Review Article

Ambient air quality with emphasis on roadside junctions in metropolitan cities of Pakistan and its potential health effects

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Keywords:
Ambient Air, Particulate Matter, Heavy Metals, Health Effects

Funding
None

Competing Interest
None declared.

Received: July 2, 2012
Accepted: August 26, 2012

Abstract

Underdeveloped countries are undergoing economic development at a rapid rate, which most often correlate with elevated urban air pollution in many cities. Pakistan is amongst those countries that are going through this industrialization phase and with a great increase in motorization and use of energy. According to the WHO[1,] two third of the deaths in year 2000 were caused by exposure to urban air pollution in developing countries of Asia. To provide estimates of the quantitative relation between exposures and occurrences of diseases, epidemiologic studies together with toxicological and clinical investigations are required. Owing to limitations of the available epidemiologic and environmental studies in Pakistan, no authentic correlation among afore said factors can be made. This review is based upon peer-reviewed literature on the adverse health effects of air pollution in Pakistan and other major cities around the World. On the basis of this review it is possible to assess the status and to determine the trends in air pollution sources, emissions, concentrations, and exposures in four metropolitan cities (Karachi, Lahore, Rawalpindi, and Peshawar) of Pakistan.

Environmental pollution in these cities is analyzed in terms of Particulate Matter (PM) and derived particle mass concentrations. Detected 24 hour averaged PM_{10} and $PM_{2.5}$ concentrations in all four cities are up to 6 times higher than the maximum PM concentrations recommended by the WHO guidelines. The low $PM_{2.5}/PM_{10}$ ratios revealed a high proportion of coarser particles, resulting in reduced visibility. The heavy metal concentrations from various studies are also presented for comparison with the standards set in the world.

Introduction

Due to rapid industrial growth, urbanization and hence increase in traffic volume over the last few decades, under developed countries like Pakistan have undergone substantial increases in terms of emission sources of air pollutants. Important anthropogenic sources that contribute to the drastic rise in urban values of airborne particulate matter (PM) emissions originating not only from incomplete combustion, such as vehicular traffic, factories, refineries and wood burning but also from large scale construction activities. Soaring population densities of metropolitan areas either by migration or natural growth has resulted in an unprecedented rise in traffic volume and construction activities, which ultimately have resulted in severe environmental impacts.[2] Consequently, air pollution has emerged as one of the most significant threats to urban environments, quality of life and health of the population in the affected areas where emission control technologies, strategies and legislative standards are hardly implemented.

Particulate matter is considered as a prime pollutant of concern for mega cities. This prompted Gurjar et al.[3] to declare Karachi as one of the most polluted megacities in the world and with regards to PM concentrations ranking at the fourth place. Similarly, Aziz and Bajwa[4] estimated that inappropriate operation for example, incomplete combustion due to the mass-transit system in Lahore is responsible for an additional 23–26% release in noxious CO. They also found a strong correlation between the mass-transit system and urban air pollution.[5] Parekh et al.[6] measured the average daily TSP concentrations at Karachi and Islamabad and found concentrations to be 4 to 8 times higher than the WHO guidelines. Follow-up investigations in metropolitan areas of Pakistan conducted by Ghauri et al.[7] confirmed the

ISSN (print): 2218-3299
ISSN (online): 2219-8083

high total suspended particulate (TSP) load and PM_{10} levels as recorded by Parekh et al.[6] – both nicely correlate it with traffic density.

The alarming high TSP and PM concentrations indeed pose severe threats to the local population (e.g. street vendors and small business entrepreneurs) while working in these environments without proper precautions). Several studies have shown that chronic exposure to air pollutants is directly correlated to cardiovascular disorders,[8,9] asthma,[10] chronic obstructive pulmonary diseases such as bronchitis/emphysema,[11] and other respiratory diseases.[12] Heavy metals present in suspended PM are considered to be a health hazard since they are readily absorbed by the lung tissues. Toxicological in vitro and in vivo studies have shown that metals are harmful components of PM as they can cause different cardiovascular and lung diseases.[13] In addition, these observed adverse effects persist even several weeks after exposure. Hence, the purpose of the review article is to highlight the rapidly deteriorating air quality in metropolitan cities of Pakistan. This review also tackles harmful airborne heavy metal concentrations and their health effects. Finally, international practices to control environmental pollution and some suggestions to improve the environmental condition in Pakistan are also provided.

