Chapter 52
Brick Kilns: Types, Emissions, Environmental Impacts, and their Remedial Measures

Hamaad Raza Ahmad, Zia Ur Rahman Farooqi, Muhmmmad Sabir, and Muhammad Fahad Sardar

52.1 Introduction

The study of bricks gives a tentative idea about civilizations. Centuries back, straw and mud were used to make bricks. Oldest brick works date back to more than 10,000 years. In the Indo-Pak subcontinent, history of bricks is approximately 5000 years old, i.e., from "Indus Valley Civilization". A report published by Ismail et al. (2012) mentions that there were more than 0.30 million brick kilns working worldwide. Pakistan has more than 6000 brick kilns (Ismail et al. 2012). Out of these, more than 400 working brick kilns are found within the territories of Faisalabad (Ismail et al. 2012). China, Pakistan, India, and Bangladesh contribute 75% of bricks produced worldwide, out of which Pakistan's share is about 8% (Ishaq et al. 2010).

Agricultural productive lands are being utilized for brick production, which is one of the reasons for decrease in agricultural lands (Ozturk et al. 1995; Abdalla et al. 2012). Brick production is usually done on local fertile lands. Clayey soils are being used for brick manufacturing having a high capability of retaining heavy metals. In Pakistan, brick kilns are mostly located in the surroundings of big cities, making it a biggest source of air and soil pollution in these cities (Ismail et al. 2012).

Environmental pollution and surface soils degradation are caused by many factors (Ozturk et al. 1993, 1994a, b, 2011). Out of these, brick kilns are on the top of the list (Ozturk et al. 1995). Surface soils from fertile agricultural land are being used to make bricks resulting in deleterious effects on soil fertility. Most of the brick kilns in Asia are structured poorly, use fuel of inferior quality, and contribute to Sulfur and black CO_2 discharge (Guttikunda et al. 2013). The brick kilns also contribute towards environmental pollution (Skinder et al. 2014) as kiln emissions contain heavy metals which can harm crops grown on agriculture land located in the

H. R. Ahmad (✉) · Z. Ur R. Farooqi · M. Sabir · M. F. Sardar
Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan

M. Öztürk et al. (eds.), *Biodiversity, Conservation and Sustainability in Asia*,
https://doi.org/10.1007/978-3-030-73943-0_52

neighborhood of kilns (Ishaq et al. 2010). Brick kiln's exhaust contributes oxides in the environment, including COx, NOx, Sox, etc., along with hydrocarbons and particulate matters (Abdalla et al. 2012). Earlier studies have indicated that the concentration of particulate matter in the air around the brick kiln sites is approximately 3.5 times more as compared to the season in which brick kilns are not working. All these are adversely affecting the environment and living beings. Human health of nearby areas especially brick workers, infants, and women is adversely affected. Particulate matter emitted from kilns has a high capability to travel in the air, and affects the respiratory system making it harmful for humans. It is a mixture of different organic and inorganic materials toxic to living beings adversely affecting children and elderly people because of the weak disease defense system at these ages (Sheikh et al. 1976; Guttikunda and Goel 2013). According to an estimate by WHO, almost three million deaths are to be caused by air pollution, out of which 800,000 deaths are in result of lung cancer, circulatory system, and respiratory disorders. In 2003, approximately 1.5million deaths have been reported in south Asia only (World Bank 2011).

Deteriorated regions from brick production sites are increasing day by day, coupled with increasing production of bricks. An increase in soil temperature at brick kiln sites not only changes the physicochemical properties of soils, but this change also influences the population of soil organisms. Almost 25–30 years are required to make the land productive again, whose topsoil has been used for brick production. Each kiln uses 350 tons of wood as fuel every year, which can end up with destructive consequences (Bhat 2017). Brick kilns can produce both short- as well as long-term effects on environmental health. Reduced vegetation, fruit fall, and their spoilage together with decreased production of crops are some short-term impacts while ozone layer depletion, decline in soil fertility and productivity, smog formation, and heavy metal contamination are long-term effects of kilns.

