Brick kiln emissions and its environmental impact: A Review

Bhat Mohd Skinder*, Afeefa Qayoom Sheikh, Ashok K. Pandit and Bashir Ahmad Ganai

Centre of Research for Development/Department of Environmental Science, University of Kashmir Srinagar (J&K) India.

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Brick manufacturing is the fastest-growing industrial sector in many countries (like china, India, Bangladesh and Pakistan) and among the top three sectors, along with vehicle exhaust and resuspended road dust, contributing to the air pollution and health problems in Dhaka (Bangladesh). The total emissions from the brick manufacturing in the Greater Dhaka region, to produce 3.5 billion bricks per year has been estimated about 23,300 tons of particulate matter having aerodynamic diameter < 2.5 μm (PM_{2.5}), 15,500 tons of sulfur dioxide (SO_{2}), 302,000 tons of carbon monoxide (CO), 6,000 tons of black carbon (BC) and 1.8 million tons of carbon dioxide (CO_{2}). Emission of individual air pollutant from brick kilns varied significantly during a firing batch (seven days) and between kilns. Average emission factors per 1,000 bricks were 6.35 to 12.3 kg of CO, 0.52 to 5.9 kg of SO_{2} and 0.64 to 1.4 kg of particulate matter (PM). Presently sulphur dioxide (SO_{2}), oxides of nitrogen (NO_{x}) and suspended particulate matter (SPM) are the main issue pertaining to air pollution problems in developing countries, where it contributes both to urban pollution and to regional acid depositions. Among man-made sources, coal combustion in stationary sources accounts for 74%, industries 22% and transportation 2% of the total oxides of sulphur (SO_{x}) and it is considered that SO_{2} is the chief emission in brick production. On an international basis, 75 to 85% of SO_{2} emissions are the result of fossil fuel burning. It is predictable that just about 93% of the global SO_{2} emissions are emitted in the northern hemisphere. It has been revealed that biomass is responsible for the emission of both trace and non trace gases such as carbon dioxide (CO_{2}), methane (CH_{4}) and oxides of nitrogen (NO_{x}) from traditional brick industries and lots of toxic fumes containing suspended particulate matters rich in carbon particles and high concentration of CO and SO_{2} get produced. Studies have shown the average value of particulate matter of size less than ten microns and total suspend particles for the pre-operation time of brick kilns was 0.029 and 0.033 mg/m³, respectively whereas, it reached 0.050 and 0.056 mg/m³, respectively during the brick kiln operation time. Similarly, recent studies on brick kilns in District Budgam of Kashmir valley (India) have shown some major negative impacts on the environment in respect of air quality, human health and vegetation in particular.

Key words: Pollution, emissions, environment, industrialization, transportation, brick kiln, human health, vegetation.

INTRODUCTION

The literature concerning air pollution with special reference to brick kilns across the globe dates back to the beginning of the nineteenth century. Since the available information in the form of published literature is so enormous, it is not possible to cite all the available literature in the body of present review paper. Hence only important and relevant literature has been cited in the present review paper under the following subheadings:

*Corresponding author. E-mails: mskbhat@gmail.com.
(i) Sources of air pollutants,
(ii) Environmental health effects of air pollutants,
(iii) Environmental stress to crop plants due to air pollutants,

**SOURCES OF AIR POLLUTANTS**

Sulphur dioxide (SO₂) is one of the main products released from the combustion of sulphur containing compounds in most energy fuels having significant environmental concern. The term SO₂ is a generic term describing emissions of SO₂ and SO₃. At low concentrations it is a colourless and odourless gas. On a worldwide scale, anthropogenic emissions stand for a major contribution to the SO₂ emitted to the atmosphere (IARC, 1992) and these emissions are just about equal to natural emissions (WHO, 1979). On an international basis, 75 to 85% of SO₂ emissions are the result of fossil fuel burning while the rest of the emissions are the outcome of refining and smelting (Friend, 1973). It is predictable that just about 93% of the global SO₂ emissions are emitted in the northern hemisphere and the left over 7% are emitted in the southern hemisphere (WHO, 1979). The highest sources of SO₂ emissions are from the burning of fossil fuels and smelting sulphide ores (Weil and Sandler, 1997). One more noteworthy cause is petroleum refining (HSDB, 2002). Other less important sources comprise chemical and associated products manufacturing, metal processing, other industrial processes and vehicle emissions (ATSDR, 1998). Brick manufacturing is the fastest-growing industrial sector in Bangladesh and among the top three sectors, along with vehicle exhaust and resuspended road dust, contributing to the air pollution and health problems in Dhaka. The total emissions from the brick manufacturing in the Greater Dhaka region, has been estimated at by Guttkunda et al., 2013, 23,300 tons of PM₂.₅, 15,500 tons of SO₂, 302,000 tons of CO, 6,000 tons of BC, and 1.8 million tons of CO₂ emissions from the clusters of brick kilns, to produce 3.5 billion bricks per year. Emission of individual air pollutant from brick kilns varied significantly during a firing batch (seven days) and between kilns. Average emission factors per 1,000 bricks were 6.35 to 12.3 kg of CO, 0.52 to 5.9 kg of SO₂ and 0.64 to 1.4 kg of PM (Le and Oanh, 2010).

