Chapter

Industrial Air Emission Pollution: Potential Sources and Sustainable Mitigation

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Abstract

Air of cities especially in the developing parts of the world is turning into a serious environmental interest. The air pollution is because of a complex interaction of dispersion and emission of toxic pollutants from manufactories. Air pollution caused due to the introduction of dust particles, gases, and smoke into the atmosphere exceeds the air quality levels. Air pollutants are the precursor of photochemical smog and acid rain that causes the asthmatic problems leading into serious illness of lung cancer, depletes the stratospheric ozone, and contributes in global warming. In the present industrial economy era, air pollution is an unavoidable product that cannot be completely removed but stern actions can reduce it. Pollution can be reduced through collective as well as individual contributions. There are multiple sources of air pollution, which are industries, fossil fuels, agro waste, and vehicular emissions. Industrial processes upgradation, energy efficiency, agricultural waste burning control, and fuel conversion are important aspects to reducing pollutants which create the industrial air pollution. Mitigations are necessary to reduce the threat of air pollution using the various applicable technologies like CO_2 sequestering, industrial energy efficiency, improving the combustion processes of the vehicular engines, and reducing the gas production from agriculture cultivations.

Keywords: environmental, pollution, industrial, emission, global warming

1. Introduction

A unique chemical wrapping that promotes life on glob and support numerous activities often referred to as air. Rapid industrialization is becoming serious concern for fresh air and healthy life [1–3]. Abundant discharge of industrial toxin making natural environment harmful, unstable, and uncomfortable for physical and also for biological environment and it leads to pollution by energy sources and chemical substances. Physical and biological environment are damage by the heat and pollutants in the air. These pollutants including vapors, aerosols, solid particles, toxic gases and smoke drive from industrial processes. Emission of air pollutants is also because of many human actions. List of six air pollutants presented by World health organization (WHO) which known as classic air pollutants in industrialized countries as nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO), and suspended particulate matter [4]. A number of industrial sources are responsible for the emission of carbon monoxide along with, fuel-fired boilers, internal combustion gas boilers and gas stoves [5]. The quality of the combustion process is primary indicated by carbon dioxide. Emissions of CO_2, as a result of combustion of fuels, are creating consequences on environment [6]. For the industrial combustion system carbon dioxide was also examined a major greenhouse gas [7]. For the emission of carbon dioxide from any type of combustion source a prescribed national standard was present but it is important to check that carbon dioxide emission enter into air at steep rate. Oxides of nitrogen as nitrogen dioxide (NO_2) and nitric oxide (NO) produce from thermal power plants, vehicles, industrial process and, coal burning processes [8]. Oxides of nitrogen are produced by the reaction of free oxygen and nitrogen of air which achieved at high temperature during combustion process. Fuels, rich in sulfur contents produce sulfur dioxide (SO_2) gas when used for the energy. Bennett [9] reported sulfur dioxide lifetime is about 10 days in air. Industrial stacks emitting sulfur dioxide because fuels contain a standards higher concentration of sulfur. Generally, in Pakistan the electric power supply is not adequate and consistent for supporting employments; consequently, to overcome electric energy shortage all business sectors still extensively use their private generator (**Figure 1**).

These generators mostly installed next to their services or along the road which is not an appropriate location. Therefore, by importing exhaust gases into the air they create many complications to the people who are traveling on the roads and the resident. Smoke opacity of industrial gas is also a parameter which has considerable potential to enhance environmental air pollution by smoke particles emission. Industrial stack points were also analyzed with reference to clean air for smoke opacity (%). It was noticed that boilers operating on furnace oil have larger value of smoke than on natural gas. According to an estimate, at least 3000 different chemicals have been identified in air through sampling of various nature. A term commonly used to describe any harmful chemical or other substance that pollutes