Heavy metals like lead, zinc, chromium, cadmium, and antimony are present in an adequate amount in the fuel used in brick kilns, i.e., wood, tires, coal, and poor-quality furnace oil. Combustion of all these materials as fuel for kilns contributes in air pollution and heavy metal contamination (Ismail et al. 2012). Soil can retain a substantial amount of lead, chromium, manganese, zinc, and nickel if irrigated with contaminated waters. The contaminated soil and groundwaters pose a major health risk for living beings (Ismail et al. 2012) as these contaminants are notorious for their chemical and biological impacts (Bhat 2017; Khan et al. 2019).

Plants are proven to be more sensitive towards such contaminations than humans or animals (Azim et al. 2013). Basically manganese, zinc, copper, nickel, and iron are the micronutrients for plants, but these can prove dangerous above certain levels and their excess in the surroundings is a source of pollution. The investigation by Bhat (2017) reveals the role of brick kiln industry in respiratory disorders. Dust exposure is a factor responsible for respiratory irritation and inflammation as well as cardiovascular diseases (Guttikunda et al. 2013). An increase in temperature is responsible for the destruction of micro soil flora. The respiratory system is commonly damaged through the entry of pollutants via inhalation. The polluted air could be a cause of breaking down of our natural body defense mechanism, making humans sensitive to respiratory disorders like asthma, bronchitis, emphysema, and lung cancer. Air pollution can also adversely affect our blood circulatory system and CNS (central nervous system) (Bhat 2017).

Red bricks are produced using common sources of energy, i.e., biomass (Alam 2006). An increase in the demand for bricks has led to the use of varying types of fuels as wood is sometimes unavailable or nonsustainable source. In view of such situations, the pollutant types change and increase depending upon the type of fuel used. This also ends up with loss of productive land, nutrient, and humus depletion from the soil. An increase in soil erosion is other significant impact of brick kilns on the environment.

52.2 Types of Brick Kilns

52.2.1 Bull's Trench Kilns (BTC)

These are huts like brick kilns. The source of the fire is low-quality coal, shells, rice husks, mustard threads, and old tires. These kilns are usually built by digging the soil. The base of the kilns has twelve valve like structures which burn two rounds of bricks at a time. These are built underground to reduce heat loss thereby contributing significantly to air pollution, primarily due to the release of suspended particles ($PM_{2.5}$, $PM_{10,}$ and black carbon) during the dry season (Fig. 52.1). Such types of

Fig. 52.1 A typical Bull's trench brick kiln from Pakistan

brick kilns are common in Pakistan, Afghanistan, India, and Nepal (Abdalla et al. 2012).

52.2.2 Fixed Chimney Kiln (FCK)

It is a modified shape and form of bull's trench kilns. These too are common in Asia, mainly used in the dry season having a constant fire. In FCK, fire always moves to the direction of wind. It has a stable operation system that produces strong winds accelerating the combustion process. Such kilns contribute significantly to air pollution by introducing CO_2, PM, SOx, and NOx, which affect the quality of air and adversely the soil, plants, and humans. The length of FCK is the same as that of the BTC, but the width is much larger than the BTC for the underground pipes. On the edges of the FCK there is better insulation than BTC, which usually reduces the loss into the surroundings.

52.2.3 Habla or Zigzag Kiln

These measure 75 × 24 m in size and are 16.5 m tall. They have a fan used to inject atmospheric fluxes. The blower is used to heat the furnace gas from the furnace which is releasd into the atmosphere under a chimney. There are different rooms in the hearth, the exhaust gases follow a zigzag path, due to the particular structure of different parts in these kilns. The furnace is reported to save 15–20% more fuel than BTK.

52.2.4 Hoffman Kiln

These are rectangular in shape, extensively used to make bricks. These kilns are divided into several parts and the brick travels through the honeycomb to the brick socket and goes in the opposite direction. The top of the stove is a judge with a fire extinguisher. Its ovens or ring stoves are rectangular, usually used to make bricks. It is divided into several parts and is related to the installation and uninstallation of building parts. The brick travels through the honeycomb to the brick socket and goes in the opposite direction. The top of the stove has a judge with fire extinguisher. To reduce environmental damage, walls of such kilns are sealed and insulated.

52.2.5 Vertical Shaft Brick Kiln (VSBK)

This technology has been produced by China and these are in the form of a rectangular stove. The gap between the furnace wall and the outer wall of the furnace is filled with rice husk or clay. This technology consumes less fuel and produces less gas. VSBK has been running for many years. In Pakistan, the media, also known as Bathi, uses agricultural wastes and is common in Pakistan's rice-growing areas.

