

## Chapter 8

# Air Pollution and Disasters

**Abstract** Many disasters lead to air pollution and vice versa. This chapter elaborates major air pollution issues due to earthquake, tsunami, volcanic eruption, epidemics, extreme temperature, insect infestation, mass movement, wars, and fire accidents.

A disaster is a hazard resulting in significant physical damage, loss of life, or impact to the environment. In modern academia, disasters are considered as the consequence of improper risk management. Hazards that strike areas with low vulnerability area or uninhabited region will never become disasters. Developing nations suffer the greatest impact in terms of life, economic loss, and environmental degradation. Disasters can be natural or anthropogenic and could be sudden onset (as in case of flash flood, cloud burst or explosion in industry) or prolonged onset (like drought or civil conflict). Air pollution may subsidize or enhance due to disasters. Disasters like earth quake, war and volcanic eruption add to air pollution. Disaster disturbs the air quality within airsheds. Disasters disturb the air quality for a long or short period. The exposure of life to large concentration of pollutants within short period may result in unpredicted impact as witnessed in release of toxic gases in industrial accidents.

As per Gribble (2002) 3700 naturally occurring organo-halogens are known to exist as on date. The presence of many fluoro-alkanes in geothermal emissions is well documented, even though how these compounds are formed remains a mystery.

Air quality management during disaster depends on preparedness of the community and external aid. Air pollution can lead to disasters and disasters can result in air pollution. In either the case human health or environment will be affected. The notable among the air pollution episodes are Meuse Valley episode in 1930, episode in Donora in Pennsylvania of USA, London episode in 1952, Bhopal episode in India that occurred in 1984, Chernobyl episode in 1986, southeast Asian haze of 1997, and Fukushima Daiichi nuclear disaster of 2011.

Quantity of emissions released during disaster is difficult to assess hence following equations are used to estimate quantity of pollutants emitted.

$$Q_i = M_i/C_i$$

where,

$Q_i$  release rate of pollutants into atmosphere

$M_i$  measured air concentration of pollutants

$C_i$  dilution factor (calculated under assumption of unit release rate)

Total release of pollutant is calculated using following equation

$$S_i = \sum [Q_{i,j} \times T_j]$$

where

$Q_{i,j}$  release rate of pollutant  $i$  at time  $j$

$T_j$  Duration of release

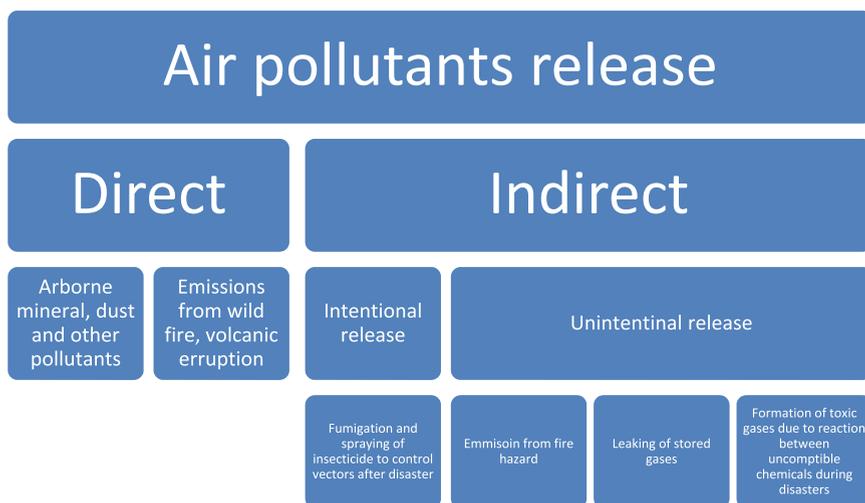
A temperature inversion in Meuse valley of Belgium lead to increase concentration of pollutants emitted from industries along narrow valley of Meuse river resulting in death of about 60 and sickness of 6000 people in valley. The temperature inversion in Donora of Pennsylvania, USA killed 20 people and sickened 7000 people in 1948 due to air pollutants emitted from industries located in the valley of Monongahela River.

Most of the natural disasters in urban area trigger technological accidents. Such incidents/accidents that lead to technological accidents due to natural disasters are called “Natech” (Campedel 2008) or natural-technologic or *na-tech* events (Young et al. 2004). Several effects could take place in industries and in the storage sites, resulting in damage of pipelines, storage tanks, and process equipment resulting in the release of hazardous materials. Examples of Natech include flood in 2002 at the Samir refinery in Mohammedia, Morocco; Kocaeli earthquake that occurred in 1999 in Turkey; nuclear disaster in the year 2011 at the Fukushima Nuclear Power Plant in Japan.