Metropolitan cities of Pakistan

Karachi

It is the largest city of the country with more than 16 million people. As shown in Figure 1, Karachi is located in the south of Pakistan (Lat: 24° 51'N; Long: 67° 02' E). It lies on the flat, sandy coast facing the Arabian Sea just north of the Indus River delta. Its climate is a relatively mild, subtropical/arid with low rainfall (mean annual rainfall 250 mm). The maximum temperature during summer (Apr-Aug) and winter (Dec-Feb) ranges from 30 to 44 °C and from 12 to 25 °C, respectively. Parekh et al.[6] and Khwaja et al.[14] created a map of Karachi that points out the main industrial, residential and commercial areas of the city. Major industries include textiles, pharmaceutical, cement factories, oil refineries, automobiles, chemicals, heavy machinery, shipbuilding and a steel mill.

Lahore

It is the capital of Punjab province and the second largest city of Pakistan with a population of approx. 10 million people. It is situated (Lat 31° 32'N; Long 74° 22' E) along the Ravi River near the border to India. The climate in Lahore is hot semi-arid with rainy and extremely hot summers and dry winters. The temperature in summer ranges between 36 and 46 °C. The major industries in Lahore include automotive and motorcycling manufacturers, as well as the steel, chemicals, pharmaceuticals, engineering, and construction sectors.

Rawalpindi

It is the 3rd largest metropolitan city of Pakistan with a population of 4.5 million and situated in Punjab province (Latitude 33° 40'N and Longitude 72° 30'E) (Figure 1). The climate of

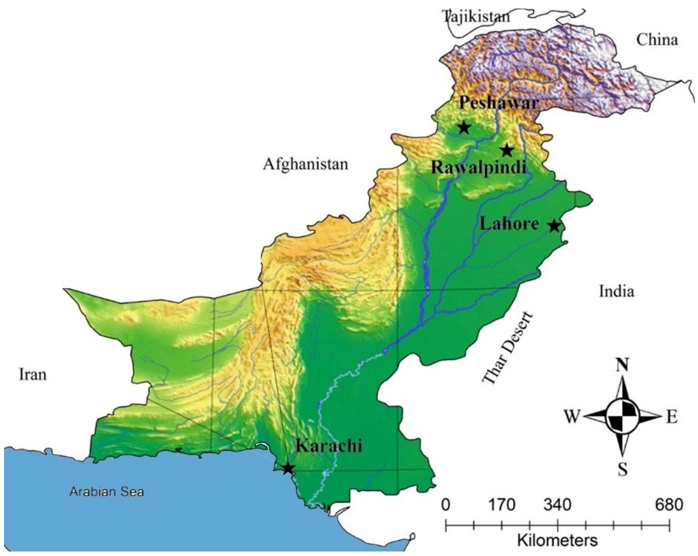

Figure 1: Map of Pakistan showing locations of metropolitan cities under discussion.

Rawalpindi is humid subtropical with hot summers and mild wet winters. The mean maximum temperature in summer is 38°C and in winter is 8°C. Rawalpindi houses industries of chemical, textile and metalworking sectors.

Peshawar

Peshawar, the capital city of the province Khyber Pakhtunkhwa is located in the northern part of Pakistan (Latitude 34° 02' and Longitude 71° 37') as shown in Figure 1. The climate of Peshawar is tropical with a mean maximum temperature of 40 °C in summer (May-Aug) and 10 °C in winter (Nov-Mar). The relative humidity varies from 46% in June to 76% in August. Peshawar has a large industrial base including production facilities in the food processing, steel industry, cigarettes, textiles, pharmaceuticals, and cartonage sectors.

PM Concentrations

Particulate Matter (PM) consists of airborne particles with an aerodynamic diameter less than or equal to 10 microns – also called PM_{10}, whereas PM with an aerodynamic diameter less than or equal to 2.5 microns is grouped as $PM_{2.5}$. $PM_{2.5}$ differs from PM_{10} both in origin and chemistry. PM is one of the most often used criteria to describe pollution level in a given area, and is a key player for most adverse health effects. PM originates from a variety of sources, such as power plants, industrial and chemical processes, vehicles as well as agricultural activity. They are also formed in the atmosphere by transformation of primary gaseous emissions. Both PM_{10} and $PM_{2.5}$ are linked with adverse health effects including increasing morbidity and mortality in susceptible individuals.[9]

