academicJournals

Vol. 6(1), pp. 1-11, January 2014
DOI: 10.5897/JENE2013.0423
ISSN 2006-9847 ©2014 Academic Journals
http://www.academicjournals.org/JENE

Journal of Ecology and the Natural Environment

Review

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.

Accepted 3 December, 2013

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_x 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 (SO_2) is one of the main products released from the combustion of sulphur containing compounds in most energy fuels having significant environmental concern. The term SO_x is a generic term describing emissions of SO_2 and SO_3. At low concentrations it is a colourless and odourless gas. On a worldwide scale, anthropogenic emissions stand for a major contribution to the SO_2 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 SO_2 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 SO_2 emissions are emitted in the northern hemisphere and the left over 7% are emitted in the southern hemisphere (WHO, 1979). The highest sources of SO_2 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 Guttikunda et al., 2013, 23,300 tons of $PM_{2.5}$, 15,500 tons of SO_2, 302,000 tons of CO, 6,000 tons of BC, and 1.8 million tons of CO_2 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 SO_2 and 0.64 to 1.4 kg of PM (Le and Oanh, 2010).

A significant feature of SO_2 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 SO_x in brick making has received considerable attention (Wilson and Johnson 1975; Amison, 1992; Junge, 1992; Hofer, 1994). Presently, SO_2 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 SO_x (De, 2012). SO_2 is the chief emission in brick production (Junge, 1992). The oxidation of pyrite (FeS_2) takes place in a stepwise approach with an initial release of SO_2 around 450°C from brick making raw material with an additional increase in temperature and the subsequent emission of sulfates occurs as SO_2 (Banerjee et al., 1980; Junge, 1992; Sanders, 1995). But Parsons et al. (1997) opined SO_2 can also be released during oxidation of sulfur containing carbonaceous matter at low temperatures. The successive emission of SO_2 begins above 750°C and can continue through the firing cycle (Junge, 1992). The residence time of SO_2 in the atmosphere ranges from about 2 to 8 days (Katz, 1977), while as Hidy (1994) gives residence times of SO_2 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 NO_x, 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 (SO_x, NO_x 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, SO_2, NO_x 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 NO_x and 5 tons of SO_x (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 SO_x, NO_x 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, SO_x and NO_x, 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).

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). 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 (SO_4^{2-}) concentrations in rain water are due to strong SO_2 emissions from coal fired thermal power plants (Demirak, 2007). While as it has been predicted that 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 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 SO_x, NO_x, CO_x 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 SO_2 from motor vehicles is very low as compared to stationary sources using solid and liquid fuels (Williams, 2000). Furthermore concentration of 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 (SO_x, NO_x and PM), fumes from brick kilns also contribute to the increase in the level of local 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_2, CH_4, N_2O, 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 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 SO_2 and PM in the environment of Kathmandu valley; contributing over 60% of the emissions (Maity, 2011). The major removal mechanisms of SO_2 from the atmosphere are dry deposition and chemical oxidation (Cheng et al., 2006). It is indicated that almost 10% SO_2 removal efficiency could be achieved using water as scrubbing liquid without any additive under certain hydrodynamic conditions (Bandyopadhyay, 2009).

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 1763ºC). The second reaction is also favored at temperatures about 1100ºC, but the amount of NO_2 formed is usually less than 0.5% of the total NO_x at 1100ºC. It is also formed by photolytic reaction; further man-made sources annually release 5×10^7 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_2 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 the precursor 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 day which may be attributed to the photochemical reaction taking place for ozone production during the 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 (Emberson 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/m³, respectively whereas, it reached 0.050 and 0.056 mg/m³, 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; Arditsoglou 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 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). 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, 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 (Prieditis 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 was statistically significant (Myers et al., 1989; Mustajbegovic et al., 2003; Mwaiselage, et al., 2005; Kakooei and Marioryad, 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 (Grahame 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 (Ozolincius 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 SO_2 on broad leaved species is tan to dark brown interveinal bifacial necrosis (Panwar, 1982). The most disperse and injurious pollutants in industrial areas are SO_2, NO_x, CO, tropospheric ozone (O_3) 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 SO_2 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, NO_x 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 $\mu g/m^3$ for 1 h, 500 µg/m3 for 8 h, and 40 $\mu g/m^3$ 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 (Kainulainen et al., 1995) and chlorophyll content (both chlorophyll ‘a’ and chlorophyll ‘b’) decreasing with the increase in SO_2 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 SO_2 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 SO_2 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 SO_2 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 SO_2 injury, as compared to the very youngest and oldest leaves (Heather, 2003). The crop species that are usually considered susceptible to SO_2 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 (NO_x and SO_x) 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_2 separately and in the mixture are known to reduce the yield of many crop plants (Heggesbad and Lesser, 1990; Renaurd 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 (Gheorghe 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 crystalloid 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 (Emberson 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., 2005; 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 apoplast 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 and 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 (Emberson 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.

ACKNOWLEDGEMENTS

The first author acknowledges the immense help received from the scholars whose articles are cited and included in references of this manuscript. The author is also grateful to publishers of all those articles, journals and books from where the literature for this article has been reviewed and discussed.