Natural disasters are prominent mechanisms of hazardous material (*hazmat*) releases. Na-tech releases may be small (e.g.: paints, solvents, and other chemicals stored in household) or large (e.g.: explosion of fuel storage tank). Disaster-related hazardous material releases may affect large areas and people. Smoke from Indonesian wildfires spread to Kuala Lumpur and Singapore (Swinbanks 1997), where outpatient attendance for haze-related conditions increased by 30 % (Emmanuel 2000).

Figure 8.1 Air pollutants released from disaster. Table 8.1 shows scale of disaster due to air pollution. Disaster-related hazardous substance releases can have an effect on large geographic areas and people (Young et al. 2004). Many na-tech releases from inadequate building structure, poor storage well (Whitman 1986).

Pollutants released to the environment cycles between air, land, as well as water until it is finally removed from the system through burial in lake sediments or deep ocean sediments and through entrapment in secure mineral compounds. Disasters can increase the release of the pollutants accumulated in living/non-living things. While the wild fires release the chemicals entrapped in biomass, volcano/tsunami/earthquake can release the elements/compounds present in earth/seabed.



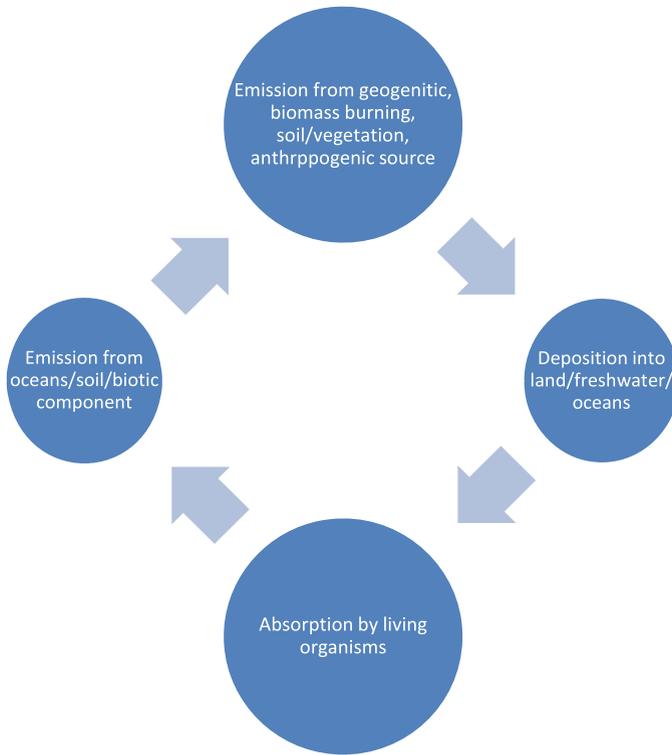
**Fig. 8.1** Air pollutants released from disaster

**Table 8.1** Scale of disasters due to air pollution

| Environmental issue      | Global | Regional to continental | Local to regional | Local |
|--------------------------|--------|-------------------------|-------------------|-------|
| Climate change           | x      |                         |                   |       |
| Ozone depletion          | x      |                         |                   |       |
| Tropospheric ozone       | x      | x                       | x                 |       |
| Acidification            | x      | x                       | x                 |       |
| Corrosion                |        | x                       | x                 | x     |
| Urban air quality        |        |                         | x                 | x     |
| Industrial emissions     |        |                         | x                 | x     |
| Nuclear emergencies      |        | x                       | x                 | x     |
| Chemical emergencies     |        | x                       | x                 | x     |
| Food poisoning epidemics |        |                         |                   | x     |

Methylmercury, the most toxic substance is mainly formed in aquatic environments by natural microbial processes. Subsequently mercury escape to air and washed into water bodies. A geothermal activity emits mercury to the atmosphere as well as releases it to the deep oceans (UNEP 2013).

Figure 8.2 shows biogeocycle of pollutants that are disturbed during disasters there by releasing air pollutants. Air pollution during disasters are not researched and documented because monitoring of air pollution is not a priority activity during disaster and lack of funds towards research with respect to air pollution during disasters. Further even if the monitoring devices exist in disaster prone area, the devices will get affected and stop functioning due to damage or power cut.



**Fig. 8.2** Biogeochemical cycle of pollutants

Land use planning should evade hazard zones such as 100-year flood plains and fault lines for locating landfills, waste lagoons, chemical storage facility as well as industrial facilities. Using special designs for pipeline supports and tanks can improve structures' capacity to withstand the disaster (Selvaduray 1986). Release of petroleum during the Northridge earthquake as well as ammonia releases during flooding in Brazil might have been prevented by proper engineering design and location of facilities. Nuclear power stations and industrial facilities that have been particularly designed to withstand natural catastrophe.

## 8.1 Floods

Floods usually occur due to rain, destruction of dams, overflow of water bodies, and cloud burst. It is usually assumed the flood will not lead to air pollution. But the pollutants like methane and hydrogen sulphide may be released during flood due to purification of organic matter. Presence of pyrite in flooded area may undergo

aqueous oxidation generating sulfuric acid which could be released to air. Many dimensions of air pollution and flood are shown in Fig. 8.3.