The adverse health effects of PM prompted governments to establish strategies to control air pollution. Air quality guidelines and standards are developed to reduce adverse impacts on human health and the environment. The WHO recommended guidelines for maximum PM_{10} concentrations are

50 μg/m³ (24-h average), whereas for $PM_{2.5}$ it is 25 μg/m³. The studies that have been conducted in Pakistan over time to evaluate PM-levels used various measurement techniques and equipment. These studies have shown variable concentration level which of course depends on season and time of measurement, local weather conditions and also of the employed equipment. Therefore it is not obvious to inter-compare all of these studies; however a general trend in increase of concentration with the passage of time can be highlighted on the basis of these studies. PM concentrations (24 hour averages) recorded during various studies at metropolitan cites of Pakistan are briefly described here. Ghauri et al.[7] reported four seasonal mean PM_{10} concentration of 193 μg m^{-3} in Karachi, 200 μg m^{-3} in Lahore, 185 μg m^{-3} in Rawalpindi and 219 μg m^{-3} in Peshawar using high volume sampler. Using a high volume sampler, Zhang et al.[15] found PM_{10} concentrations in Lahore that ranged from 158 to 733 μg m^{-3}, with an average concentration of 459 μg m^{-3} during spring season. In a study by Lodhi et al.[16] for $PM_{2.5}$ concentration source apportionment in Lahore using a reference air sampler found mean values of 191 μg m^{-3} and 143 μg m^{-3} in winter and spring respectively. Mahboob and Makshoof[17] using a high volume sampler at Lahore found a 3 days average PM_{10} concentration of 660 μg m^{-3} during the months of April and May. In a recent study by Alam et al.[18] using an optical particle counter documented 24 hour average PM_{10} concentrations of 461 μg m^{-3}, 198 m^{-3}, 448m^{-3}, and 540 m^{-3} for Karachi, Lahore, Rawalpindi and Peshawar respectivey. The corresponding 24 hour average $PM_{2.5}$ concentrations were 185 μg m^{-3} and 91 μg m^{-3}, 140 μg m^{-3} and 160 μg m^{-3} respectively.

The high PM concentrations in all sampled cities have both natural and anthropogenic origin.[16,19] The natural sources contribute mineral dust and sea salt particles, whereas anthropogenic sources include industrial emissions, vehicular emissions, the re-suspension of road dust, construction activities, and biomass burning, which can be seen to have contributed to aerosol concentrations over Karachi and Lahore.[14,16,20] According to Alam et al.[18] air masses that reached Peshawar were from Afghanistan, carried desert dust that added its share to the local anthropogenic aerosol concentrations. Air masses that reached Karachi carried sea salt particles from the Arabian Sea, which combined with industrial and vehicular pollutions to result in the elevated PM concentrations.[18] In order to show the extent of PM concentration in metropolitan air of Pakistan, a global comparison with other mega cities in the world is shown in Figure 2.

$PM_{2.5}/PM_{10}$ ratio

Some of the health outcomes are based on $PM_{2.5}$ rather than PM_{10}. The ratio of $PM_{2.5}$ to PM_{10} is defined to allow permissible limits of fine particles in the air. For urban areas in industrialized nations, $PM_{2.5}$ is 0.50 -0.65 of PM_{10}.[21] Some of unindustrialized nations have also adopted the similar ranges. For example, in China the reported ratio in four major urban locations was in the range of 0.51-0.72.[26] However, in underdeveloped and arid countries with unpaved roads and less vegetation, the ratios are likely much lower due to large proportion of PM_{10}. Hence, for this type of region having high portion of crustal material in ambient air, a lower ratio i.e. 0.5 is assumed.[26] Due to better legislation and execution a higher cleansing factor of 0.65 is applicable in highly industrialized areas like North America, Europe, Japan, Singapore, Australia and New Zealand. However, the use of filters and catalytic converters in these areas result in more combustion-related aerosols that are typically below 1 micron (PM_1).