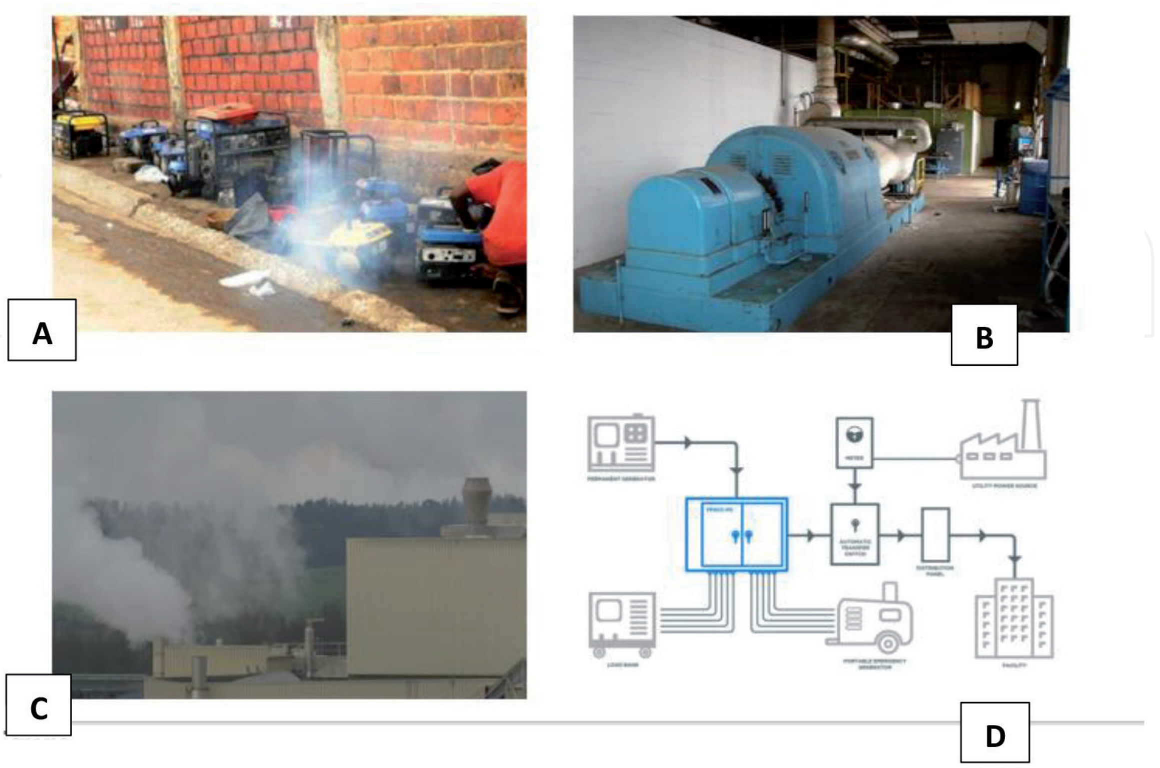

Figure 1.
Presentation of energy sources based upon hydrocarbon fuels: (A) domestic generator; (B) power houses; (C) industrial generators; and (D) energy production.

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the air we breathe, thereby reducing its life-sustaining quality is called air pollutant. In principle, air pollutants refer to any chemical substance that exceeds the concentration or characteristics identified as safe for the natural ingredients in the air both by nature or anthropogenically. More strictly, pollutants can be defined a substance which is potentially unsafe to the well-being or health of humans, plant and animal life, or ecosystems. Air pollution is characterized as "the presence of substances in the atmosphere that may adversely affect humans and the environment." It may be a single chemical that is initially produced, or chemicals that are formed by subsequent reactions. According to the World Health Organization (WHO), poor outdoor air caused 4.2 million premature deaths in 2016, of which about 90% were in third world countries. Indoor smoke poses a health threat to 3.0 billion people through heating system and burning biomass, kerosene and coal [10, 11]. Air pollution is linked to a high incidence of respiratory diseases such as cancer, heart disease, stroke and asthma [12]. According to estimates from the American Lung Association, nearly 134 million people are at risk due to air pollution [13]. Although these effects come from long-term exposure, air pollution can also cause acute problems such as sneezing and coughing, eye discomfort, headache, and dizziness [14]. Particles smaller than 10 microns (classified as PM10 or PM2.5 even smaller) pose higher health risks because they can be breathed deeply into the lungs and can enter the bloodstream where air pollutants and nanoparticles have the direct impact on our health [15].