A water-reactive substance like alkali metals, iron sulfide, uranium, lithium, sodium, potassium, rubidium, calcium, phosphorous, caesium, sulphuric trioxide and oleum release air pollutants due to reaction. Some chemicals are also pyrophoric and will ignite releasing air pollutant.

Standing water due to flood will become breeding ground for microbes and can become airborne and be inhaled resulting in lung disease. The contaminants and microorganisms left behind after flood pose health risk. Due to the time spent in emergency camps may increase the risk of infectious diseases. Damp buildings as well as furniture promote the growth of dust mites, microorganisms, mold and

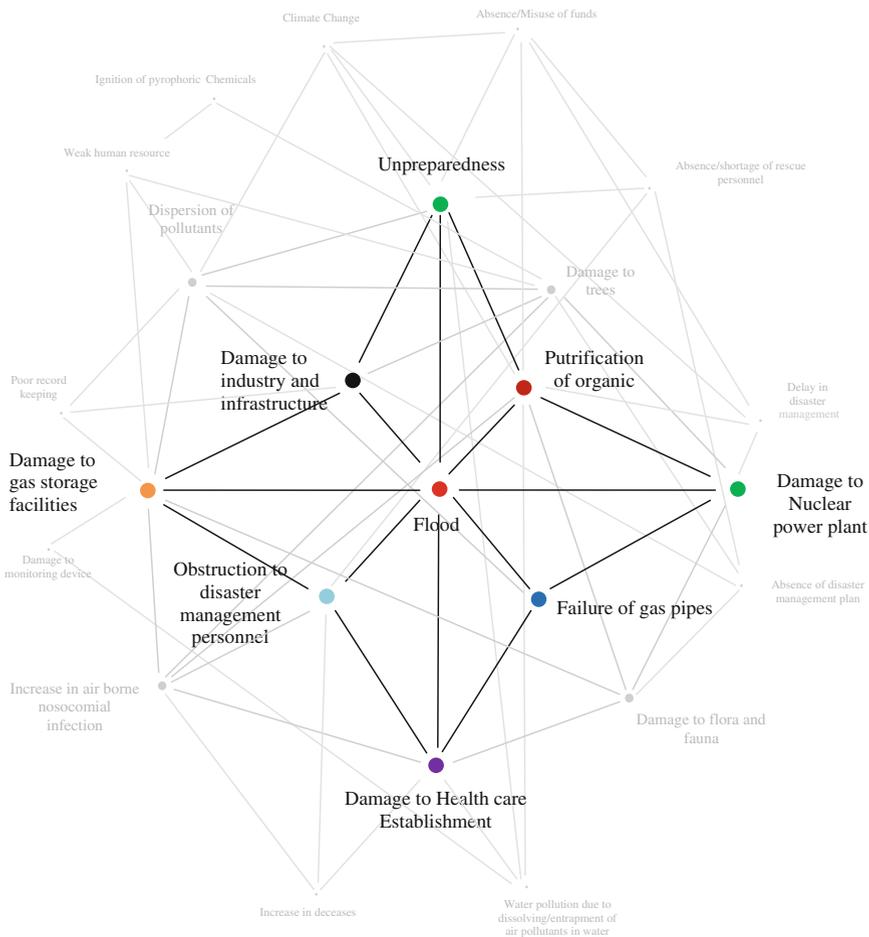


Fig. 8.3 Many dimensions of air pollution and flood

cockroaches that can aggravate asthma, allergies, wheeze, cough and hypersensitivity pneumonitis.

Leakage of variety of gas both in residences and industry can lead to health as well environmental hazard. The geothermal water from underneath the glacier may lead to release of hydrogen sulphide when exposed to air during flood which may include glacial outburst flood. A flood can expose people to lead from contaminated soil, deteriorating paint, and dust from chipping or peeling paint. Further asbestos in flood debris can also contribute to air pollution.

## 8.2 Drought

Drought is affecting millions of people, especially poor as well as underprivileged. Their vulnerability is increased by ongoing environmental degradation as well as inefficiency of governance. Drought are classified into three types: meteorological, agricultural, and hydrological.

Meteorological drought is shortage of precipitation from “normal rainfall”. Agricultural drought is shortage in water to crop. Hydrological drought is shortage in surface/subsurface water supplies, resulting in shortage of water to meet normal water requirements.

1930s witnessed drought followed by infamous dust storms (Schubert et al. 2004). The drought and dust storms created major environmental catastrophes in USA and led to the popular description of most of the southern Great Plains as the dust bowl (Worser 1979).

The Dust Bowl, during the 1930s is also popularly phrased as dirty thirties. Severe drought and unanchored soil lead to formation of dust clouds that sometimes blackened the sky. These billows of dust often referred as “black blizzards” or “black rollers” reached Washington, D.C. as well as New York city and reduced visibility to a meter or less. Extended drought in 1930 resulted in exposure of ploughed field to wind erosion.