REFERENCES

Agrawal M (2005). Effects of air pollution on agriculture: An issue of national concern. Natl. Acad. Sci. Lett. 23(3&4): 93-106.

Agrawal M, Deepak SS (2003). Physiological and biochemical responses of two cultivars of wheat to elevated levels of CO_2 and SO_2, singly and in combination. Environ. Pollut. 121:189-197.

Agrawal M, Singh B, Agrawal SB, Bell JNB, Marshall F (2006). The effect of air pollution on yield and quality of mungbean grown in periurban areas of Varanasi. Water Air Soil Pollut. 169: 239-254.

Agrawal M, Singh B, Rajput M, Marshall F, Bell JNB (2003). Effect of air pollution on periurban agriculture: A case study. Environ. Pollut. 126: 323-329.

Ahmad MN (2010). Air pollution impacts to agricultural crops. Ph.D. Thesis. University of York Environment.

ALA (American Lung Association) (2006). Research Highlights: Health Effects of Particulate matter and Ozone. Air Pollution. North east diesel Organization.

Alam SA (2006). Use of biomass fuels in the brickmaking industries of Sudan: implications for deforestation and greenhouse gas emission, Dept. Forest Ecol. Univ. Helsinki, Finland. pp.16-17.

Alberta M, Marzluff JM, Shulenberger E, Bradley G, Ryan C and Zumbrunnen C (2003). Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. Bioscience, 53: 1169-1179.

Ali M, Athar M (2006). Air polluting due to traffic, air quality monitoring along three sections of national high way N-5, Pakistan. Environ. Monit. Assess. 1(3): 25-28.

Al-Khalaf AK (2006). Influence of meteorological and related factors on surface ozone pattern at Makkah station. J. Environ. Sci. 11: 1-19

Amdur MO (1978). Effects of sulfur oxides on animals. In: Nriagu, J.O. (ed.). Sulfur in the Environment. Part II: Environmental Impacts. John Wiley & Sons, Toronto. pp. 61-74.

Amison A (1992). Stack Emissions in the Brick Industry. Ceram. Ind. 138(3): 61-64.

Anda A (1986). Effect of cement kiln dust on the radiation balance and yields of plants. Environ. Pollut. 40: 249-256.

Arditsoglou A, Samara C (2005). Levels of total suspended particulate matter and major trace elements in Kosovo: a source identification and apportionment study. Chemosphere 59: 669-678.

Ashenden TW, Williams IAD (1980). Growth reduction in *Lolium multiflorum* Lam. and Phleum pratense L. as a result of sulphur dioxide and nitrogen dioxide pollution. Environ. Pollut. 21: 131-139.

Asgher MS, Singh AL (2003). Land degradation through brick kiln: a case study of Aligarh, India. Indian J. Reg. Sci. 35(2):77-84.

Assadi A, Abdollah GP, Fatemeh M, Nasrin T and Leila A (2011). Impact of air pollution on physiological and morphological characteristics of *Eucalyptus camaldulensis*. J. Food Agric. Environ. 9(2): 676 - 679

ATSDR (Agency for Toxic Substances and Disease Registry) (1998). Toxicological Profile for Sulfur Dioxide. ATSDR, Public Health Service, US Department of Health and Human Services. Atlanta, GA. pp. 185.

Aziz HM, Ahmed SB and Saleh IA (2010) 'Respiratory Hazards Among Egyptian Ceramics Workers. Researcher 2 (6):65-73.

Balkhi M, Amin S, Masood A (2009). Effect of aqueous sulphur dioxide on the biochemical and antioxidant properties of *Malva sylvestris*. Asian J. Environ. Sci. 3(2):139-145

Bandyopadhyay A (2009). Abatement of particulate laden SO_2 in tapered bubble column with internals. Air Qual. Atmos. Health 2:147-155.

Banerjee AC, Rangaswamy P, Sood S 1(980). Mechanism of oxidation of iron pyrite in dynamic air. Therm. Anal. pp. 241-246.

Bobak M (2000). Outdoor air pollution, low birth weight, and prematurity. Environ. Health Perspect. 108: 173-176.

Brosnan DA (2000). Ceramic and Brick Manufacturing, p. 681-690. In: Air Pollution Engineering Manual, Air and Waste Management Association. John Wiley and Sons.

Brosnan DA, John PS (1998). Environmental regulations and their effect on ceramic manufacturing in North America, Qualicer: General Conferences and Communications. I: 215-224. Castellon, Spain.

Calatayud A, Ramirez JW, Iglesias DJ, Barreno E (2002). Effects of O_3 on photosynthetic CO_2 exchange, chlorophyll a fluorescence and antioxidant systems in lettuce leaves. Physiol. Plant. 116: 308-316.

Callen MS, Cruz MT, Lopez JM, Navarro MV, Mastral AM (2009). Comparison of receptor models for source apportionment of the PM_{10} in Zaragoza (Spain). Chemosphere 76:1120-1129.