52.2.6 Hathras Brick Kiln

Very commonly found in Pakistan in which people use firewood or natural gas. According to the report by USAID (1991), these kilns are widespread in Pakistan due to the use of readily available agricultural wastes such as rice husks, bark, cow yarn, and plant roots. Their disadvantages are combustion temperature required to bake bricks from 900 to 1000 °C, which is usually not achieved as such production is as low-quality bricks. Another type of Bathas brick oven is prevalent. Coal, natural gas, cabinet oil, old tires, and wood are often used as sources of fire. Workers engaged in brick kilns are responsible for digging, distributing water, molding, laying, burning, and transporting.

52.3 Types of the Raw Materials Used

52.3.1 Coal

Low-quality and sulfur-containing coal is cheaper than crude oil and natural gas, so it plays a vital role in the fuel used in brick kilns around the world. Coal-burning has become a critical environmental issue due to its pollution, which is life-threatening. Emissions from the combustion of sulfur, nitrogen, carbon, and volatile organic compounds (VOCs), ozone gas exposure on the ground, rise in soil pH, eutrophication, global warming, and VOCs can be harmful to agriculture, water, and health. It is estimated that half a ton of coal is needed to produce a thousand bricks.

52.3.2 Woodfire

Shisham, Ber, Eucalyptus, and their sawdust from Multan, Muzaffargarh, and Chichawatni are used as fuel. The use of wood as fuel produces 52% less atmospheric particles than other fuels.

52.3.3 Old Tires

The burning of old tires is also widespread in brick kilns, but these result in emission of considerable amount of zinc in the atmosphere. Bhat (2017) have reported that burning of rubber tires as fuel results in the emissions which include carbon, fine dust particles, hydrocarbons, sulfur dioxide, nitrogen oxides, fluorine compounds, and small amounts of carcinogenic dioxins.

52.3.4 Motor Oil

It is used as a lubricant in automobiles, but when used as a fire source in a brick furnace, it produces large amounts of toxins, like polycyclic aromatic hydrocarbons, lead, zinc, and arsenic, thereby contributing much in the pollution.

52.3.5 Plastic Bottles

Use of plastic bottles in brick kilns contributes towards the release of chloride, phosgene, and acrylonitrile into the atmosphere.

52.3.6 Saw Dust

This is a better source of fuel than wood due to the lack of water and the density of the material. After the fire is opened, there is very little ash (about 1.5%) in the bark briquettes, and up to 50% of the ash remains with the use of wood.

52.3.7 Rice Husk

Rice husks are agricultural waste from rice-growing areas. These are among the foremost leading products in the milling process and account for 20% by weight. The rice husk consists mainly of lignocellulose and silicon and has excellent potential as an energy source.

52.4 Impacts on Soil Health

The land used for making bricks is generally a highly productive area (Ozturk et al. 1995, 2011), generally run by rich families. Poor farmers consider it beneficial to relinquish their land for 3–4 years for quick earnings. However, when the bricks are formed, 1.2–1.8 m of the fertile soil, which supports plant growth by supplying nutrients is removed/polluted. Nearly 0.003 m^3 soil volume is used in the production of 1 brick. Brick kilns take an average of 4–5 rounds a year. In one cycle, 4 ha of land upto a depth of 1.2 m is used to produce one million bricks. Thus, one brick kiln consumes an average of 12,000 m^3 of fertile soil to produce four million bricks a year. These kilns are among the biggest sources of environmental pollution, adversely affecting both the soil and air quality (Hakeem et al. 2015). Inspite of the rise in brick prices, their production is increasing tremendously. These kilns cause an increase in the temperature of the area, which affects the physicochemical properties of the soil, air quality, and the diversity of life in agricultural soils. The high temperatures caused by the production of bricks also destroy the microbial community beneficial to the soil. High-temperature environments are dangerous not only for humans but also for animals. It also has a detrimental effect on brick workers, children, and women (Guttikunda et al. 2013).