Emissions of isoprene as well as terpenes from vegetation which has a significant impact on ozone as well as fine particle formation will be reduced due to drought. The overall pollution will increase as gross leaf areas in the vicinity of drought prone area will decrease and so as scrubbing effect due to absence of precipitation. Dry, clear skies influence light available for enhancing photochemical reactions. Changes in soil moisture will change height to which pollutants in the air can mix in the atmosphere.

Climate change brings numerous economic activities with it. Increase in heat enhances demand for cool drinks, ice cream, sunburn creams, and electricity demand towards air-conditioning/refrigeration which may increase electricity demand and associated emissions.

Several years of drought resulted in desiccation of Old Wives Lake, in southern Saskatchewan. The wind generated airborne silt, sodium sulfate, and clay due to which residents reported nasal, respiratory and eye irritation (Gomez et al. 1992).

### 8.3 Wild Fire

Wild fire is fire in an area of combustible vegetation in the wilderness area that include forest and grass land. Wildfire occur due to lightning, spontaneous combustion, sparks from rock falls, volcanic eruption, coal seam fires, cooking in forests, sparks from equipment discarded cigarettes, intentional fire by terrorist, shooting by poachers, preparation of forest land for agriculture by firing, and power line arcs. During wild fire, burning logs can roll downhill igniting dried vegetation in lower elevation. Dry climbers become fire ladders and burns trees. Methane formed due to litter decomposition catches fire easily thereby spreading fire. Lower precipitation, higher temperature, drop in humidity increases spread of fire.

Millions of hectares of the forests are destroyed by wild fires every year resulting in air pollution. Annually fires burn about 500 million hectares of open forests, woodland, tropical as well as sub-tropical savannahs; 20–40 million hectares of tropical forests; and 10–15 million hectares of boreal as well as temperate forest (Goldammer 1995).

Air quality of thousands of km is affected by wildfires (Sapkota et al. 2005). Apart from smoke comprising of unburnt carbon particle, the emission from wild fire comprises carbon monoxide, ash particulates, methyl chloride, methyl bromide, polynuclear aromatic hydrocarbons, aldehydes, VOCs.

Due to intervention of anthropogenic activity, forests have become dump yards for waste that include hazardous waste. Fires in such area contribute to toxic air pollutants. The pollutant concentration and type depends on the nature of substance burnt and hence it is highly difficult to characterise emissions.

The notable massive forest fires often occur at Southeast Asia. The 1997 Southeast Asian haze caused mainly due to slash and burn agricultural practice was worsened by quasi-periodic El Nino drought. Large area of southeast Asia were affected by emissions of 45,600 km<sup>2</sup> of vegetation burnt on Indonesian islands of Kalimantan and Sumatra resulting in concentration of total suspended solids of more than 2000 µg/m<sup>3</sup> in locations close to extensive fire activity. The resulting haze covered more than 3 million km<sup>2</sup> affecting Indonesia, Singapore, Thailand, Brunei and Malaysia. The haze also occurred 2005, 2006 and 2013 affecting life in south East Asia. Local sources of pollution due to industries increased toxicity. Urbanised as well as industrialised Klang Valley of Malaysia increased pollution aggravating the situation. The problems due to haze lead to ASEAN (Association of South East Asian Nations) Agreement on Transboundary Haze Pollution signed in 2002 by ASEAN nations to decrease haze pollution in Southeast Asia.

Wild fires can significantly contribute to illnesses of the respiratory system (WHO 2002; Bowman and Johnston 2005; Moore et al. 2006). 1997 Indonesia fires increased cardiovascular and respiratory diseases, and affected living in South-East Asia (Sastry 2002; Frankenberg et al. 2005; Mott et al. 2005). Smoke containing ozone, sulfur dioxide, nitrogen dioxide, carbon dioxide as well as particulate matter resulted in hospital admissions of at least 8000 in Malaysia during the Indonesian

forest fires in 1997 (Swinbanks 1997). Fatalities due to too much carbon monoxide concentrations only or along with other pollutants were reported during wild fires in Côte d'Ivoire (1982–1983), China (1987) and Australia (1983) (Schwela et al. 1999).

Wild fire not only destroys wild life habitats that include nests and burrows, it affects healthy wild life as well in. The young and weak animals/birds are easily get killed due to wildfire.

Wildfire suppression can be as simple as beating the fire with sticks or throwing sand. Advanced suppression methods include use of Silver iodide to encourage snow fall, dropping fire retardants and water by unmanned aerial vehicles. Fire retardant may also be applied prior to wildfires as a precautionary measure. The secondary impact of the application of aerial fire retardants includes impact on land, water and vegetation.