Chauhan A, Joshi PC (2010). Effect of ambient air pollutants on wheat and mustard crops growing in the vicinity of urban and industrial areas. New York Sci. J. 3(2):52-60.

Chen YM, Lucas PW, Wellburn AR (1990). Relative relationship between foliar injury and change in antioxidants levels in red and Norway spruce exposed to acidic mists. Environ. Pollut. 69:1-15.

Cheng S, Li J, Feng B, Jin Y, Hao R (2006). A Gaussian-box modeling approach for urban air quality management in a northern Chinese city-1 model development. Water Air Soil Pollut. 178: 137-157.

Chung YS (2008). Observations of massive air-pollution transport and associated air quality in the yellow sea region. Air Atmos. Health 1: 69-79.

Chung YS, Kim HS, Dulam J, Harris J (2003a). On heavy dust fall observed with explosive sandstorms in Changwon-Changju, Korea. Atmos. Environ. 37: 3425-3433.

Chung YS, Kim HS, Han KY, Jugder D (2003b). On East Asian sand dust storms and associated significant dust fall. Water Air Soil Pollut. 3: 259-277.

Cofala J, Amann M, Gyarfas F, Schoepp W, Boudri JC, Hordijk L, Kroeze C, Li JF, Lin D, Panwar TS, Gupta S (2004). Cost-effective control of SO_2 emissions in Asia. J. Environ. Manage. 72: 149-161.

Costa DL, Amdur MO (1996). Air Pollution. p. 857-882. In: Klaasen, C.D., Amdur, M. O. and J. Doull (eds.), Casarett and Doull's Toxicology. The Basic Science of Poisons. 5th edn. Mcgraw-Hill, New York.

Croitoru L, Sarraf M (2012). Benefits and costs of the informal sector: The case study of brick kilns in Bangladesh. J. Environ. Prot. 3: 476-484.

De AK (2012). Environmental Chemistry, (7^{th} ed). New Age International (P) Limited Publisher, New Delhi.

Dehghan F, Mohammadi S, Sadeghi Z, Attarchi M (2009). Respiratory complaints and spirometric parameters in tile and ceramic factory workers. Tanaffos 8(4):19-25

Demirak A (2007). The Influence of a Coal-Fired Power Plant in Turkeyon the Chemical Composition of Rain Water in a Certain Region. Environ. Monit. Assess. 129:189-196

Donaldson K (2001). Ambient particle inhalation and the cardiovascular system: Potential mechanisms. Environ. Health Perspect. 109(4): 523-527.

Elampari K, Chithambarathanu T, Sharma KR (2010). Examining the variations of ground level ozone and nitrogen dioxide in a rural area influenced by brick kiln industries. Indian J. Sci. Technol. 3(8): 900-903

Emberson LD, Ashmore MR, Murray F, Kuylenstierna JCI, Percy KE, Izuta T, Zheng Y, Shimizu H, Sheu BH, Liu CP, Agrawal M, Wahid A, Abdel-Latif NM, Van Tienhoven M, De-Bauer LI, Domingos M (2001). Impacts of air pollutants on vegetation in developing countries. Water Air Soil Pollut. 130: 107-118.

Emberson LD, Buker P, Ashmore MR, Mills G, Jackson LS, Agrawal M, Atikuzzaman MD, Cinderby S, Engardt M, Jamir C, Kobayashi K, Oanh NTK, Quadir QF, Wahid A (2009). A comparison of North American and Asian exposure-response data for O_3 effects on crop yields. Atmos. Environ. 43: 1945-1953

Environment Improvement Programme (EIP), Kathmandu (1995). Assessment of the Applicability of Indian Cleaner Process Technology for Small Scale Brick Industries of Kathmandu*.* Metropolitan Environment Improvement Programme, Kathmandu.

EPA (2012). What Are the Six Common Air Pollutants? Environmental Protection Agency. Retrieved from http://www.epa.gov/air/urbanair/

EPA (Environmental Protection Agency) (2007). Air pollution in Peshawar. NWFP-Pakistan.

Erickson PA (1979). Environmental Impact Assessment: Air Borne Particles. New York: University Park Press.

Fatima I (2011). Impact of brick kiln emissions on the ambient air quality and vegetation: A case study of district Budgam. M.Phil dessertation, University of Kashmir.

Friend JP (1973). The global sulfur cycle. In: Rasool, S.I. (ed.), Chemistry of the Lower Troposphere, Plenum Press, New York. pp. 177-201.

Ganai BA, Aliya A, Masood A, Zargar MA, Ganaie SA (2007b). Sulphite toxicity on spinach (*Spinacea oleracea*). J. Res. Dev. 7:109-118

Ganai BA, Nowsheen Q, Masood A, Zargar MA, Javaid IB (2007a). Effect of sulphur dioxide on *Malva sylvestris*. J. Res. Dev. 7:19-24

Ganai BA, Zaar A, Rafiq SK, Masood A, Zargar MA, Kumar R (2010). Impact of brick kiln emissions on biochemical parameters of *Malva sylvestris* Lin. Ad. Plant Sci. 23(2): 545-546.