Heavy metals like cadmium, chromium, lead, manganese, and nickel released from the furnace chimneys leak into the soil and stay there for a long time, ultimately moving down to water sources. With the passage of time, a considerable amount of metals accumulate in the biosphere. Out of these lead, cadmium, and chromium can live longer in the soil. They therefore quickly reach toxic levels in the surrounding environments (Shaikh et al. 2012). Regardless of the source of metals lead, cadmium, and chromium contamination is a concern due to their longevity in the soil. Rural and urban areas are ideal for their accumulation.

52.5 Brick Kiln Emissions

The type of furnace, the fuel used, and the operating conditions of the furnace are factors that influence the change in brick furnace emissions. In the process of making bricks, the oxides C, N, and S are released together with the particles and hydrocarbons, which can adversely affect the environment (Ishaq et al. 2010). The types of emissions from brick kilns largely depend on the type of fuel used. Most common fuels are; forest trees, engine oils used in recycled paper, solid waste, and so on. The brick kilns also produce halogen gases (chlorine, fluorine, and bromine) as well as other toxic gases. The emissions from the kilns mostly contain SOx, NOx, and CO. The kilns at the same time produce dust particles, hydrocarbons with nitrogen, sulfur, and carbon monoxide, including carcinogenic dioxins. Sulfur oxides dissolve in water and adversely affect the upper respiratory tract (Table 52.1). The Cancer Research Institute has included H_2SO_4 in the carcinogenic group 1.

Table 52.1 Emissions from the brick kiln clusters in some Asian countries

Country	Type of brick kilns	Energy source	Emissions
India	Fixed and moving chimney Bull's trench	Firewood, rice husk, dung, coal, and lignite	CO_2, CO, SO_2, NOx, particulate matter (PM)
Bangladesh	Fixed chimney bull trench kilns, Hoffman and zig Zag kilns	Coal and agricultural waste	$PM_{2.5}$, CO, SO_2, NOx, heavy metals
Jammu & Kashmir	Bull's trench kilns	Coal, slack coal, lignite	SO_2, NOx, PM, and black carbon
Sudan	Clay brick kilns	Coal, wood, crop residues, natural gas or oil.	CO_2, CO, SO_2, NOx, F, PM
Nepal	Single chimney; double chimney; No chimney brick kiln	Woods, recycled motor oils, coals, fuel oils, diesels, tires, trashes, and plastics	CO_2 emissions; air pollution in the form of CO, SPM, SO_2, HF emissions
Pakistan	Green brick making Bull trench kilns	Coals, waste, wood Old rubber tyres, low-quality coal, wood, and used oil	Dust, gases, and other particulates

Plants and aquatic systems are adversely affected by the toxic chemicals released by the brick kilns. Due to their poor structure, incomplete combustion of burning materials, the production of carbon monoxide increases and at the same time increases the risk of cardiological failures in humans.

52.6 Impacts on Plants

The brick furnace is the main source of fluorides (F) in the atmosphere. Fluoride in the form of hydrogen fluoride (HF) is toxic to plants (Guttikunda et al. 2013). It is released from the brick ovens are absorbed by the upper parts of the plants then enter directly into the plant metabolism. The fluoride compounds impair the photosynthetic process and cause a damage to it, eventually affecting growth of crops. A survey conducted by Ahmad et al. (2012) in Peshawar city of Pakistan has revealed that when apricot, plums, and mango are exposed to brick kiln emissions, they show severe pollution symptoms, such as burning of foliage and burning of lime ends. Mango, apricots, and pumpkins are most affected near the brick fireplace, with more damage to the outer surface of mature trees and apricot trees compared to the younger and more shaded interior of the BKF sites. A decline in the growth of the fruit too has been observed together with scars on the ripe fruits. However, the black carbon produced from brick kilns contains dust, which too can have detrimental effects on surrounding vegetation. When dust falls on branches, it blocks the pores and affects normal gas exchange, thus greatly affecting the photosynthesis rate. (Sheikh et al. 1976).

The effects of kiln emissions significantly affect the vegetation cover but the severity of effects is based on the duration of exposure to the emissions. The depositions close the pores, thus preventing gas exchange. There is also release of toxic gas into the plant tissues which affects growth. These are the basis for assessing the damage caused by kiln smoke. The reduction in the growth of a stem is direct indication of the harmful effects of smoke. Skinder et al. (2014) have studied the effects of Kiln emissions on the vegetables in Kashmir Basin. They report that kiln emissions have a negative impact on the growth and quality of *Brassica* and *Solanum* species.