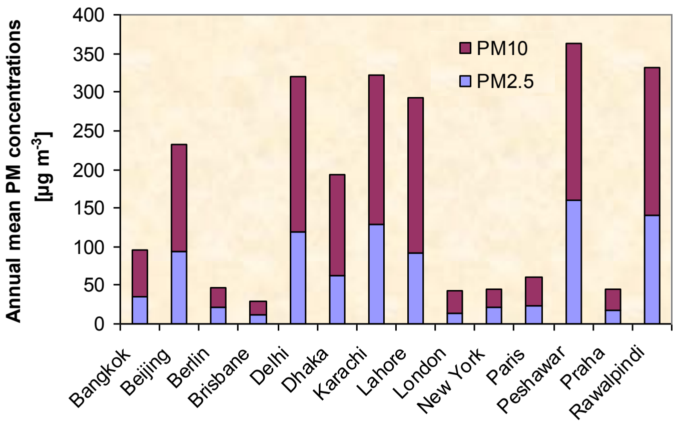

Figure 2: Annual mean PM concentration in selected world cities. Values other than specified are taken from WHO.[22] $PM_{2.5}$ concentration for Karachi, Lahore, Rawalpindi and Peshawar are adopted from Alam et al.[18] $PM_{2.5}$ for Beijing is adopted from Song et al.[23] $PM_{2.5}$ value for Dhaka is adopted from Mahmud et al.[24] $PM_{2.5}$ value for Delhi is adopted from Tiwari et al.[25]

In metropolitan cities of Pakistan the ratio $PM_{2.5}/PM_{10}$ recorded by Alam et al.[18] was 0.4, 0.45, 0.31 and 0.30 for Karachi, Lahore, Rawalpindi and Peshawar respectively. Since they used an optical particle counter with a lower cut-off diameter of 0.25 nm in diameter, a portion of $PM_{2.5}$ mass is missing in the data, leading to lower $PM_{2.5}/PM_{10}$ ratios. Stone et al.[27] recorded a daily ratio of 0.5 in Lahore on 84% of days during a study from January 2007 to 19 January 2008. A comprehensive study tackling $PM_{2.5}$ inventories in various metropolitan cities of Pakistan is still required. An inter-comparison of PM ratios of Pakistani megacities with other megacities around the globe is shown in Figure 3.

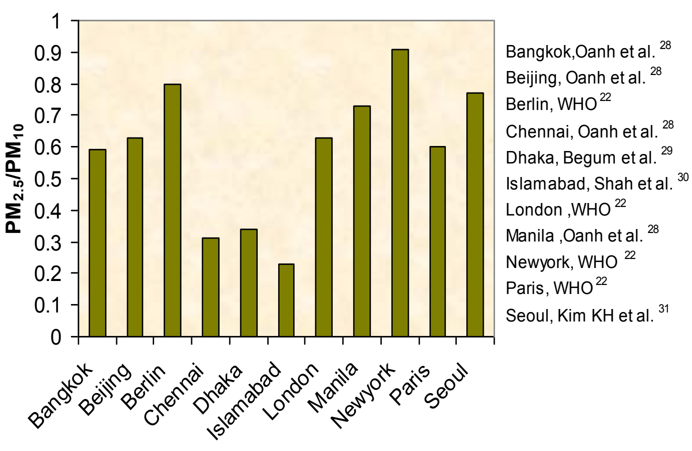

Figure 3: Inter-comparison of $PM_{2.5}/PM_{10}$ ratios among various mega cities of the World.

Mass concentration

In terms of environment and health effects mass concentration measurement is amongst the convenient methods to describe aerosol concentration. The mass concentration is equivalent to the density of the ensemble of aerosol particles in air. Mass concentration can be obtained either by weighing filters before and after sampling using an analytical balance or by using the mathematical expression:

$$M(d_{pi}) = \pi \cdot \rho \cdot d_{pi}^{3} \cdot N(d_{pi})/6$$

where ρ is density, d_{pi} is the diameter and N is the number concentration of particles. The particle mass concentration is usually described by their bimodal distribution i.e. fine and coarse particle. The particles diameter threshold of 2.5 µm is considered as the dividing line between fine and coarse particles. Both the fine and coarse particle mass concentration differ due to their source of formation. Fine particles are usually composed of combustion aerosols i.e. sulfates, nitrates, carbon lead and some trace elements – classical representatives of incomplete combustion. Whereas coarse particle are composed crustal material, silicon compounds, sea salts, Iron and Aluminum etc and usually originate by mechanical means.