Gheorghe IF, Barbu I (2011). The Effects of Air Pollutants on Vegetation and the Role of Vegetation in Reducing Atmospheric Pollution. p. 241-280. In: Mohamed Khallaf (ed.). The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources. InTech, Europe

Ghose MK, Majee SR (2002). Assessment of the status of work zone air environment due to opencast coal mining. Environ. Monit. Assess. 77: 51-60.

Gilbert OL (1968). Biological Indicators of Air Pollution. University of Newcastle upon Tyne, Newcastle upon Tyne, Great Britain.

Godzik S, Sienkiewicz J (1990). Air pollution and forest health in central Europe: Poland, Czechoslovakia, and the German Democratic Republic. p. 155-170. In: Grodzinski, W., Cowling, E. B. and Breymeyer, A. I. (eds.). Ecological Risks Perspectives from Poland and the United States. National Academy Press, Washington, D.C.

Goyal SK, Ghatge SV, Nema P, Tamhane SM (2006). Understanding urban vehicular pollution problem vis-à-vis ambient air quality- a case study of a Megacity (Delhi, India). Environ. Monit. Assess. 119: 557-567.

Grahame TJ, Schlesinger RB (2009). Cardiovascular health and particulate vehicular emissions: a critical evaluation of the evidence. Air Qual. Atmos. Health 3(1): 3-27.

Gupta S, Narayan R (2010). Brick kiln industry in long-term impacts biomass and diversity structure of plant communities. Curr. Sci. 99(1):72-79

Guttikunda S (2009). Impact Analysis of Brick Kilns on the Air Quality in Dhaka, Bangladesh: SIM-Air Organization. http://www.sim.org.

Guttikunda SK, Begum BA and Wadud Z (2013). Particulate pollution from brick kiln clusters in the Greater Dhaka region, Bangladesh. Air Quality, Atmos. Health, 6(2): 357-365

Halvani GH, Zare M, Halvani A, Barkhordari A (2008). Evaluation and comparison of respiratory symptoms and lung capacities in tile and ceramic factory workers of Yazd Arh Hig Rada. Toksikol 59: 197-204

Hassan M, Waseem M and Ihtisham R, Waqar A, Adil S, Ali SS (2012). Application of air dispersion model for the estimation of air pollutants from coal fired brick kilns samples in Gujrat. Sci. Int. 24 (4): 141-145.

Heather G (2003). Effect of air pollution on agricultural crops. Ministry of Agriculture, Ontario, Canada.

Heggesbad HE, Lesser VM (1990). Effect of ozone, sulphur dioxide, soil water deficit and cultivars on yields of soybean. J. Environ. Qual. 19: 488-495.

Heyder J, Takenaka S (1996). Long term canine exposure studies with ambient air pollutants. In: Paoletti and Costabel, U. (eds.) Series, Respiratory Effects of Air Pollution. Eur. Respir. J. 9: 571-584.

Hidy GM (1994). Atmospheric Sulfur and Nitrogen Oxides: Eastern North America Source Receptor Relationships. Academic Press Inc, San Diego. p.447.

Hofer M (1994). The exhaust gas problems in the brick and tile industry. Zeigelindustrie International, 47(9): 552-557.

Holleman W (2001). Inorganic Chemistry. Acad. Press, San Diego, CA.

HSDB (Hazardous Substances Data Bank) (2002). Hazardous Substances Data Bank Sulfur Dioxide (HSN 228). Toxicology and Environmental Health Information Program, National Library of Medicine, Bethesda, MD.

Hussan A, Bhat GA, Sheikh MA (2013). Impact of brick kiln and vehicular emissions on lichen diversity in Khanabal Area of Anantnag District (J&K), India. Int. Res. J. Environ. Sci. 2(4):30-33

IARC (1992). Sulfur Dioxide and Some Sulfites, Bisulfites and Metabisulfites. IARC Working Group. TA: IARC Monographs on the Evaluation of Carcinogenic Risk to Human. 54:131-188.

Irshad AH, Ahmad SF, Sultan P (2011). Effect of sulphur dioxide on the biochemical parameters of spinach (*Spinacea oleracea*). Trakia J. Sci. 9(1): 24-27

Ismail M, Muhammad D, Khan FU, Munsif, F, Ahmad T, Ali S, Khalid M, Haq N, Ahmad M (2012). Effect of brick kilns emissions on heavy metal (Cd and Cr) Content of Contiguous Soil and Plants. Sarhad J. Agric 28 (3): 403-409.

Jacobson JS, Hill AC (1970). Recognition of air pollution injury to vegetation. A Pictorial Atlas. Air pollution control Association, Pittsburg.

Jain M, Saxena NC (2001). Air quality assessment along Dhanbad Jharia Road. Department of Mining Engineering, I.I.T., Kharagpur India and Center of Mining environment, Indian School of Mines, Dhanbad, India.

Joshi PC, Swami A (2007). Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. Environmentalist 27: 365-374.