A significant feature of SO₂ is that once it is emitted into the atmosphere it can be converted through complex oxidation reactions into fine particulate sulfate and removed from the atmosphere by wet or dry deposition (De, 2012). The emission of SO₃ in brick making has received considerable attention (Wilson and Johnson 1975; Amison, 1992; Junge, 1992; Hofer, 1994). Presently, SO₂ is the main issue pertaining to air pollution problems in developing countries, where it contributes both to urban pollution and to regional acid depositions (Cofala et al., 2004). Among man-made sources, coal in stationary sources accounts for 74%, industries 22% and transportation 2% of the total SO₂ (De, 2012). SO₂ is the chief emission in brick production (Junge, 1992). The oxidation of pyrite (FeS₂) takes place in a stepwise approach with an initial release of SO₂ around 450°C from brick making raw material with an additional increase in temperature and the subsequent emission of sulfates occurs as SO₃ (Banerjee et al., 1980; Junge, 1992; Sanders, 1995). But Parsons et al. (1997) opined SO₂ can also be released during oxidation of sulfur containing carbonaceous matter at low temperatures. The successive emission of SO₂ begins above 750°C and can continue through the firing cycle (Junge, 1992). The residence time of SO₂ in the atmosphere ranges from about 2 to 8 days (Katz, 1977), while as Hidy (1994) gives residence times of SO₂ in the lower atmospheres of one to three days and HSDB (2002) gives residence times ranging from one to five days.

On an average, a brick kiln producing 800,000 bricks, uses large amounts of rubber to start the burning process and burns a total of eight tons of low quality coal or 20 drums of used vehicle oil, thus releasing many toxic pollutants such as NOₓ, CO and dioxins (EPA, 2007). In the same year (EPA, 2007) studied the rising number of brick kilns in Peshawar city of Pakistan, which has almost doubled the level of air pollution (SO₂, NOₓ and volatile organic compounds (VOCs)). A rapid increase in the brick production and the clustering of brick kilns has given rise to environmental concerns throughout the world. Combustion of coal besides other biomass fuels in brick kilns results in the emissions of PM, BC, SO₂, NOₓ and CO (Maithel et al., 2002). Estimations designate that annual emissions from brick kiln industry were 80 tons of particulate matter, 30 tons of carbon, 7 tons of NOₓ, and 5 tons of SO₂ (Asgher and Singh, 2003). The emission of these pollutants has an adverse effect on the health of brick kiln workers and vegetation around the kilns. In recent years, higher cost and shortage of good quality bituminous coal has resulted in increased use of high-ash, high-sulphur coal, as well as use of industrial wastes and loose biomass fuels in brick kilns. All of these have resulted in new air emission challenges. Good quality agricultural topsoil is mainly used for brick production which leads to the land degradation (Greentech Knowledge Solutions, New Delhi, 2012). Due to the blooming of brick kilns in the Kashmir valley the concentration of SO₂, NOₓ and PM around brick kilns areas were above the permissible levels during the operational phase of the brick kilns (Fatima, 2011; Hussan et al., 2013). Further, the brick making industries in the Sudan act as a serious agent of deforestation and can be considered important sources of greenhouse gas emission and also toxic fumes containing suspended particulate matters rich in carbon particles and high concentration of CO, SO₂ and NOₓ, as they use huge amount of fuel wood coming from unsustainably managed forest and dung cake for brick burning with the brick kilns of low combustion efficiency. Therefore, brick making industries can be considered as one of the important sources of greenhouse gases (World Bank, 1998; FAO, 1999; Alam, 2006). At the same time long-
term brick kiln industrial activity affected the soil characteristics, structure of plant biomass and species diversity. This structural alteration is indicative of adjustment implications for plant communities in anthropogenic ecosystems (Gupta and Narayan, 2010).