In Pakistan, particle mass concentration as measured by Alam et al.[18] found maximum concentrations of 559 µg m^{-3} in Peshawar and 573 µg m^{-3} at M. A. Jinnah Road, Karachi. Whereas in the same study peak concentrations of 318 µg m^{-3} and 523 µg m^{-3} were recorded in Rawalpindi and Lahore respectively. According to this paper, these concentration peaks are directly related to traffic in general, and to heavy traffic in particular. At the sampled sites they also found that coarse particle mass concentrations are about 2-5 times higher than the fine particle mass concentration. In a follow-up investigation, Alam et al.[32] analyzed the physico-chemical properties of aerosols and found that in Karachi these aerosols in fact do originate from vehicular and industrial emission as well as mineral dust. Stone et al.[26] reported that $PM_{2.5}$ in Lahore is predominantly of organic origin and is directly attributable to non-catalyzed vehicle exhaust, diesel and mainly originates from non-catalyzed gasoline vehicles, diesel and residual oil combustion, coal soot, biomass burning, and vegetative detritus.[7,15]

Heavy metals concentrations

Exhaust fuel contains heavy metal including lead, mercury, cadmium, silver, nickel, vanadium, chromium and manganese. Heavy metals cannot be degraded or destroyed. However, they can become airborne, and can be inhaled to bio-accumulate within the human body. Only to a small extent some of these are utilized as trace elements, i.e. are essential