Joshi SK, Dudani I (2008). Environmental health effects of brick kilns in Katmandu valley. Katmandu Univ. Med. J. 6(1): 3-11.

Junge K (1992). Reduction of sulphur emissions in the Thermoreactor. *ZI-Annual for the Brick and Tile, Structural Ceramics and Clay Pipe Industries.* pp. 32-46.

Kainulainen P, Holopainen JK, Okasanea J (1995). Effects of sulphur dioxide on the concentration of carbohydrates and secondary compounds in Scot pine (P*inus sylvestris* L.) and Norway spruce (P*icea abies* L.) seedlings. New Phytol. 130: 231-238

Kakooei H, Marioryad H (2005). Exposure to inhalable flour dust and respiratory symptoms of workers in flour mill in Iran. Iranian J. Environ. Health Sci. Eng. 2(1): 50-55

Katz M (1977). The Canadian Sulphur Problem. p. 21-67. In: Sulphur and Its Inorganic Derivatives in the Canadian Environment. Ad hoc Panel of Experts Management Subcommittee, NRC Associate Committee on Scientific Criteria for Environmental Quality, National Research Council of Canada, Ottawa.

Khan S, Soja G (2003). Yield responses of wheat to O_3 exposure as modified by drought-induced differences in O_3 uptake. Water Air Soil Pollut. 147: 299-315.

Kolkmeier H (1991). Emissions. Ziegelindustrie International. 44 (10): 544-549.

Kondo N, Sugahara K (1978). Changes in transpiration rate of SO_2 resistant and SO_2 sensitive plants with SO_2 fumigation and participation of abscisic acid. Plant Cell Physiol. 19: 365-373.

Koskela R S, Mutanen P, Sorsa JA, Klockars M (2005). Respiratory disease and cardiovascular morbidity. Occup. Environ Med. 62(9): 650-655.

Kukkonen J, Bozó L, Palmgren F, Sokhi RS (2001). Particulate Matter in Urban Air. National Environmental Research Institute. Frederiksborgvej 399, DK-4000 Roskilde, Denmark.

Kumar R, Joseph AE (2006). Air pollution concentrations of $PM_{2.5}$, PM_{10} and NO_2 at ambient and Kerbsite and their correlation in metro city Mumbai. Environ. Monit. Assess. 119: 191-199

Kumar SR, Thambavani SD (2012). Effect of cement dust deposition on physiological behaviors of some selected plant species. Int. J. Sci. Technol. Res. 1(9): 98-105

Kurpa SV, Kickert RN (1989). The greenhouse effect:Impacts of ultraviolet-B (UV-B) radiation, carbon dioxide (CO_2) and ozone (O_3) on vegetation. Environ. Pollut. 61: 263-392.

Lalitha J, Dhanam S, Ganesh KS (2013). Air Pollution Tolerance Index of Certain Plants around SIPCOT Industrial Area Cuddalore, Tamilnadu, India. Int. J. Environ. Bioenergy 5(3): 149-155

Le HA and Oanh NTK (2010). Integrated assessment of brick kiln emission impacts on air quality. Environ. Monit. Assess., 171: 381-394.

Lerman S (1972). Cement-kiln dust and the bean plant (Phaseolus vulgaris L. Black Valentine Var.); indepth investigations into plant morphology, physiology and pathology. Ph.D. Dissertation, University of California, Riverside.

Likens GE, Wright RF, Galloway JN, Butler J (1979). Acid rain. Sci. Am. 241: 43-51

Linaker C, Smedley J (2002). Respiratory illness in agricultural workers. Occup. Med. 52: 451-459

Liu N, Peng CL, Lin ZF, Lin GZ, Pan XP (2007). Effects of simulated SO_2 pollution on subtropical forest succession: Toward chlorophyll fluorescence concept. Pak. J. Bot. 39(6):1921-1935

Loppi S, Corsini A (2003). Diversity of epiphytic lichens and metal contents of *Parmelia caperata* thalli as monitors of air pollution in the town of Pistoia. Environ. Monit. Assess. 86: 289-301.

Maclean DC (1981). Air Quality Standards for Fluoride to Protect Vegetation: Regional, Seasonal, and other Considerations. The 74th Annual Meeting and Exhibition of the Air Pollution Control Association, Philadelphia, PA.

Magas OK, Gunter JT, Regens JL (2007). Ambient air pollution and daily pediatric hospitalizations for asthma. Environ. Sci. Pollut. Res. 14:19-23.

Maggs R, Wahid A, Shamsi SRA, Ashmore MR (1995). Effects of ambient air pollution on wheat and rice yield in Pakistan. Water Air Soil Pollut. 85: 1311-1316.

Maithel S, Vasudevan N, Johri R, Kumar A (2002). Pollution Reduction and Waste Minimization in Brick Making. Tata Research Institute, Habitat Place, Lodhi Road, New Delhi.

Maity S (2011). Overview of Brick Industry in Kathmandu Valley, Nepal. Retrieved from http://www.devalt.org/newsletter

Mayer H (1999). Air pollution in cities. Atmos. Environ. 33: 4029-4037.