$\text{SO}_2$ is a prime pollutant which is released directly to the atmosphere from domestic and industrial processes, particularly those using petroleum and coal combustion (Wellburn, 1998; Emberson et al., 2001). $\text{SO}_2$ can be oxidized in the atmosphere to form sulphate aerosols that contribute to acid deposition (Holleman, 2001). Thus elevated level of sulphate ions ($\text{SO}_4^{2-}$) concentrations in rain water are due to strong $\text{SO}_2$ emissions from coal fired thermal power plants (Demirak, 2007). While as it has been predicted that $\text{SO}_2$ concentrations from point source emissions are lower than those from area source emissions during the non heating season (Cheng et al., 2006), it has also been discussed that temperature has a significant effect on $\text{SO}_2$ concentrations, and humidity and wind speed have insignificant effect (Salam et al., 2008). Most of the brick kiln plants use a low quality coal or other solid waste material and thus results in the production of $\text{SO}_x$, NO, CO and PM along with many other organic pollutants due to burning of substandard waste material. Therefore, with a rapid but unrestrained development, emissions from these sources is constantly increasing and unfavorably distressing the environment (Elampari et al., 2010; Hassan et al., 2012). The concentration of $\text{SO}_2$ from motor vehicles is very low as compared to stationary sources using solid and liquid fuels (Williams, 2000). Furthermore concentration of $\text{SO}_2$ from motor vehicles has been found in higher concentration in winter months followed by summer and monsoon months (Goyal et al., 2006; Emberson et al., 2009), also in industrial areas (Reddy and Ruj, 2003). But apart from the industrial and vehicular exhausts ($\text{SO}_x$, NO and PM), fumes from brick kilns also contribute to the increase in the level of local $\text{O}_3$ at surface levels (Pudasainee et al., 2006). It has been revealed that biomass is responsible for the emission of both trace and non trace gases such as CO, CH$_4$, NO$_2$, NO$_x$ and NO from traditional brick Industries and lots of toxic fumes containing SPM rich in carbon particles and high concentration of CO and $\text{SO}_x$ get produced (Alam, 2006). It has also been reported that brick kilns, producing in excess of 350 million bricks are the major and single source of $\text{SO}_2$ and PM in the environment of Kathmandu valley; contributing over 60% of the emissions (Maity, 2011). The major removal mechanisms of $\text{SO}_2$ from the atmosphere are dry deposition and chemical oxidation (Cheng et al., 2006). It is indicated that almost 10% $\text{SO}_2$ removal efficiency could be achieved using water as scrubbing liquid without any additive under certain hydrodynamic conditions (Bandyopadhyay, 2009).

$\text{NO}_x$ represents composite atmospheric gases, NO and NO$_2$, which are primarily involved in air pollution. NO is a colourless, odourless gas, but NO$_2$ has reddish-brown colour and pungent suffocating odour (De, 2012). The formation of NO is favored at high temperature, usually attained during much combustion process involving air (1210 to 1763°C). The second reaction is also favored at temperatures about 1100°C, but the amount of NO$_2$ formed is usually less than 0.5% of the total NO$_x$ at 1100°C. It is also formed by photolytic reaction; further man-made sources annually release $5 \times 10^7$ tons of NO$_x$ (De, 2012). The NO$_2$ levels depend mainly on chemical reactions and not on direct emissions (Mayer, 1999). NO$_x$ emissions in brick making mainly originate from the oxidation of nitrogen in the atmosphere by burning (Pauls, 1989; Amison, 1992). Pauls (1989) mentioned that there can be emissions of NO$_x$ during the oxidation of nitrogen containing organic compounds and thus NO$_x$ giving off from the brick kilns has a major role in the formation of ozone and the presence of NO$_x$ is very essential since NO$_x$ can be the only potential source of ozone in the brick kiln areas. Several studies have also shown that the emission of NO$_x$ in brick making has not been found to be significant (Pauls, 1989; Kolkmeier, 1991; Amison, 1992). However, if there is a fractional amount of NO$_x$ present in the troposphere, it receives solar radiation and the O$_3$ is produced (Tang, 2009).

It is considered that coal-fired power plants and vehicles are the nation's largest source of NO$_x$ and is produced in high temperature combustion processes (Memon, 2000; Emberson et al., 2001). NO$_x$ is emitted from a variety of natural and anthropogenic sources (Al-Khalaf, 2006). But its concentrations in the atmospheric surface stratum of rural areas increases by traditional brick kiln industries (Elampari et al., 2010). Due to the improper construction of kilns large amount of fumes is released which may contain gases like CO, CO$_2$ and NO$_x$ and hence brick kilns are acting as a point source of pre-cursor gases of ozone. The local meteorological factors (clear sky conditions and intense solar flux density) and the activities involved in the brick kilns played a great impact on the observed pattern of NO$_x$. So the mean concentration of NO$_2$ at night was greater than that of daytime using NO$_2$ as a fuel (Elampari et al., 2010). NO is by far the most important nitrogen containing species emitted into the atmosphere on a mass basis from human activities involving motor traffic and combustion in power stations, in the home or in industrial processes (Williams 2000; Kumar and Joseph, 2006; Ali and Athar, 2006). NO$_x$ levels were found to be stabilized in residential and industrial zones but increased alarmingly at commercial zones representing higher traffic activities (Goyal et al., 2006). Moreover, NO$_x$ concentration has been found maximum at the time of the evening due to high traffic density of public and commercial vehicles (Jain and Saxena, 2001). NO$_2$ levels were also higher in the post monsoon season followed by winter and pre-monsoon seasons (Goyal et al., 2006).