Spreading of smoke in hilly terrain depends on the narrowness of valleys and may get stagnated for many days thereby forcing displacement of large animal and birds. Small animals may die to exposure due to small lung size and large quantity of polluted air.

## 8.4 Earthquake

Earthquake is shaking of land due to seismic waves. The majority earthquakes occur along the boundaries of the tectonic plates. Nations around the Pacific Ocean frequently experience earthquakes as they are situated in boundary of the Pacific plate. About 80 % of the world's major earthquakes are felt along a belt around the Pacific Ocean. Hence this belt often referred as 'Ring of Fire'.

Earthquake, in Taiwan on September 21, 1999 and March 31, 2002 was preceded by abrupt increase in SO<sub>2</sub> concentrations several hours prior to the earthquake possibly due to seismic triggered degassing (Hsu et al. 2010). Air pollution in the affected areas due to the Great Hanshin Earthquake in Hyogo, Japan on 17th January 1995 resulted in maximum TSP concentration of 150 µg/m<sup>3</sup> at five locations (Gotoh et al. 2002). After earthquake in Kobe City, Japan in 1995, dust and irritants generated during demolition work were considered as a factor in the worsening condition of asthma patients (Nukushina 1995). Hazardous substance (like asbestos; fiberglass; mercury; chemicals from leaking transformers and broken chemical containers etc.) exposures accounted for 20 % of after-earthquake work-related injuries after Loma Prieta earthquake in the year 1989 near Santa Cruz, California (Durkin et al. 1991; Nathan et al. 1992).

Impact on air quality of earthquake prone area depends on activities and infrastructure in the area. An area with atomic power plant or nuclear research centre will result in emission of radioactive material during earthquake. Damage to petroleum storage area and subsequent smoke during earthquake will result in

emission of pollutants due to combustion of petroleum product. The damage to industry may result in emission of stored chemicals.

On 11th March 2011, earthquake in the northeastern coast of Japan and tsunamis occurred over the east coast of the Tohoku Region (Nagamatsu et al. 2011) that resulted emissions from failure at the Fukushima Nuclear Power plant.

The Whittier Narrows quake in October 1987 resulted in at least two hazardous material incidents: (1) the release of 2/3 of a 1-ton chlorine container at a facility in Santa Fe Springs; and (2) chemical spills, a major fire and asbestos contamination in California State University, Los Angeles (Tierney 1989). Tipping of 1-gallon container storing sodium metal during the quake resulted in fire. Water leaking from ruptured safety shower reacted with the sodium generating hydrogen gas that ignited and spread, vaporizing mercury as well as exposing asbestos (Lindell and Perry 1996).

Earthquake in Northridge, California in USA resulted in nine petroleum pipeline ruptures, 752 natural gas line breaks, 60 emergency hazmat incidents that included release of sulphuric acid during train derailment (Lindell and Perry 1997, 1998).

Hazardous releases were reported from about 200 laboratories, 100 industrial facilities and commercial activities (like drug stores, hair salons as well as restaurants) and residences after the Loma Prieta quake 1989 at California. Three of the largest releases associated this quake were between 5000 and 20,000 pounds of ammonia from a food processing plant, 50,000 gallons of aqueous solution from a semiconductor facility, and 15,000 yard<sup>3</sup> of fuel from underground storage containers (Young et al. 2004).

## 8.5 Tsunami

Tsunami is series of water waves due to displacement of a large quantity of water in water body. Air contaminants released during tsunami depends on the development and activities of the tsunami affected area. The flooding of sea/lake water over land is likely to emit pollutants associated with flood already discussed in Sect. 8.1.

The nuclear disaster at the Fukushima Nuclear Power Plant in Japan on 11 March 2011, lead to meltdown of three of the plant's nuclear reactors when the plant was hit by the tsunami activated by the Tōhoku earthquake. The disaster resulted in release of substantial quantities of radioactive materials becoming the largest nuclear after Chernobyl. The disaster caused the month-long emission of radioactive substance into the atmosphere (Chino et al. 2011).

Severe pneumonia known as 'tsunami lung', was reported in region affected by the Indian Ocean tsunami (Chierakul et al. 2005; Allworth 2005; Athan et al. 2005) a disease that occur due to inhalation of salt-water contaminated with bacteria and mud.

## 8.6 Volcanic Eruption

A volcano is a hole on the crust of a planetary mass such as the Earth, which allows volcanic ash, gases and hot lava to escape from below the surface. Earth's volcanoes occur as the planet's crust is made up of 17 major, rigid tectonic plates that float on magma. Erupting volcanoes can pose threat to aircraft, as ash particles can be melted in engine and then adhere to the turbine blades disrupting the functioning of the turbine. Large eruptions can obscure entry of solar rays and cool the troposphere; but they also absorb heat released from the Earth, resulting in warming of stratosphere. Historically, volcanic winters have resulted in catastrophic famines (Texsor et al. 2004).