Maynard RL, Waller R (1999). Carbon Monoxide. In: Holgate ST, Samet JM, Koren HS & Maynard RL (eds.). Air Pollution and Health. Academies Press: Harcourt Brace & Company, Publishers.

Mejstrik V (1980). The influence of low SO_2 concentration on growth reduction of *Nicotiana tabacum* L. W. Samsum and *Cucumis sativus* L. C.V. Unikat. Environ. Pollut. 21: 73-76.

Memon E (2000). Environmental effects of thermal power plant emissions- A case study. A thesis of Master of Engineering. Canada: Faculty of Engineering and Applied Science, Memorial University of Newfoundland

Middleton JT, Kendrick JB, Schwalm HW (1950). Injury to herbaceous plants by smog or air pollution. Plant Dis. 34: 245-252.

Miller PR (1983). Ozone effects in the San Bernardino National Forest. In: Proceedings of Symposium on Air Pollution and the Productivity of the Forest. Pennsylvania State University Press, State College, PA. pp. 161-197.

Mishra V (2003). Cyber seminar on Health Effects of Air Pollution. Minnesotans for Sustainability.

Murray F, Wilson S (1988). The joint action of sulphur dioxide and hydrogen fluoride on the yield and quality of wheat and barley. Environ. Pollut. 55: 239-249.

Mustajbegovic J, Zuskin E, Schachter E, Kern J, Milas ML, Pucarin J (2003). Respiratory findings in tobacco workers. Chest 123:1740-1748

Mwaiselage J, Bratveit M, Moen BE, Mashalla Y (2005). Respiratory symptoms and chronic obstructive pulmonary disease among cement factory workers. Scand J. Work Environ. Health 31 (4): 316-323

Myers JE (1989). Respiratory health of brick workers in Cape Town, South Africa: Appropriate dust exposure indicators and permissible exposure limits. Scand J. Work Environ. Health 15: 198-202

NAPAP (National Acid Precipitation Assessment Program) (1990). *Effects of Pollution on Vegetation*. Washington, D.C. Government Printing Office.

Nihlgard B (1985). The ammonium hypothesis - an additional explanation to the forest dieback in Europe. Ambio. 14 (2): 844.

OAQPS Fact Sheet (1997). Health Effects of Particulate Matter. United States Environmental Protection Agency.

OECD (Organisation for Economic Co-operation and Development) (1981). The Costs and Benefits of Sulphur Oxide Control. Paris.

Ozolincius R, Stakenas V, Serafinaviciute B (2005). Meterological factors and air pollution in Lithuanian forests: Possible effects on tree condition. Environ Pollut. 137 (3): 587-595.

Panwar K (1982). Pollution studies in Nagada area due to Birla Industrial Complex discharges. Ph. D. thesis, Vikram University, Ujjain.

Pauls N (1989). *Survey of the Emission of Pollutants in Brick and Tile Production*. ZI-Annual for the Brick and Tile, Structural Ceramics and Clay Pipe Industries. pp. 69-77.

Pawar K, Dubey PS (1983). Effect of atmospheric pollutant on the morphology and pigment content in proceeding of sixth world congress on air quality. Paris. 2: 501.507.

Pawar K, Dubey PS (1985). Effects of air pollution on the photosynthetic pigments of *Ipomea fistulosa* and *Phoenix sylvestris*. In: All India seminar on Air Pollution Control. pp. 19-21.

Pawar K, Dube B, Maheshwari R, Bafna A, (2010). Biochemical aspects of air pollution induced injury symptoms of some common ornamental road side plants. Int. J. Biol. Med. Res. 1(4):291-294

Petkovsek SAS, Batic F, Lansik CR (2008). Norway spruce needles as bioindicator of air pollution in the area of influence of the sostanj thermal power plant, Slovenia. Environ. Pollut. 151: 287-291.

Pope CA (2000). Review: Epidemiological basis for particulate air pollution health standards. Aerosol Sci. Technol. 32: 4-14.

Pope CA (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. J. Am. Med. Assoc. 287:1132- 1141.

Pope CA, Dockery DW (1992). Acute health effects of PM_{10} pollution on symptomatic and asymptomatic children. Am. Rev. Respir. Dis. 145: 1123-1128.

Prakesh G, Gupta V, Poonia S, Sangita, Gupta S (2002). Effect of SO_2 exposure on the chlorophyll contents in *Raphanus sativus* L. and *Brassica rapa* L. Plant Arch. 2 (2): 165-170.

Prieditis H, Adamson IYR (2002). Comparative pulmonary toxicity of various soluble metals found in urban particulate dusts. Exp. Lung Res. 28: 563-576

Pudasainee D, Sapkota B, Shrestha ML, Kaga A, Kondo A, Inoue Y (2006). Ground level ozone concentrations and its association with NO_x and meteorological parameters in Kathmandu valley, Nepal. Atmos. Environ. 40: 8081-8087

Quiterio SL, Da Silva CRS, Arbilla G, Escaleira V (2004). Metals in airborne particulate matter in the industrial district of Santa Cruz, Rio de Janeiro, in an annual period. Atmos. Environ. 38: 321-331.