SPM are finely divided solids or liquids that are dispersed
throughout the air and are produced from combustion processes, domestic and industrial activities, as well from natural sources such as volcanoes, dust and forest fires (Emerson et al., 2001). As EPA in 2012, defined, tiny airborne particles or aerosols that are less than 100 micrometers are collectively. SPM in the atmosphere is normally defined as two size classes, PM$_{10}$ (particles with aerodynamic diameter <10 μm) and PM$_{2.5}$ (particles with aerodynamic diameter < 2.5 μm). From all the sources it is estimated that about 800-2000 million tons are being injected into the atmosphere while as statistics concerning man made particulate pollution indicates that fuel combustion from stationary sources, industrial processes and miscellaneous sources contribute about uniformly (1/3rd each) the total particulate emission (200 to 450 million tons/year), in addition, in developed countries like USA, the annual particulate discharge is about 20 × 10$^6$ as well as 5 × 10$^6$ tons of fine particles (De, 2012). SPM can be a local problem close to large sources, but under certain circumstances it can be a local scale pollution issue. The particle size and composition depends upon the source; for instance, mineral dusts start off from mineral oxides and the matter from the earth’s crust (UNEP, 2007). SPM is usually divided into two types: primary particles which start off directly from sources and secondary particles produced by the amalgamation with other compounds for instance the photo-oxidation of NO$_x$ to form nitrates (Sharma, 2012). Particulate matter emissions in brick production consist of mineral matter specifically dust entrained in process gases and condensable particulate matter. Condensable particulate matter hypothetically can contain metals that have been volatilized during firing (Brosnan and John, 1998; Brosnan, 2000).

For Dhaka, one of the most polluted cities in Asia, studies show that five months per year, brick kilns are the city’s main source of fine particulate pollution, accounting for 38% of total fine particulate mass (Croitoru and Sarraf, 2012). According to a study conducted by the World Bank (1997) in Kathmandu valley, the main contributing sources for total SPM are cement factory (36%), brick kilns (31%), domestic fuel combustion (14%), road resuspension (9%) and vehicle exhaust (3.5%). However, for the PM$_{10}$ concentration, which is of a more apprehension as these particles can enter the respiratory system; contribution of brick kilns was found to be more than other sources (28%) (World Bank, 1997). Studies have shown the average value of particulate matter of size less than 10 microns and total suspend particles for the pre-operation time of brick kilns was 0.029 and 0.033 mg/m$^3$, respectively whereas, it reached 0.050 and 0.056 mg/m$^3$, respectively during the brick kiln operation time, thus concluded that ambient air pollution due to brick kilns in the rural areas is a real problem (Joshi and Dudani, 2008). The concentration of particulate matter in brick kiln areas were found beyond the permissible limits while as, along the distance the concentration goes on decline (Hassan et al., 2012). Moreover, Ismail et al. (2012) has publicized high load of dust with 23.8 to 46.0 g m$^{-2}$ month$^{-1}$ at 50 m distance ahead of brick kilns and heavy metals in the dust samples showed that cadmium (Cd) and chromium (Cr) are added into the environment with a rate of 0.08 and 0.52 mg m$^{-2}$ month$^{-1}$ respectively, resulting in higher pollution prospective near the brick kiln chimneys.

In addition, local traffic is the dominating source of ultra fine particles, while regional and long range transport can have a dominating effect on the fine particulate mass (Kukkonen et al., 2001). Subsequently it was observed that coal combustion is the main source of airborne particles (Xie et al., 2009). The PM$_{10}$ and PM$_{2.5}$ concentrations showed a high increase when compared with total suspended particulate (TSP) concentrations in anthropogenically polluted air (Chung et al., 2003a,b; Chung and Kim, 2008). In addition, particulate mass originates mostly from fine particles and about 88% of PM$_{10}$ mass were from PM$_{2.5}$ (Salam et al., 2008). Among the inorganic compounds, most essential ones are the trace metals, which are emitted by diverse natural and anthropogenic sources such as crustal materials, road dust, construction activities, motor vehicles, coal and oil combustion, incineration and other industrial activities (Watson et al., 2002; Quiterio et al., 2004; Arditisoglou and Samara, 2005; Shah et al., 2006; Shah and Shaheen 2010).