52.7 Harmful Impacts on Human Health

The health issues resulting from immediate and short-term exposure to SO_2 emitted from the kilns include instant bronchial constriction, respiratory contraction, enhanced pulmonary resistance, increased reactivity in the respiration. In contrast, issues resulting from long-term exposures include inflammation of mucosal tissues and increased secretory activity (Fig. 52.2).

The most common route of entry for the pollutants is the inhalation through mouth and nose, and it adversely damages the respiratory system. Long-term exposure to air pollution results in an overload of pollutants adversely damaging the natural defense mechanism of the body against diseases, causing severe disorders of respiratory systems such as asthma, lung cancer, severe bronchitis, etc. (Table 52.2). Air pollution can also severely affect our body systems along with respiratory defects such as the nervous system and cardiovascular system.

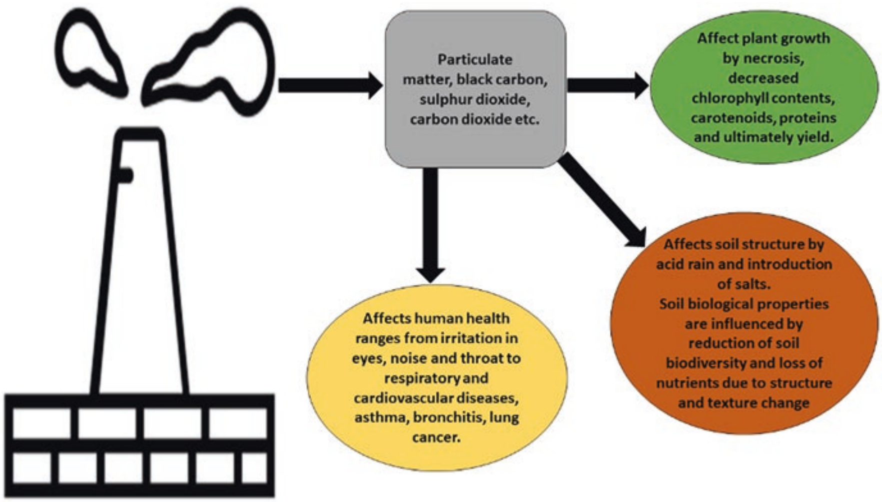

Fig. 52.2 Harmful effects on the human health from brick kiln emissions

Table 52.2 Data on the health effets from Brick Kiln emissions in some Asian countries

Country	Brick Kiln health effect	References
Nepal	Nasal, abdominal abnormalities in childrens	Joshi and Dudani (2008)
Pakistan	Respiratory diseases	Shaikh et al. (2012)
India	Smog, respiratory diseases, asthma	Guttikunda and Goel (2013) and Singh and Asgher (2005)
Bangladesh	Irritations, pulmonary and respiratory diseases, asthma	Motalib et al. (2015)
Mexico	Respiratory diseases, asthma	Blackman et al. (2006)
Croatia	Chronic cough, chronic phlegm, chest tightness	Zuskin et al. (1998)
Sudan	Eye, lungs, and throat infections	Alam (2006)

Inhalation of noxious substances in the workplace leads to the development of short- and long-term pulmonary diseases like obstructive inhalation disorders, toxic lung injuries. Long-term exposure to urban air pollution is responsible for shortened life spans and disturbed lung functioning. In several cases, symptoms of tuberculosis have been recorded in the wokers of brick kilns (Shriraam et al. 2020).