Rajput M, Agrawal M (2004). Physiological and yield responses of pea plants to ambient air pollution. Indian J. Plant Physiol. 9(1): 9-14.

Rajput M, Agrawal M (2005). Biomonitoring of air pollution in a seasonally dry tropical suburban area using wheat transplants. Environ. Monit. Assess. 101: 39-53.

Rao DN (1981). Phytomonitoring of air pollution, WHO workshop on biological indicator and indices of Environmental Pollution, Osmania University, Hyderabad: 1-8.

Reddy GS, Ruj B (2003). Ambient air quality status in Ranignaj-Asansol area, India. Indian J. Environ. Prot. 10 (2): 105-112.

Renaurd JP, Allard G, Mauffette Y (1997). Effects of ozone on yield growth and root starch concentrations of two alfalfa (*Medicago sativa* L.) cultivars. Environ. Pollut. 95: 273-281.

Salam A, Hossain T, Siddique MNA, Alam AMS (2008). Characteristics of atmospheric trace gases, particulate matter, and heavy metal pollution in Dhaka, Bangladesh. Air. Qual. Atmos. Health 1:101-109.

Sandelius AS, Naslund K, Carlson AS, Pleijel H, Sellden G (1995). Exposure of spring wheat (*Triticum aestivum*) to ozone top chambers. Effects on acyl lipid composition and chlorophyll content of flag leaves. New Phytol. 131: 231-239.

Sanders JP (1995). Transport of internally generated SO_2 through porous clay ceramics. Ph. D. dissertation, Clemson University.

Schwartz J (1996). Air pollution and hospital admissions for respiratory disease. Epidemiology 7(1): 20-28.

Scott HM (1998). Effects of Air Emissions from Sour Gas Plants on the Health and Productivity of Beef and Dairy Herds in Alberta, Canada. Ph. D. thesis University of Guelph.

Seinfeld JH, Pandis SN (1998). Atmospheric Chemistry and Physics: Pollution to Climate Change. John Wiley & Sons, Inc., New York.

Shah MH (2009). Atmospheric Particulate Matter: Trace Metals and Size Fractionation, Saarbrucken, Germany. p. 228.

Shah MH, Shaheen N (2010). Seasonal behaviours in elemental composition of atmospheric aerosols collected in Islamabad, Pakistan. Atmos. Res. 95: 210-223.

Shah MH, Shaheen N, Jaffar M, Khalique A, Tariq SR, Manzoor S (2006). Spatial variations in selected metal contents and particle size distribution in an urban and rural atmosphere of Islamabad, Pakistan. J. Environ. Manage. 78: 128-137

Shannigrahi AS, Fukushima T, Sharma RC (2004). Anticipated air pollution tolerance of some plant species considered for green belt development in and around an industrial/urban area in India: An overview. Int. J. Environ. Stud. 61(2): 125-137.

Sharma PD (2012). Ecology and Environment (11^{th} ed). Rastogi Publications, Meerut, U. P., India.

Shukla J, Pandey V, Singh SN, Yunus M, Singh N, Ahamad KJ (1990). Effect of cement dust on the growth and yield of *Brassica campestris* L. Environ. Pollut. 66: 81-88.

Sifermann-Harms D (1987). The light harvesting and protective functions of carotenoids in photosynthetic membranes. Physiol. Plant 69: 561-568.

Singh LB (1990). Phytotoxic influence of SO_2 pollution on leaf growth of *Vigina mungo* L. J. Environ. Biol. 11 (2): 111-120.

Singh LP, Bhardwaj A, Deepak KK (2000). Respirable Suspended Particulate Matter (RSPM) and respiratory symptom among casting industry workers: An exploratory study in Northern India. Int. J. Adv. Eng. Technol. 2(1):251-259.

Singh LP, Bhardwaj A, Deepak KK, Sahu S (2011). Small and medium scale casting and forging industry in India: An ergonomic study. Ergonomics S. A. 22(1): 36-56.

Singh LP, Bhardwaj A, Deepak KK, Singh S (2009). Occupational heat exposure in extreme weather conditions in small and medium enterprises (SME) in India. Int. J. Hum. Geogr. Environ. Stud. 1(1) 32-38

Singh N, Rao DN (1981). Certain responses of wheat plants to cement dust pollution. Environ. Poll. (Ser. A.) 24: 75-81.

Singh N, Rao DN (1982). The influence of ozone and sulphur dioxide on *Cicer arietinum* L. J. Indian Bot. Soc. 61: 51-58.

Sinha S, Sheekesh S (2002). Air quality status and management options for the mining belt of Goa. Indian J. Environ. Prot. 22: 241-253.

Skinder BM (2013). Impact of brick kiln emissions on vegetation and human health. M.Phil. dissertation submitted to P.G. Department of Environmental Science, University of Kashmir (J&K India).

Su YC, Ho CL, Wang EI, Chang ST (2006). Antifungal activities and chemical compositions of essential oils from leaves of four *eucalyptus*. Taiwan J. For. Sci. 21:49-61.