**ENVIRONMENTAL HEALTH EFFECTS OF AIR POLLUTANTS**

Emissions from brick kilns is comprised of fine dust particles, hydrocarbons, SO$_x$, NO$_x$, fluoride compounds, CO and small amount of carcinogenic dioxins (Environment Improvement Programme, 1995). SO$_2$ is a water soluble, irritant gas, which predominantly affects the upper airways. Infiltration of the air pollutants is larger through mouth inhalation than with nose inhalation and while work working. Sulphuric acid has been classified as a group-1 carcinogen by the International Agency for Research on Cancer (IARC, 1992; Scott, 1998). Acute exposure to SO$_2$ produces instant bronchial constriction, contraction of the airways, amplified pulmonary resistance, increased airway reactivity and changes in metabolism while as chronic exposure consequences in inflammation of the mucosal tissues and increased secretions (WHO, 1979; Amdur, 1978;). Mutilation of lung function and condensed life span in humans has been attributed to long standing exposures to urban air pollution (Costa and Amdur, 1996; Heyder and Takenaka, 1996). Disclosure to sulfur dioxide in the ambient air has been linked with reduced lung function, increased prevalence of respiratory symptoms and diseases, irritation of the eyes, nose and throat and early mortality. Children, the elderly and those previously suffering from respiratory ailments, such as asthmatics, are mostly at risk. Health impacts appear to be linked particularly to concise exposures to ambient concentrations above 1,000 μg/m$^3$ (acute
exposures calculated over 10 min) (World Bank Group, 1998). The undesirable effects associated with exposure to \( \text{SO}_2 \) seem inferior with humid conditions (WHO, 1979). Sulphuric acid also binds to the surface of particulates in the air, the minor the particulate the greater the surface area and larger the capability to penetrate the lungs more profoundly (Costa and Amdur, 1996). \( \text{SO}_2 \) has been reported to stay in the lungs for up to one week or more (Balchum et al., 1960a; cf. WHO, 1979). Once inhaled, \( \text{SO}_2 \) dissolves in the aqueous surfaces of the respiratory system as sulphite and bisulphite, which is immersed into the cells in the respiratory tract and dispersed through the body (Yokoyama et al., 1971; Costa and Amdur, 1996; Wellburn, 1998). Brick kiln industry play important role in the development of respiratory related diseases as has been investigated by Zuskin et al. (1998), there was a significantly higher prevalence of chronic cough (31.8%), chronic phlegm (26.2%), and chest tightness (24.0%) in exposed workers, compared with control workers (20.1, 18.1 and 0%) \((P < 0.05)\) and this increased symptom frequency was also documented among non-smokers studied by age and by length of employment, suggesting a work-related effect in brick kilns.

In Bangladesh, it is reported that brick kilns produced PM\(_{2.5}\). This fine PM is considering more harmful to human health, because it has the capacity to travel deeper into the respiratory system and cause premature mortality and respiratory ailments (Guttikunda, 2009). From these PM, mainly both elder people and children are suffered more than any ages because on these stages of life our disease prevention mechanisms become weaker (OAQPS Fact Sheet, 1997). American Lung Association (ALA) found in their research that, for the PM in air premature deaths rate increased three times higher than the previous studies. Child mortality rate were also increase for air pollution (ALA, 2006). Recent studies have revealed that a traditional oven emits about 863 pounds of pollutants for each production and burns covering approximately 10,000 bricks (TCEQ, 2002). A health survey clearly showed that people who are living near brick kilns are more likely to suffer from illnesses caused by kilns pollution, comparing those who are living in areas without the kilns. School children nearby brick kilns were had the worse condition of health and they were suffered for higher prevalence of upper respiratory tract infections like pharyngitis and tonsillitis (Joshi and Dudani, 2008).