Brick kiln emissions produce large amounts of sulphur dioxide due to the burning of low-quality fuel. Exposure to it in ambient air results in a disturbed lung function, increase in the incidence of respiratory diseases, irritation of ENT (eyes, nose, and throat), and early death. Under rainy conditions SO_2 forms H_2SO_4 which binds to the surface of particles in the air; minor the particle size greater is the surface area for attachment and higher the capability to enter into the plants and lungs affecting these severely (Sagdas and Ozturk 1991; Guttikunda et al. 2013). SO_2 is reported to stay in lungs for 7 days or more. Once in the body, it gets dissolved into the liquid surface of the respiratory system as sulphite and bi-sulphite which pass into respiratory tract cells and get dispersed throughout the body (Shaikh et al. 2012). The brick production is thus playing a vital role in developing respiratory diseases. Ahmad et al. (2012) have reported that there is high incidence of chronic cough (31.8%), chronic phlegm (26.2%), and chest tightness (24%) in the workers exposed to pollution from brick kilns compared to the workers (20.1, 18.1, 0%) in other factories. This increase in the frequency of prevalence has also been documented among nonsmokers investigated by age and duration of employment. The people who are at the most risks for respiratory issues are kids, elderly persons, and the persons already suffering from such issues. Health impacts from air pollution are also linked with short-term exposure to ambient concentrations above 1000µg/m^3(short-term exposures calculated over 10 min). In Larkana and Dadu districts of Sindh in Pakistan, Shaikh et al. (2012) have reported that 22.4% of brick kiln workers suffer from chronic cough, 13.8% suffer from strokes such as shortness of breath two or more times, and 17.1% of workers suffer from chronic bronchitis. However, in 8.2% doctors have diagnosed asthma. Among nonsmokers, 8.9% suffer from chronic bronchitis. Multivariate analysis has revealed that workers engaged in brick burning suffered much more from chronic bronchitis and asthma compared to workers engaged in transportation and placement.

A report by Misra et al. (2020) suggests that total suspended particles are contributed by different sources like cement factories 36%, brick kilns 31%, domestic fuel combustions 14%, road resuspensions 9%, and vehicle exhaust 3.5% in Kathmandu valley. The kilns are the second largest contributors towards TSP. PM_{10} particulate matter of size 10 microns also severely damages the respiratory system, and these are contributed upto 28% by brick kilns, the second-largest contributor towards it. EPA has defined TSP as tiny air-borne particles or aerosols as less than 100-micron in diameter. Poorly designed brick kilns result in incomplete combustion of coal, which results in the emission of toxic gases (SO_2, NO_x, CO), hydrocarbons, and fluoride compounds along with particulate matter. It is reported that brick kilns mostly produce $PM_{2.5}$ in Bangladesh. This highly fine particulate matter is considered highly dangerous to human health as it can travel longer distances and cause severe respiratory ailments and even premature deaths (Guttikunda et al. 2013). The people who are at risk from PM include elderly ones and children than any other aged people, because during these ages disease prevention mechanisms are weaker. American lung association has conducted research and found that rate of premature deaths resulting from PM in the air has increased 3 times compared to previous surveys conducted. Health surveys suggest that more vulnerable are those people living near brick kilns as compared to those who live away from these areas. Same is the case with school children in which children near kilns have a worse condition of health and are more vulnerable to the prevalence of respiratory tract disorders like pharyngitis and tonsillitis. Maithel et al. (2012) have reported that dust exposure of people engaged in work is a risk factor for short-term and long-term respiratory irritation, inflammation of breathing ways, and incidence of cardiovascular diseases. There is considerable evidence about elevated amounts of carbon monoxide causing unwanted health effects on CNS and finally resulting in occasional headache, nausea, exertion, and breath disturbance.

Many studies have revealed a correlation between increased disease and death rate and enhanced levels of airborne dust particles (Wei and Yang 2010). The epidemiological studies of the rapid deterioration of air quality in many countries around the world have shown an increase in bronchitis, asthma, cough, eye irritation, decreased lung function, emphysema, fibrosis, and allergic rhinitis, and low birth weight (Table 52.2).

The heavy metals associated with kiln emissions too result in short- and long-term adverse health effects, mostly related to the respiratory disorders, heart issues, lung cancer, and damage to other organs. Many studies conducted in the mining areas have shown high concentrations of particulates in ambient air (Islam et al. 2020) together with the oxides of carbon, nitrogen, and sulfur. All these lead to decreased functioning, increased headache, pneumonia, muscle fatigue, dizziness, and emphysema. The function of brain and heart is also influenced by such pollution. There is evidence that SO_2 and particulate matter are more deadly in combined form as compared to their individual occurrence. Data show that a higher percentage of workers at such workplaces do not use personal protective equipments which lead to the incidence of respiratory disease symptoms among them (Shaikh et al. 2012).