Volcanic activity is linked to the active zones of plate tectonics. The emission from volcano depends on the pressure, temperature and chemical composition of magma type. Most of the magma erupted is of basaltic composition and erupt commonly along mid-oceanic ridges in deep sea water. In some locations, such as in Iceland and the Azores these volcanoes erupt into the atmosphere. Such eruptions into atmosphere are called subaerial eruptions.

The composition of volcanic gases is generally controlled by the equilibrium among exsolved gas at the top as well as the silicate melt in the magma (Symonds et al. 1994). The composition varies widely between volcanoes and depends on volcano's state of activity.

There are three common types of magma: Andesitic, Basaltic and Rhyolitic. Andesitic magma erupts explosively since it tends to have high gas content. It is viscous and hence traps gas, and explosively erupts due to pressure built by gases. High viscosity in Andesitic magmas related to high silica content. Basaltic lava flows easily due to low viscosity (due to low silica content) and low gas content. Rhyolitic magma erupts catastrophically since it has high gas content. It is viscous (due to presence of high silica content) and traps gas, builds pressure resulting in explosive eruption.

As per Baxter et al. (1990) and Bernstein et al. (1986) CO<sub>2</sub>, CO, H<sub>2</sub>S, radon, hydrogen fluoride, silica as well as halogenated hydrocarbons are released during volcanic events. 50 and 90 % of volcanic emission comprises water vapor and 1–40 % comprises of carbon dioxide by volume. Sulfur gases in volcanic emission vary typically from 2 to 35 % by volume. Hydrogen chloride forms with 1–10 % of emissions from volcano. Hydrogen bromide will be in the range of 10<sup>-6</sup> parts per volume and Hydrogen fluoride forms less than 1 ppm of volcanic emission (Texsor et al. 2004).

Stratospheric aerosols generated by short lived volcanic eruption will have small to moderate volume impact compared to moderate (10–20 km<sup>3</sup>) volume basaltic flood lava eruption. Iceland is the only place on the earth where eruption of this scale is occurring releasing 5–9 megatons of SO<sub>2</sub> per km<sup>3</sup> of magma erupted (Thordarson and Self 2003). Lakiflood lava eruption in the year 1783–1784 at Iceland emitted 122 megatons of SO<sub>2</sub> and maintained a sulfuric aerosol mask over the Northern Hemisphere for more than five months. The volcano resulted in release

of 95 megatons of SO<sub>2</sub> into the lower stratosphere/upper troposphere with eruption columns extending 9–13 km (Thondarson and Self 2003).

Quiet escape of hot sulphur-rich gases from new volcanic bodies known as Solfataric activity have been studied by Isidorov et al. (1990, 1991; Isidorov 1990) at Kamchatka volcanoes located in the Siberian peninsula, identified several organofluorines in the volcanic solfataric gases.

Volcanoes also emit mercury when they erupt. Geothermal activities also emit mercury present in the underground to the atmosphere as well as discharge it to the deep oceans. As per UNEP (2013) some recent studies suggest that natural sources account for around 10 % of the about 5500–8900 tonnes of mercury presently being emitted/re-emitted from all sources to the atmosphere.

## 8.7 Epidemics

Not all epidemics pose same importance with respect to air pollution. The transportation of pollutants that is biologically active like microbes are responsible for Swine flue, avian flue and Severe acute respiratory syndrome (SARS) may not change the air quality beyond the legal ambient air quality limits but harm human and animal life to great extent. SARS caused by the SARS coronavirus caused an eventual 8096 cases and 775 deaths between November 2002 and July 2003. Within weeks, SARS spread to in 37 countries in early 2003. Influenza A (H1N1) a human-to-human transmission disease is transmitted by direct body contact or respiratory droplets.

## 8.8 Extreme Temperature

Heat and cold waves (also referred extreme heat and cold temperature) cause human discomfort and ailments. A heat wave is a prolonged time of excessively hot weather. A heat wave is measured comparative to the normal weather in the area. Old wave or cold snap or deep freeze is weather phenomena distinguished by cooling of air over a large area.

Rising temperatures can result in smog pollution and increase rate of formation of secondary pollutants like Ozone. Higher temperature can increase pollen production plants and enhance wildfire risks. On the other hand Cold wave reduces dispersion of pollutants and traps pollutants. As per AIRPARIF (2013), an intense cold wave in February and an average high temperature in March are favorable to pollution of particulate matter.

But people with asthma, allergies, and other respiratory diseases face the most serious threats, since exposure to increased pollution heightens sensitivity to allergens.

## 8.9 Insect Infestation

Insect infestation is pervasive influx as well as development of insects affecting humans/animals/crops/material. Locusts and grasshoppers are main economic pests of crops as well as grasslands all over the world's dry zones. Chemical pesticides have been used for controlling locusts and grasshoppers for decades. The main classes of chemical pesticides used to control desert locust are organochlorines, organophosphates, carbamates, synthetic pyrethroids, phenyl pyrazoles, and biological pesticides (Wiktelius et al. 2003). Biological pesticides which comprises of spore of microorganism capable of killing target insects are used to avoid impact of chemical insecticide on environment.