Studies show that work related dust exposure is a risk factor for acute and chronic respiratory irritation, inflammation and cardiovascular diseases (Koskela et al., 2005). It is also reported that elevated amounts of CO, which is formed in brick kilns due to poor kiln design that consequences in incomplete combustion of coal, could also cause undesirable health effects on central nervous system and eventually resulted in symptoms of headache, nausea, exertion and shortness of breath (Seinfeld and Pandis, 1998; Zuskin et al., 1998; Maynard and Waller, 1999). Plentiful epidemiological studies have exposed a correlation between prominent levels of airborne particulates and amplified rate of morbidity and mortality (Pope, 2000; Shah, 2009). Likewise, epidemiological studies done with respect to the worsening ambient air quality at different places around the world have revealed the evidence of an increase in the rate of bronchitis, asthma, decreased lung function, pharyngitis, cough, eye irritation, fibrosis, emphysema, allergic rhinitis and low birth weight (Pope and Dockery, 1992; Schwartz, 1996; Bobak, 2000; Donaldson, 2001; Pope et al., 2002; Callen et al., 2009). The airborne particulates and associated trace metals have been related to both acute and chronic adverse health effects which mostly consist of respiratory diseases, lung cancer, heart diseases and damage to other organs (Priedits and Adamson, 2002; Magas et al., 2007; Wild et al., 2009). Lots of studies conducted in the coal mining areas showed higher ambient particulate concentrations (Ghose and Majee, 2002; Sinha and Sreekesh, 2002; Suman et al., 2007) and also reported that CO, NO\(_x\), and SO\(_x\) causes dizziness, headache, fatigue, and impaired judgment, lung irritation, bronchitis, pneumonia, asthma, respiratory infections, pulmonary edema and emphysema. They also influence the functioning of brain and heart. Further, analyzed particulate matter combined with sulphur oxides is more detrimental than either of them separately, while as ground level ozone in photochemical smog causes chest constriction and irritation of the mucous membrane. Some of the problems linked with pollution of the atmospheric air as shortage of oxygen for animal respiration, poor visibility, irritation of the eyes, increase cases of upper respiratory infections and unpleasant odours (Mishra, 2003). Further, increased prevalence of respiratory complaints like cough, sputum, wheezing and dyspnea among exposed workers of cement, tile and ceramic factories compared to control wasstatisticallysignificant(Myersetal.,1989;Mustajbegovic et al., 2003; Mwaiselage et al., 2005; Kakoei and Marionyad, 2005; Ugheoke et al., 2006; Halvani et al., 2008; Dehghan et al., 2009; Aziz et al., 2010). It has been observed that 78% of the workers are not using Personal Protective Equipment (PPE) which leads to the respiratory symptoms among the workers (Singh et al., 2000, 2009, 2011). While as, the most common respiratory symptoms reported by farm workers (wheeze, dyspnea and cough) which were relatively unfocused and can be associated with several occupational respiratory disorders (Linaker and Smedley, 2002). Studies revealed that the vehicle emissions such as BC, carbonaceous gases and ultra fine particulate matter (PM\(_{1.0}\)) are chief environmental grounds of cardiovascular mortality and morbidity in the United States (Graham and Schlesinger, 2009).

**ENVIRONMENTAL STRESS TO CROP PLANTS DUE TO AIR POLLUTANTS**

Plants are main indispensable parts of ecosystems and their sensitivity to air pollution is more considerable than
standards of air pollution (Thomas, 1991). Air pollution has become a serious environmental stress to crop plants due to increasing industrialization and urbanization during the last few decades (Rajput and Agrawal, 2004). Among plants, conifers become visible to be more sensitive to the effect of sulfur dioxide (Ozolinicius et al., 2005). Plant species vary in their sensitivity level to pollutants (Jacobson and Hill, 1970). Diverse changes induced by different air pollutants in plants with respect to morphological, anatomical and physiological characteristics have been investigated (Rao, 1981; Pawar and Dubey, 1983). The most frequent injury indicator produced by SO2 on broad leaved species is tan to dark brown interveinal bifacial necrosis (Panwar, 1982). The most disperse and injurious pollutants in industrial areas are SO2, NOx, CO, tropospheric ozone (O3) and heavy metals, as well as suspended particulate matter (Assadi et al., 2011). A range of air pollutants is recognized as phytotoxic agents and phytotoxicity of SO2 has been documented for about a century (Godzik and Sienkiewicz, 1990), sound effects of ozone for more than 30 years (Miller, 1983), acidic precipitation for more or less 20 years (Likens et al., 1979) and effects of prominent levels of nitrogen compounds, NOx and ammonia in the last decade (Nihlgard, 1985). Significance of other pollutants such as peroxy acetyl nitrate (PAN) (Su et al., 2006), fluorides (Maclean, 1981) or heavy metals has also been documented (Unsworth and Harrison, 1985). Plants in the immediate vicinity of emissions sources are more vulnerable. It has been revealed that the most sensitive species of plants start on to show visible signs of damage at concentrations of about 1,850 μg/m3 for 1 h, 500 μg/m3 for 8 h, and 40 μg/m3 for the maturing season (cf. NAPAP, 1990). It is possible that over the long term, sulfur input to soils will affect crop yields (OECD, 1981; NAPAP, 1990). Sulfur dioxide shows negative effects in terms of foliar injury, physiological and biochemical alterations on vegetation (Kaunilainen et al., 1995) and chlorophyll content (both chlorophyll 'a' and chlorophyll 'b') decreasing with the increase in SO2 concentration (Prakesh et al., 2002).

Also phaeophytin, carotenoids, carbohydrates, proteins and phenolic content decreased on exposure to sulfur dioxide (Ganai et al., 2007a,b; Balkhi et al., 2009, Jan et al., 2010; Irshad et al., 2011) and short term treatment of SO2 damaged pigment system-II (PSII), decreased the fluidity of thylakoid membrane and affected the process of electron transport (Liu et al., 2007). Impact of brick kiln emissions on Malva sylvestris in respect to biochemical parameters (photosynthetic pigments, starch, carbohydrates) showed a negative trend as compared to control (Ganai et al., 2010) and similarly Pawar et al. (2010) showed that air pollutant reduces the photosynthetic activity of Kachnar leaves and there was a significant increase in the amount of phenol in the Kachnar leaves associated with the degree of injury of the leaves. The particulates and gaseous pollutants, alone and in combination can cause grave setbacks to the overall physiology of plants (Ashenden and Williams, 1980; Mejstrik, 1980; Anda, 1986). Of all plant parts, the leaf is the most sensitive part to the air pollutants (Singh, 1990).