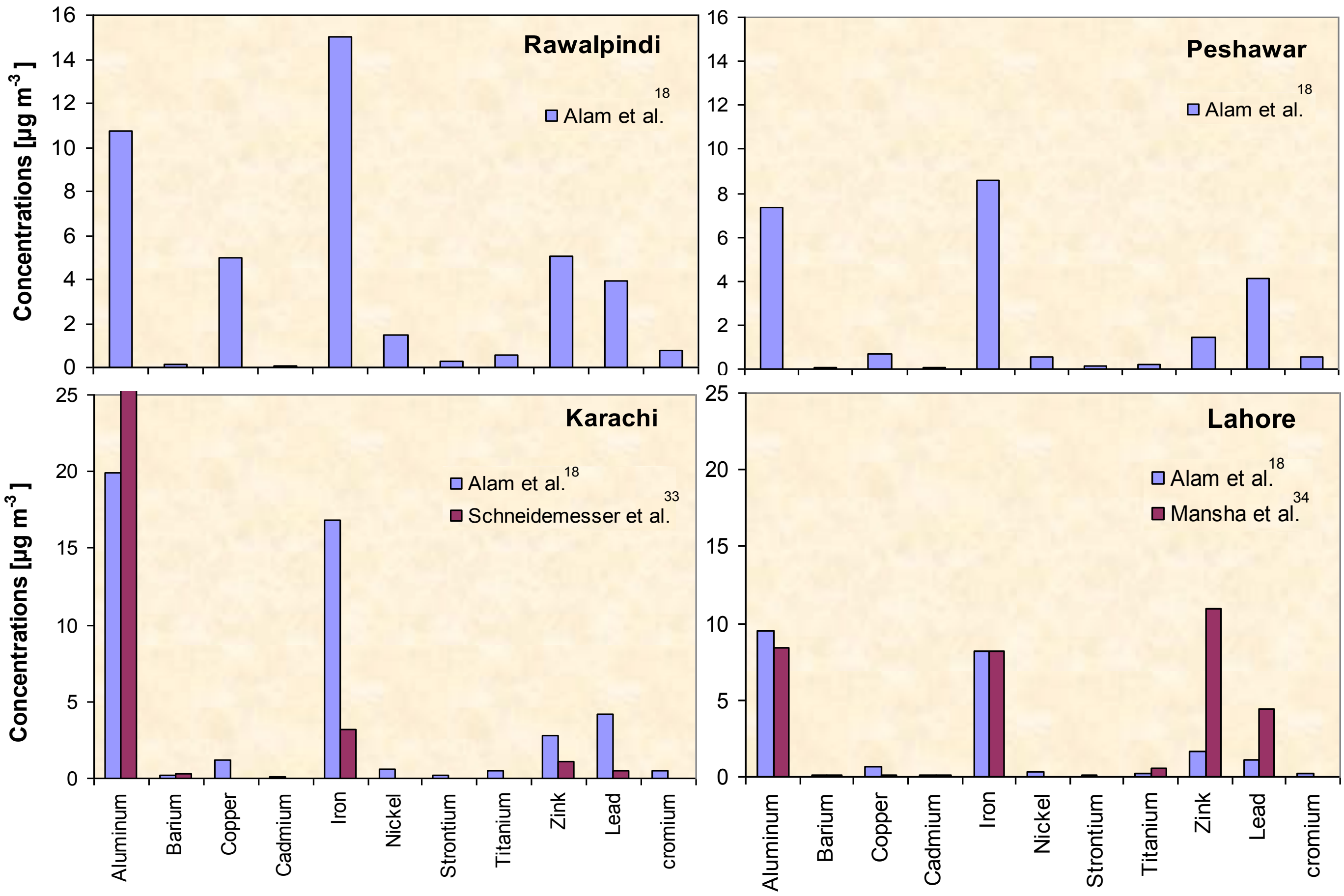

Figure 4: Elemental concentration recorded during various studies in metropolitan cities of Pakistan.

to maintain normal metabolic functions. Although threshold values for the deposited mass of heavy metals in the lung with respect to their location and consequent harmful effect has not yet been thoroughly investigated. However, investigations have shown that at relatively higher concentrations they can be toxic.[35] Previous studies have shown the harm full effects to the lungs caused by the inhalation of the harmful pollutants. Elevated and thus toxic lead concentrations have been reported by Smith et al.[36] and Parekh et al.[37] in urban areas of Pakistan. Alam et al.[18] found concentration of heavy metals in urban air to be 20-40 % higher than the recommended WHO guidelines. Their documented heavy metal concentrations are shown in Figure 4.

Health effects

Several epidemiological studies have linked both PM_{10} and specially $PM_{2.5}$ with significant health problems, including: premature mortality, chronic respiratory disease, respiratory emergency room visits and hospital admissions, aggravated asthma, acute respiratory symptoms, and decreased lung function. Like the other criteria pollutants, the elderly, whose physiological reserves decline with age, as well as children, with their respiratory systems still developing, are most at risk from exposure to particulate matter. Also, individuals with preexisting heart or lung disease and asthmatics are sensitive to PM exposure. Fine particulate pollution ($PM_{2.5}$), is of specific concern because of its larger surface area to volume relationship, it contains a high proportion of adsorbed various toxic metals and acids, and from an aerodynamic perspective it can penetrate deeper into the respiratory tract.[38]

In recent studies Ebersviller et al.[39] has shown that atmospheric gases that are toxic can, through physical/thermal processes, cause non-toxic PM to become toxic. The time scale for these inter-phase dynamics is on the order of seconds. This means that vehicle emissions (and other PM) may not be exceptionally toxic as they enter the atmosphere but, when mixed into an aged or ageing air mass, can change dramatically in composition and biological effect by the time they drift off-road and reach neighbouring general population.[39] Thus, a PM concentrations can become a pre-concentrator and carrier of gas-phase toxics into the regions of the lungs where they may not normally reach and the toxics load can be released even if the PM mass is mostly cleared.[39]

The harmful effects in terms of deposited heavy elements in the pulmonary region can be estimated on the basis of their deposited amount and their specific blood absorption rates. For example, lead toxicity is associated with deficits in central nervous system functioning especially in younger ages. Absorption into blood from the lungs can cause high blood pressure and damage to renal function.[40] Inhalation of Cadmium is identified as a potential human carcinogen, causing lung cancer. Breathing lower levels for years leads to a build-up of cadmium in the kidneys that can lead to severe kidney disease. Other effects that may occur after breathing cadmium for a long time are lung damage and fragile bones.[40] It is difficult to distinguish mercury toxicity symptoms from those of some other common ailments, however acute exposure to mercury has shown adverse effects on the central nervous system, kidneys and thyroid to develop. Long term low level exposure to mercury can cause bronchial irritation, pneumonitis.[41] Occupational exposure to arsenic, by inhalation, is causally associated with lung cancer.[41] Chronic exposure to heavy metal laden air has also been shown to induce epigenetic changes in metal workers .[42]

International practices to control environmental pollution

Controlling environmental pollution of various emission sources and application of emission standards are required in order to set specific limits to the amount of pollutants released into the atmosphere. Many emissions standards focus on regulating pollutants released by automobiles, industry and power plants. Common practices to control pollution are to establish emissions standards through technology i.e. by regulating the emissions of nitrogen oxides (NO_x), sulfur oxides, particulate matter (PM) or soot, carbon monoxide (CO), or volatile hydrocarbons.