Aerial spraying with aircraft is widely used to control insect infestation. The pesticide is usually applied as an Ultra Low Volume (ULV) formulation, with drop size ranging between 40 and 20  $\mu\text{m}$ . Desert locust control is emergency operations and hence it is difficult to get trained personnel and pesticides with least environmental impact. Aerial spraying often cover large surfaces of unpolluted areas and often take place over different ecosystems and landscapes affecting flora and fauna.

Birds feeding on locusts may be enormously vulnerable to aerial spraying of pesticide (Mineau 2002). The birds will get affected due to shortage of food due to death of insects and toxic food due to chemicals that may present on food the birds ultimately feed on. These compounds are harmful for humans (Reichhardt 1998), aquatic organisms, honeybees as well as other insects (Mullié and Keith 1993; Krall 1995). A reduction in insect availability may lead to shortage of food to resident predatory species that consume locusts during the outbreaks (Culmsee 2002).

## 8.10 Mass Movement

Mass movement disasters include dry land movement and wet land movement. Mass movement include landslide and avalanches. A landslide or landslip is the outward and downward movement of soil/rock material on slopes.

Mass movement depends on slope angle, slope orientation, weather, snowfall, terrain, snow pack conditions and vegetation. Mass movement can be triggered by both natural as well as anthropogenic causes.

Mass movement is triggered due to ground movement like deep failure of slopes, rock falls, and flow of shallow debris in sloppy terrain. Landslides may occur due to natural or artificial causes.

One or more of following condition can lead to land slide: (1) jointed rocks, (2) steep slope, (3) fine-grained permeable rock or sediment, (4) large quantity of water, (5) clay or shale layers subject to lubrication and (6) volcanic activity.

Even though landslides usually occur in mountainous areas, they can also occur in roadway and building excavations, lateral spreading landslides, river buff failures, collapse of mine-waste piles, collapse in open-pit mines and quarries.

Airborne arthrospores dislodged from soil during landslides at Northridge, USA, in the year 1994 (Schneider et al. 1997).

## 8.11 Air Pollution Due to Anthropogenic Disasters

Anthropogenic disasters are hazards caused due to human intent; error; negligence; or involving a failure of anthropogenic system. This includes social hazards (such as wars and conflicts) and technological hazards (like fire accidents, structural collapse).

The notable industrial disaster at Bhopal in occurred in 1984 at the Union Carbide India Limited, India exposed more than 500,000 people to methyl isocyanate (MIC). The major wars in the history of mankind have severely caused air pollution and so as act of terrorism and mutiny. The terror attack on twin towers in USA on September 11, 2001 resulted in thousands of tons of toxic debris comprising more than 2500 contaminants spread across Lower Manhattan (Anita 2006). About 18,000 people developed illnesses due to toxic dust (Shukman 2011).

### 8.11.1 Wars and Conflicts

Wars and conflicts are part of civilisation since beginning of the civilisation. Invention of fire and weapons are used for self protection followed by defence and attack. The Wars and conflict occur for innumerable reasons but end up with loss of lives and property. War and conflict restricted to land in old days was extended to water and air. People built forts to protect themselves. This was followed by naval and air force.

It is essential to know the ongoing conflicts and possible air pollution as the pollutants gradually move to neighbouring countries and beyond. The failure of nuclear plants or testing of nuclear weapons are usually kept secret. But the ill effect will spread beyond boundaries and affect own cities as well as that of neighbouring countries.

Emission from war and conflicts include emission from use/manufacture of ammunition, fuel use in transportation, manufacturing of ammunition, destruction of infrastructure. Urban settlements, fuel storage, power station, military camps, roads, bridges, airports, ports are main targets of wars to weaken the opponents.

Mutiny and terrorism will aim haphazard use of explosives due to absence of planning, training and information.

The use of chemical, biological and nuclear weapons will have different impacts on environment. The emissions from these weapons vary depending on constituents of the weapon. Biological warfare also known as germ warfare use of biological toxins or agents like microbes to kill or incapacitate people, animals or plants as an act of war. A chemical weapon uses chemicals formulated to impose death or injure

human beings. A nuclear weapon is made up of radioactive material used for mass destruction.

Conflict in Kuwait in January 1991 ended up in the discharge of about 6–8 million barrels of oil, followed by the fire of more than 600 oil wells and destruction of sewage treatment plants. The total estimated crude oil burned during Gulf war was 52.5 million metric tons generating smoke of 29.2 t/d/well resulting in 1.2 million metric tons of SO<sub>2</sub> and 0.3 million metric tons of NO<sub>x</sub> (Khordagui and Al-Ajmi 1993). Oiling and petroleum hydrocarbon pollution was restricted largely to the northwestern region of the Gulf, while air pollution from the burning oil wells were more widespread (Price et al. 1994).