Acid deposition can smash up forests and crops by acidification of soil and it also causes lakes and stream acidification (USEPA, 2007). The gaseous SO2 can cause direct injury to crops and forests by entering the leaves through the stomata and deposition to external surfaces, leading to negative effects on the growth. Yield of the plant and acute visible injury to plants is caused by absorption of high concentrations of SO2 over a relatively short time; in addition, foliar symptoms are generally interveinal chlorosis (whitened areas) which run through to the edges of the leaves thus, the fully expanded leaves are more sensitive to acute SO2 injury, as compared to the very youngest and oldest leaves (Heather, 2003). The crop species that are usually considered susceptible to SO2 are alfalfa, barley, wheat, clover, oats, pumpkin, radish, spinach, lettuce, squash, beans and tobacco and resistant crop species include asparagus, cabbage, corn, onion and potato (Thomas and Hendricks, 1956; Kondo and Sugahara, 1978). The adverse effects of air pollution on vegetation have been well reviewed in terms of foliar injury, physiological as well as yield characteristics (Singh and Rao, 1981; Murray and Wilson, 1988; Wilson and Murray, 1990; Agrawal et al., 2003; Agrawal and Deepak 2003; Rajput and Agrawal, 2005; Agrawal, 2005; Maggs et al., 1995; Shukla et al., 1990; Agrawal et al., 2003). Chauhan and Joshi (2010) opined that gaseous (NOx and SOx) and particulate pollutants such as SPM and respirable suspended particulate matter (RSPM) have detrimental effects on wheat and mustard crops and concluded that the total chlorophyll, ascorbic acid and carotenoids contents decreased significantly in response to air pollutants. Pollutants have been shown to reduce the synthesis of chlorophyll enhancing its degradation. Consequently, it is very clear that urban and industrial air pollution has become a serious threat to agricultural production grown adjacent to urban and industrial areas (Sandelius et al., 1995; Agrawal et al., 2003). Chlorophyll content is vital for the photosynthetic activity and Diminution in chlorophyll content used as an indicator of air pollution (Pawar and Dubey, 1985; Gilbert, 1968). Photosynthetic pigments are quite responsive to air pollutants and their sensitivity may decide the response of plants to pollutants (Chauhan and Joshi, 2010). Constant application of cement dust clogs the stomata, thus interfering with gaseous exchange (Lerman 1972). Carotenoids guard from photoxidation damage; hence, their decreases have serious outcomes on chlorophyll pigments (Sifermann, 1987). Joshi and Swami (2007) also reported a significant reduction in carotenoid content of diverse plants grown at polluted sites. The physiological condition of plants is very well indicated by their pigment content (Petkovsek et al., 2008). Ascorbic acid, a natural antioxidant in plants, has been revealed to play a vital role in pollution tolerance (Chen et al., 1990). Significant reductions in yield
have also been observed as a result of SO$_2$ pollution in many cereals and pulses (Thomas, 1961; Singh and Rao, 1982). Ozone, SO$_2$ and NO$_x$ separately and in the mixture are known to reduce the yield of many crop plants (Heggiesbad and Lesser, 1990; Renaud et al., 1997; Agrwal et al., 2006) and the yield losses often have been ascribed to reductions in photosynthetic activity and assimilate supplies to hold up reproductive development and seed growth (Kurpa and Kickert, 1989; Agrawal et al., 2003; Agrawal, 2005).

