been reported to cause atheromatous plaque. In the brain, they have a tendency to cause ischaemic stroke[40,41].

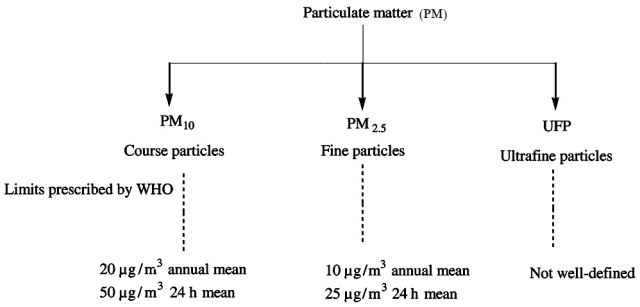

Figure 2. Classification of atmospheric pollutants on the basis of particle size.

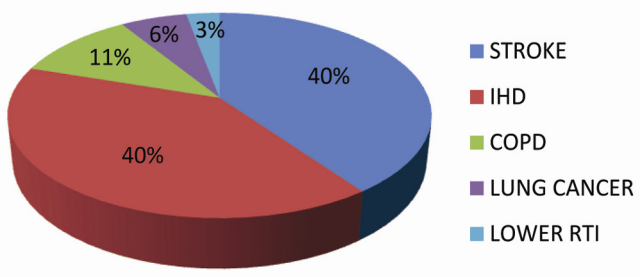

Figure 3. Disease-wise percentage mortality due to air pollution.

Carbon soot

Carbon soot contains amorphous carbon as polycyclic aromatic hydrocarbons (PAHs) produced by incomplete combustion of fuels. PAHs are among the mutagens that fall in the category of 'known human carcinogens'. They are injurious to our organ-system, including the brain[42].

Lipopolysaccharide

LPS is a pathogen-associated environmental pollutant that activates monocytes and macrophages through interference with CD14 and Tall-like receptor 4 (TCR4). The main source of LPS toxin is insanitary surroundings and improperly dumped biological waste which is a source of Gram-negative bacteria. LPS is found in the outer membrane of Gram-negative bacteria. It induces disruption of blood–brain barrier and disturbs the neuro-immune mechanism. At low dose LPS induces delayed neuro protection against ischaemia and at higher dose it induces mortality and brain oedema in stroke[43,44].

Exposure to air pollution increases the risk for many diseases such as stroke, heart disease, cancer and respiratory diseases[45]. According to WHO the relative percentage of death due to various diseases is as follows: stroke (40%), ischaemic heart disease (40%), chronic obstructive pulmonary disease (11%), lung cancer (6%) and acute lower respiratory tract infection in children (3%). This shows a greater understanding of diseases caused by substandard air quality[46,47].

Aggressive climatic condition is a progressive consequence of disturbance in environmental specifications. Extreme environmental conditions such as extreme hot and cold weather can increase the risk of stroke and blood clot. Human physiology is dependent on enzymatic activities and enzymes can coagulate and denature at high temperatures, i.e. beyond 47°C. High humidity is also an extreme environmental condition which affects human physiology. The precise interconnection of humidity and mortality is still not clearly understood. However, it can significantly affect the consequences of stroke. At high humidity, the human body manifests severe dehydration which increases the risk of stroke and related complications[48].

Conclusion

Atmospheric pollution has become a global problem at present. Pollutants have been seriously affecting human health. It is estimated that long-term exposure to pollutants like sulphur dioxide, carbon monoxide, nitrogen dioxide, mercury and lead increases the incidence of many diseases, including cerebral damage and brain stroke. The latter is a major consequence of pollution on human being and the second most common cause of morbidity and mortality. It also causes physical disability. Blood clot in cerebral hemisphere results in organ dysfunction or hemiplegia. Risk of morbidity is greater in case of long-term exposure with pollutants. The intensity of adverse effects of pollutants is not uniform across all individuals, it is more prominent in smokers. Thus it can be concluded that the human brain is sensitive to atmospheric pollutants. Despite their many adverse effects on the organ-system, ischaemic and haemorrhagic stroke are the most common ill-effects of atmospheric pollutants.

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