Suman, Papiya, Pal AK, Singh G (2007). Assessment of air quality status in Angul-Talcher coal mining area in Orissa. In: Proc. Intl. Conf. MSECCMI, New Delhi, India. pp. 577-589.

Tang L (2009). Regional and local surface ozone variations in relation to meteorological conditions in Sweden. Dept. Earth Sci. Univ. Gothenburg.

TCEQ (2002). A Study of Brick-Making Processes along the Texas Portion of the U.S.-México Border: Senate Bill 749. Texas Commission on Environmental Quality . Border Affairs Division.

Thomas H (1991). Accumulation and consumption of solutes in swards of *Lolium perenne* during drought and after rewatering. New Phytol. 118: 35-48.

Thomas MD (1961). Effects of air pollution. WHO monograph. Series No.46. (Geneva: WHO). pp. 233-278.

Thomas MD, Hendricks RH (1956). Effects of air pollution on plants. Air Pollution Handbook. McGraw-Hill Book Company, Inc., New York.

Tripathi AK, Gautam M (2007). Biochemical parameters of plants as an indicator of air pollution. J. Environ. Biol. 28 (1):127-132.

Ugheoke AJ, Ebomoyi MI, Iyawe VI (2006). Influence of smoking on respiratory symptoms and lung function indices in sawmill workers in Benin City, Nigeria. Niger. J. Physiol. Sci. 21 (12): 49.

UNEP (United Nation Environment Programme) (2007). A Review of the Measurement, Emission, Particle Characteristics and Potential Human Health Impacts of Ultrafine Particles: Characterization of Ultrafine Particles. Exposure to Environmental Hazards; Fall Semester 2003 course material. University of Minnesota, USA.

Unsworth MH, Harrison RM (1985). Is lead killing German forests? Nature 317: 674.

USEPA (United States Environmental Protection Agency) (2007). Health and environmental impacts of SO_2 [Online]. Available: http://www.epa.gov/air/urbanair/so2/hlth1.html[Accessed 05/10/2009].

Wahid A (2006). Influence of atmospheric pollutants on agriculture in developing countries: A case study with three new wheat varieties in Pakistan. Sci. Total Environ. 371: 304-313.

Wang LL, Allen DT, Mcdonald-Buller EC (2005). Air quality modelling of interpollutant trading for O_3 precursors in an urban area. J. Air Waste Manage. Assoc. 55: 1543-1557.

Warren JL (1973). Green space for air pollution control: School of Forest Resources. Technical Report No. 50, North Carolina State University, Raleigh, North Carolina.

Watson JG, Zhu T, Chow JC, Engelbrecht J, Fujita EM, Wilson WE (2002). Receptor modeling application framework for particle source apportionment. Chemosphere 49(9): 1093-1136.

Weil ED, Sandler SR (1997). Sulfur Compounds. In: Kirk-Othmer Encyclopedia of Chemical Technology, John Wiley & Sons, Inc.

Wellburn A (1998). Sulfur Dioxide, p. 23-59. In: Air Pollution and Acid rain: The Biological Impact. Longman Scientific & Technical, John Wiley & Sons.

WHO (1979). Sulfur oxides and suspended particulate matter, environmental health criteria. World Health Organization, Geneva.

Wild P, Bourgkard E, Paris C (2009). Lung cancer and exposure to metals: the epidemiological evidence. Method Mol. Biol. 472:139-167.

Williams ML (2000). Patterns of air pollution in developed countries. Department of the Environment. Transport and the Regions London, pp. 83-104.

Wilson HH, Johnson LD (1975). Characterization of air pollutants emitted from brick plant kilns. Ceram. Bull. 54 (11): 990-994.

Wilson SA, Murray F (1990). SO_2 induced growth reductions and sulphur accumulation in wheat. Environ. Pollut. 66: 179-191.

World Bank (1997). Urban Air Quality Management Strategy in Asia (URBAIR): Kathmandu Valley Report, New York, USA.

World Bank (WB) (1998). Greenhouse Gas Assessment Handbook: A practical guidance document for the assessment of project-level greenhouse gas emissions. Global Environment Division, the World Bank, USA. p. 168.

World Bank Group (1998). Pollution Prevention and Abatement Handbook.

Xie RK, Seip HM, Liu L, Zhang DS (2009). Characterization of individual airborne particles in Taiyuan City, China. Air Qual. Atmos. Health 2: 123-131.

Yokoyama E, Yoder RE, Frank NR (1971). Distribution of ^{35}S in the blood and its excretion in urine of dogs exposed to $^{35}SO_2$. Arch. Environ. Health 22: 389-395.

Zeiger E, Taiz L (2006). The Effect of Air Pollution on Plants. Plant physiology, (4th ed.) Sinauer Assoc., Sunderland, MA.

Zuskin E, Musajbegovic J, Schachter EN, Kern J, Docko-Jelinic J, Godnic-Cvar J (1998). Respiratory findings in workers employed in the brick-manufacturing industry. J. Occup. Environ. Med. 40(9): 814-820.