It has been studied that NO$_x$ or at least a combination of SO$_x$ and NO$_x$ is largely responsible for the lichen decline (Loppi and Corsini, 2003; Hussan et al., 2013). Furthermore, NO$_2$ generally affects the leaves and seedlings and its sound effects diminish with increasing age of the plant and tissue (Gheorghje and Barbu, 2011). Further, conifers are found to be more sensitive to this gas throughout spring and summer than in winter. Older needles of conifers are more susceptible to the gas (NO$_2$) than young ones. The gas causes development of crystallloid structures in the stroma of chloroplasts and puffiness of the thylakoid membrane. Consequently, the photosynthetic activity of the plant is reduced. The main route of entry of NO$_x$ into plant leaves is through the stomata, the gas then dissolves in leaf cells, giving rise to nitrite ions (NO$_2^-$) which are lethal at prominent concentrations, and nitrate ions (NO$_3^-$) that enter into nitrogen metabolism like the one absorbed through the roots (Zeiger and Taiz, 2006). NO$_x$ at elevated concentrations in the atmosphere can drastically reduce the growth of the plant particularly under elevated soil nitrogen surroundings. However, NO$_x$ can boost the nitrogen content of the plants and arouse development, when soil nitrogen is limiting and the concentration in the air is moderate. Consequently, exposure to excessive concentrations of NO$_x$ in a relatively short time, will basis abnormal symptoms (Zeiger and Taiz, 2006) and visible foliar injury to the plant in the form of patches of chlorosis and necrosis of the leaves (Ahmad, 2010). Exposing the plant to lesser concentrations of NO$_x$ for a longer period not often causes noticeable injury other than having an effect on growth by suppressing the rate of photosynthesis. NOx in mixture with other pollutants in particular SO$_2$, can cause more harm to vegetation than likely expected from the effects of the individual pollutants depending upon the environmental conditions (Emerson et al., 2001). As the NO$_x$ is the precursor of ozone formation in troposphere and tropospheric ozone (O$_3$) is an important phytotoxic air pollutant. Even though ozone has a significant role in defending the biosphere by absorbing detrimental ultraviolet radiation in the upper stratosphere but in the troposphere it is designated as a phytotoxic air pollutant (Khan and Soja, 2003). The sound damaging effects of photochemical oxidant mixtures on plants were first documented in the late 1940s (Middleton et al., 1950). Ozone is an important part of the air pollution climate in urban and industrialized areas of the world. Its effects are not limited to a small area, because Ozone (O$_3$) precursor’s travels lengthy distances in the atmosphere depending upon the wind speed and direction, with higher concentrations often found in rural areas. Ozone pollution is recognized to have significant effects on agricultural production in North America, Western Europe and many other countries of the world (Wang et al., 2015; Zeiger and Taiz, 2006). Ozone concentrations in Northern hemisphere and especially those in developing countries are expected to rise from mean 10ppm to 20ppm by the end of the 21st century due to the increase in its precursor emissions (NO$_x$ and volatile hydrocarbons), being associated with the rise in the number of motor vehicles and industrialization wide-reaching (Wahid, 2006). Ozone is a very much reactive material and before inflowing the stomata can injure the receptors of the guard cells next to the stomata, which are then incapable to respond to environmental signals (Calatayud et al., 2002), within the leaf apoplastic it reacts with water to form free radicals like hydro peroxide and superoxide’s, which reacts with intercellular fluid in the cell wall and alters the mesophyll cells just within the epidermis, being the main course of carbon dioxide from the stomata to the cells accountable for photosynthesis (Calatayud et al., 2002; Zeiger and Taiz, 2006).

Various gaseous and particulate pollutants emanating from brick kilns show negative impact on the adjacent vegetation. The relative densities of diverse herbs decline in the vicinity of brick kiln as compared to control (Sarkar and Kundu, 1996; cf. Fatima, 2011). Suspended Particulate Matter (SPM) has an effect on plants in an ample range of ways, depending upon the composition of the particles and is recognized to have direct or indirect effects on agricultural plants. Dust particles are of loca-lized significance near brick kilns, roads, quarries, cement works and other industrial areas (Zeiger and Taiz, 2006). Aside from screening out sunlight in the atmosphere, the undeviating impact of the dust on leaves reduces radiation to chloroplasts and stomatal conductance can affect control of water loss by physically preventing stomata closure (Zeiger and Taiz, 2006). The direct impact of particles containing contaminants for instance heavy metals can also cause phytotoxicity (Erickson, 1979). Accumulation of particulates on the surface of the plants can in due course alter plant vulnerability to pathogens and pests (Emerson et al., 2001) and the exposure to dust pollution stress provoked significant reductions in photosynthesis in most plants. Thus, may alter plant growth and production, without physical damage to the plant (Kumar and Thambavani, 2012). It is also the fact plants provide a vast leaf area for impingement, assimilation and accumulation of air pollutants diminish the pollutant level in the air environment (Warren, 1973; Shannigrahi et al., 2004), thus can be used as bioindicator of air pollution (Tripathi and Gautam, 2007; Lalitha et al., 2013). Recent studies on brick kilns in District Budgam have shown some major negative impacts on the environment in respect of air quality, human health and vegetation in
particular. Air quality status was turned into severe pollution during the operation phase of brick kilns and community people (including school children) were exposed to emissions from brick kilns which lead them to ailments of respiratory problems and results have also shown the negative impact of brick kiln emissions on biochemical parameters like chlorophyll, phaeophytin, carotenoids, carbohydrate, proteins and lipids of the vegetable species namely Brassica oleracea, Phaseolus vulgaris L. and Solanum melongena L. (Skinder, 2013).

CONCLUSION

It becomes clear that brick kiln emissions, urbanization and transportation are playing the leading role in deteriorating the environment in respect of air pollution, human health problems and decrease of crop production. This will also lead to global warming. Thus, concluded that ambient air pollution due to brick kilns in the rural areas is a real problem to human health and vegetation.

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