52.8 Pakistan as a Case Study

The fast development of the construction business in Pakistan has lead to the development of more and more brick kilns in the peripheries of urban areas. A huge quantity of poor-quality coal, wood, rubber tires, or wood is used as fuel in an inefficient way. These are the primary sources of heavy metal input into the environment (Bhat 2017). A survey has been conducted to assess the presence of cadmium and lead in the soil, water, plants, coal, and ash. Thirty samples from the brick oven were collected from 5 to 10 m distance and 0–15 cm depth. Brick kilns emissions move from Faisalabad city to suburbs. Therefore the soil plants and water samples from each site were collected based on the availability. The heavy metal damage at the brick oven sites indicated that cadmium and lead are present in the ranges from 0.02 to 0.66 and 0.30 to 8.6 mg kg^{-1}, respectively. In plants, these were in the range of 0.060–0.078 and 0.11–0.084 mg kg^{-1}; in the fuel used in the range 0.002–0.0418 and 0.011–0.053 mg kg^{-1}. The concentration of cadmium and lead in the ash samples was within the range of 0.003–0.043 and 0.002–0.059 mg kg^{-1}, while the concentrations in the ash sample were lower.

52.9 Emissions Control and Remedial Measure for Brick Kilns

To reduce the impact of air passing through the kilns, several initiatives are taken using advanced kiln techniques (e.g., tunneling above the kilns) or a lemon chair. The latest technologies are the command and control (CAC) approach and the market-based tool (MBI). For emissions control of CO, $SO_{2,}$ and PM; these techniques are available for emission reduction along with centralized furnaces. The amount of smoke released by the kilns at a given stage decides the amount of fee in the form of MBI. Other techniques for reducing brick kiln emissions include managing the number of kilns. The study has shown that about 7 kilns operate simultaneously, but on different working days, the maximum permissible environmental level of 10 × 10 km^2 does not exceed the corresponding NAAQS values for CO, TSP, and SO_2. A simple lime scrubber with an efficiency of about 50% can also be used. Zigzag technology and vertical brick furnaces show better performance in terms of emissions than a conventional stable chimney. This suggests that the replacement of conventional technology with Zigzag or vertical brick furnaces or other cleaning furnace technologies has a potential to contribute to environmental improvement. ZigZag furnaces seem to be a logical substitute due to their small investment, easy integration into the existing manufacturing process, and ability to transfer a stable pit furnace to Zigzag combustion (Rajarathnam et al. 2014). For the past 2 years, Pakistan's EPD has focused on the use of zigzag technology to reduce smog and environmental pollution.

References

Abdalla I, Abdalla SB, El-Siddig K et al (2012) Effects of red brick production on land use, household income, and greenhouse gas emissions in Khartoum, Sudan. J Agric Rural Dev Trop Subtrop 113:51–60

Ahmad MN, van den Berg LJ, Shah HU et al (2012) Hydrogen fluoride damage to vegetation from peri-urban brick kilns in Asia: a growing but unrecognised problem? Environ Pollut 162:319–324

Alam SA (2006) Use of biomass fuels in the brick making industries of Sudan: implications for deforestation and greenhouse gas emission. Department of Forest Ecology University, Helsinki, pp 16–17

Azim MR, Mahmood Q, Ahmad SS (2013) Risk evaluation of brick kiln smoke to kidney bean (*Phaseolus vulgaris*). Pak J Bot 45:1403–1406

Bhat S (2017) Brick kilns threaten life and agriculture in Budgam. Kashmir Read 2:1–2

Blackman A, Shih J-S, Evans D et al (2006) The benefits and costs of informal sector pollution control: Mexican brick kilns. Environ Dev Econ 11(5):603–627

Guttikunda SK, Goel R (2013) Health impacts of particulate pollution in a megacity-Delhi, India. Environ Dev 6:8–20

Guttikunda SK, Begum BA, Wadud Z (2013) Particulate pollution from brick kiln clusters in the greater Dhaka region, Bangladesh. Air Qual Atmos Health 6:357–365

Hakeem KR, Sabir M, Ozturk M, Mermut A (2015) Soil remediation and plants: prospects and challenges. Academic Press/Elsevier, London/Waltham