In the United States, emissions standards are managed by the Environmental Protection Agency (EPA). The Clean Air Act of 1963 was the first federal legislation regarding air pollution control. It established a federal program within the U.S. Public Health Service and authorized research techniques for monitoring and controlling air pollution.[43] In 1967, the Air Quality Act was enacted in order to expand federal government activities. Enforcement proceedings were initiated to control air pollution and extensive ambient monitoring studies were conducted along with stationary source inspections. This Act also authorized expanded studies of emission inventories, ambient monitoring techniques, and control techniques.[43]

The European Union has its own set of emissions standards that all new vehicles must meet. Currently, standards are set for all road vehicles, trains and 'nonroad mobile machinery' (such as tractors). No standards yet apply to seagoing ships or airplanes. European emission standards define the acceptable limits for exhaust emissions of new vehicles sold in EU member states. The emission standards are defined in a series of European Union directives staging the progressive introduction of increasingly stringent standards. For each vehicle type, different standards apply.

Chinese environmental legislation began in 1978 with formal recognition in the Constitution of the People's Republic of China. This provision mandates environmental protection as a specific constitutional component and one of the important responsibilities of the state. Rapid growth over the past 29 years has fostered the formation of a detailed environmental legal system. This system has expanded to influence the functions of local governments, including the incorporation of legislation from pollution control and prevention to natural resource protection and conservation.[44] At present, environmental law in China consists of legislation addressing comprehensive environmental protection; special litigation for pollution prevention; natural resource protection and conservation and the ratification of international conventions and treaties focusing on environmental protection.

In India, the first emission regulations were idle emission limits which became effective in 1989. These idle emission regulations were soon replaced by mass emission limits for both petrol (1991) and diesel (1992) vehicles, which were gradually tightened during the 1990s. Since the year 2000, India started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-driving cycle. Indian own emission regulations still apply to two- and three-wheeled vehicles. Current requirement is that all transport vehicles carry a fitness certificate that is renewed each year after the first two years of new vehicle registration.[45]

Suggestions to improve Air quality in Pakistan

Pakistan is signatory of Malé Declaration on control and prevention of air pollution and its transboundary effects along with seven other South Asian Countries. In fact, a little has actually been done so far and existing air quality monitoring network is inadequate. However, the Pakistani government is heading toward an air quality management in the form of a Clean Air Program and has established already some permanent air monitoring stations. However, corresponding ambient air quality standards have not yet been established. Following are suggestion that may be adopted to improve the air quality in Pakistan.

Urban traffic control management should consider in the planning management for the improvement of the public transportation system, the enforcement of funneled mounted on vehicles and have to promote the use of environment friendly alternative clean fuels. The protocol for the checking of vehicles fitness should be strictly implemented.

Alternative and efficient means of transportation i.e. metro and bus services must be introduced to encourage private vehicle users to switch to mass transportation.

Proper and adequate planning, imposition and implementation of environmental protection laws, and checks at each and every phase of urbanization could certainly bring pollution levels down to meet the stipulated WHO standards.

Further investigation in this field and an extension of the continuous air quality monitoring sites can provide the basis for setting any future emission and air quality standards based on particle number. There is need of a reliable epidemiological or toxicological monitoring system to be placed in Pakistan to provide a basis for establishing guidelines for various air pollutants. Similarly, there is need to implement the Pakistan Environmental Protection Agency (EPA) proposed maximum 24 hour PM_{10} and $PM_{2.5}$ concentration limits.

Conclusion

The available information on air quality in Pakistan is insufficient and unorganized however it highlights the alarming situation in metropolitan cities of Pakistan. However the studies which have been carried out reveal that the current levels of PM, heavy metals are many times higher than the WHO air quality guidelines. The major anthropogenic sources of air pollution originate through vehicular and industrial emissions, re-suspension of dust and burning of fossil fuel. Rapidly growing population and hence five fold increase in number of vehicles during the last 20 years is thought provoking for the authorities engaged in planning and management. In addition contribution in air pollution is originating from industrial facilities such as cement, fertilizer, steel, thermal and coal power plants, recycling and plastic industry must be included in every scenario that attempts to reduce the overall airborne pollution level.

The deteriorating situation has already been felt by government organization like the PAK-EPA, but, she is still unable to compel decision makers to implement what they have recommended so far. Pakistan still has to develop a basic air quality management system and there is an urgent need to develop comprehensive air quality standards and the corresponding legislation. In addition, there is an urgent need to conduct scientific studies on the current levels of air pollution and their health effects in various regions of the country.

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