### 8.11.2 Fire Accident

Fire accident can occur at homes, commercial establishments, industries or forests. It can occur due to many reasons. The accidents can occur due to natural disasters or due to negligence of people. The accident can be associated with explosion. The duration of fuel and pollutants released depends on the availability of fuel and substance present at the place of accident.

The Chernobyl disaster that occurred on 26th April 1986 at the Chernobyl Nuclear Power Plant, Ukraine due to fire and explosion, resulted in release of radioactive material into the atmosphere that spread over western USSR and Europe. The quantity of radioactive material released was 400 times more than the quantity of radioactive material released during the atomic bombing of Hiroshima. *Chernobyl nuclear accident led to contamination higher than in the previous two decades in the human environment of Republic of Croatia* (Lokobauer et al. 1998). Releases and succeeding transfers of radionuclides through foods, air, and water exposed people to radiation who continued to live in the regions and those evacuated from nearby settlement (Bennett et al. 2006). Even though in 1986 the <sup>137</sup>Cs levels in the environment were higher than those of <sup>90</sup>Sr, <sup>90</sup>Sr transfer to the food chain from soil is considerably more than for <sup>137</sup>Cs, in the following years (Lokobauer et al. 1998).

Fire accident at Indian Oil Corporation Limited (IOCL) located at Sitapur, India on 29th October 2009 resulted in a very high fire flames resulting in emission of black plumes resulting in death and injury of people. Air quality in Jaipur as well as nearby area of Sitapur Increased values of SPM, RSPM NO<sub>x</sub> and SO<sub>2</sub> (Sharma and Mishra 2013).

Coal fires associated with inactive/abandoned mines are reported from mining areas across the world (Glenn et al. 2011; Prakash and Gupta 1999; Stracher and Taylor 2004) and surface expressions of underground coal fires include areas of dead vegetation, baked rocks, land subsidence, gas vents and fissures (Glenn et al. 2011; Stracher 2007). Coal fires in abandoned mines, unmined outcrops as well as waste banks, constitute safety and environmental hazards. Such fires cause subsidence and air pollution. Coal fire started in 1765, was active until at least 1846 in

the Pittsburgh seam in Pennsylvania (Eavenson 1938, 1942). Lewis and Clark, in their exploration in 1805, reported that burning coal ridges were visible in the bluffs along the Missouri River (Lavender 1988). Outcrop fire that was burning since around 400–600 years in southeastern Montana, has affected a 500 acres (Shellenberger and Donner 1979). Hundreds of coal-bed fires are on fire in the Powder River Basin (PRB) in the USA and studies have shown that such fires have been occurring since thousands of years in the area (Heffren et al. 2007).

Coal fires can be extinguished by (1) physically separating coal from the burning mass; or (2) oxygen removal by introduction of an inert gas; or (3) isolation of the fire zone from fresh air; or (4) heat removal by moving a heat-absorbing agent such as inert gas or H<sub>2</sub>O.

Usually the chance of reignition is small if temperature is below 100 °C (Kim and Chaiken 1993). Fuel-removal by excavation is the most successful fire-control techniques (Chaiken 1984) wherein burning is removed and cooled to extinguish the fire by spraying with water or by spreading it out on the ground to cool in air.

The reappearance of excavated fires is normally due the failure to completely excavate or lower the temperature past the reignition point (Kim and Chaiken 1993).

Inundation methods for extinguishing coal fires involve the use of water to reduce the temperature of the burning matter. To increase the water level, dams are constructed. The Water level must cover burning coal and overlying heated rock. This method is used for small fires that are fairly accessible and near the water table. Another method provides use of water by continuous pumping or by gravity flow.

Apart from water, underground fire zone is extinguished by fine, noncombustible solids like sand, red dog, crushed limestone, silt, and fly ash. Air or water is normally used to carry the material through a borehole.

Grout slurries can also be pumped underground burning area to form fire control barriers. Cement slurry solidifies to form a seal. Grout slurries can be added with foaming agents as well as incombustible materials, such as sand/soil.

Surface sealing is a comparatively cheaper method of controlling fires in abandoned mine. It is planned to slow down ventilation of the fire zone. If the seal is maintained while all the heat in mine dissipates, the fire may ultimately be extinguished. Normally most surface seals fail within one to three years after construction due to settling, drying, shrinkage, or increased fire activity.

In western USA 85 % of fire abatement projects were surface seals due to the topography of the area, the relatively low cost, and the lack of water needed to employ other methods (Shellenberger and Donner 1979). If the seals are maintained for about 10–20 years, the fire may be put off.

Surface seals sufficiently inhibit unsightly venting, control subsidence, and limit the emission of harmful fumes. Surface seals with regular as well as periodic maintenance provide a sufficient control method (Kim and Chaiken 1993).

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