Ishaq M, Khan MA, Jan FA, Ahmad I (2010) Heavy metals in brick kiln located area using atomic absorption spectrophotometer: a case study from the city of Peshawar, Pakistan. Environ Monit Assess 166:409–420

Islam M, Jayarathne T, Simpson IJ et al (2020) Ambient air quality in the Kathmandu Valley, Nepal, during the pre-monsoon: concentrations and sources of particulate matter and trace gases. Atmos Chem Phys 20(5):2927–2951

Ismail M, Muhammad D, Khan FU et al (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

Joshi S, Dudani I (2008) Environmental health effects of brick kilns in Kathmandu valley. Kathmandu Univ Med J (KUMJ) 6(1):3–11

Khan MW, Ali Y, De Felice F et al (2019) Impact of brick kilns industry on environment and human health in Pakistan. Sci Total Environ 678:383–389

Maithel S, Uma R, Bond T et al (2012) Brick Kilns performance assessment, emissions measurements, & a roadmap for cleaner brick production in India. Study report prepared by Green Knowledge Solutions, New Delhi, India

Misra P, Imasu R, Hayashida S et al (2020) Mapping Brick Kilns to support environmental ımpact studies around Delhi using Sentinel-2. ISPRS Int J Geo Inf 9(9):544

Motalib MA, Lasco RD, Pacardo EP et al (2015) Health impact of air pollution on Dhaka city by different technologies Brick Kilns. Int J Technol Enhanc Emerg Eng Res 3(05):127

Ozturk M, Guvensen A, Yucel E (1993) Nature conservation, air pollutants and ecosystems. Air pollution II National Symposium. Anadolu University, Eskisehir, pp 265–269

Ozturk M, Guvensen A, Ozdemir F et al (1994a) Soil resources and toxic wastes. Ege Univ Sci Fac J 16(1):59–65

Ozturk M, Guvensen A, Ozdemir F, Ozcelik H (1994b) Plants and particulate pollution. Ege Univ Sci Fac J 16(1):315–322

Ozturk M, Erdem U, Butuner H, Dalgic R (1995) Non-agricultural use of land in Turgutlu-Gediz Basin. I Gediz Basin Erosion and Env Symposium, Turkey, pp 354–369

Ozturk M, Mermut A, Celik A (2011) Land degradation, urbanisation, land use & environment. NAM S & T, New Delhi

Rajarathnam U, Athalye V, Ragavan S et al (2014) Assessment of air pollutant emissions from brick kilns. Atmos Environ 98:549–553

Sagdas D, Ozturk M (1991) The effects of acid rain on the growth and development of *Hordeum vulgare*, *Vicia faba* and *Spinacia oleracea*. I Intern Env Protect Symposium, Izmir, Turkey, pp 132–140

Shaikh S, Nafees AA, Khetpal V et al (2012) Respiratory symptoms and illnesses among brick kiln workers: a cross-sectional study from rural districts of Pakistan. BMC Public Health 12(1):999

Sheikh KH, Ozturk M, Secmen O, Vardar Y (1976) Field studies of the effects of cement dust on the growth and yield of olive trees in Turkey. Environ Conserv 3:117–121

Shriraam V, Srihari R, Gayathri T, Murali L (2020) Active case finding for tuberculosis among migrant brick kiln workers in South India. Indian J Tuberc 67:38–42

Singh AL, Asgher MS (2005) Impact of brick kilns on land use/landcover changes around Aligarh city, India. Habitat Int 29(3):591–602

Skinder BM, Sheikh AQ, Pandit AK, Ganai BA (2014) Brick kiln emissions and its environmental impact: a review. J Ecol Nat Environ 6:1–11

USAID (1991) Quarterly Progress report, 1 October to 31 December 1992. Forestry planning and development project, Govt. of Pakistan-USAID. USAID, Winrock International, Islamabad

Wei B, Yang L (2010) A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. Microchem J 94(2):99–107

World Bank (2011) Introducing energy-efficient clean technologies in the brick sector of Bangladesh. https://doi.org/60155-BD

Zuskin E, Mustajbegovic J, Schachter EN et al (1998) Respiratory findings in workers employed in the brick-manufacturing industry. J Occup Environ Med 40:814–820