2. Sources of air pollution

Pollutants are commonly classified into solid, liquid, or gaseous substances that are discharged into the air from a fixed or mobile source, then transmit through air, and contribute in chemo physical transformation, and eventually return to the ground. It is impossible to describe the full range of potential sources and actual damage caused by various sources of air pollution but few which are more vulnerable are discussed below:

2.1 Combustion of fossil fuels

Fossil fuels as coal and oil for electricity production and road transportation, add huge amount of air pollutants like carbon dioxide, nitrogen and sulfur dioxide. Sulfur dioxide, oxides of nitrogen and fly ash are produced as main pollutants if coal is used as a fuel. Major pollutants during combustion of oil are oxides of nitrogen and sulfur dioxide, whereas coal emits particulate air pollution to the atmosphere. Similarly, important air pollutants emitted from power station are particulate matter (fly ash and soot) oxides of nitrogen (NO_2 and NO) and sulfur oxides (SO_3 and SO_2) [16, 17]. These pollutants and other closely related chemicals are primarily source for acid rain. When PM is released into the atmosphere due to traffic and industries, these PM scatter the visible part of the sunlight radiation, but the other part of the spectrum particularly inferred and far-infrared, cause the internal heating effect of the air atmosphere below the PM surface. The Sun radiation is heating our air from outside and the traffic and industries from inside. And the PM surface is like a shield or barrier, through the heat diffusion cannot penetrate bidirectional ways.

Volcanic eruption disperses an enormous amount of sulfur dioxide into the atmosphere along with ash and smoke particle sometimes causes the temperature to rise up over the years. Particles in the air, based on their chemical composition, can also have a direct impact of being separated from climate change. They either change the composition or size and may deplete the nutrients biosphere, damage crops, and forests and destroy cultural monuments such as monuments and statues. Many living and non-living sources emit carbon dioxide that contribute largely as pollutant. Carbon dioxide is the most common greenhouse gas, among many others which traps heat into the atmosphere via infrared radiation matching vibrations and causes climate change through global warming. Over the past 150 years, humans have driven enough CO_2 into the atmosphere to make its levels higher than they have been for hundreds of thousands of years. Air pollution in many cases prevents photosynthesis, which has a significant impact on the plants evolution, which has serious consequences for purifying the air we breathe. It also results to form acid rain, atmospheric precipitation in the form of rain, snow or fog, frost, which is released at the time of fossil fuels burning and converted by contact with water vapor in the atmosphere.

2.2 Industrial emissions

Industrial process emits huge amounts of organic compounds carbon monoxide, hydrocarbons, and chemicals into the air. A high quantity of carbon dioxide is the reasons for the greenhouse effect in the air. As the greenhouse gases absorbs infrared radiation from the surface of the planet so its presence is good for the planet. The recent climate change is due to excessive quantity of these gases as well as PM into the atmosphere [18, 19]. Different greenhouse gases contribute differently in global warming due to their unique physical and chemical properties, molecular weight and the lifetime in the atmosphere. A simple working method can calculate the relative contribution of the unit emissions of each gas relative to the cumulative CO_2 unit emissions over a fixed period of time [20, 21]. Therefore, global warming potential (GWP) can be defined as the warming effect of any greenhouse gas relative to CO_2 over a certain period of time. Greenhouse gas emissions from various sources have led to climate change, which has been accompanied by an increase in greenhouse gases [22, 23]. Greenhouse gas emissions change the Climate that is a global issue having significantly negative impacts on economic growth humans, and natural resources [24–26]. The main greenhouse gases (GHGs) and their relative quantities are carbon dioxide, (9–26%), water vapor, H_2O (36–70%), nitrous oxide (3–7%), methane, (4–9%), and other trace gases [27]. Among all the greenhouse gases, CO_2 and CH_4 cause major global surface temperature increase [28]. These gases are emitted by natural and anthropogenically. After carbon dioxide, methane is the second gas that contributes to global warming. Methane has larger impacts as a greenhouse gas than carbon dioxide, with global warming potential (GWP)s 21–25 times higher than CO_2 [29–32].

2.3 Agricultural sources

Agriculture activities often release harmful chemicals like pesticides and fertilizers [33]. Organic matter gradually reduces the water and oxygen in soil during flooding of rice fields; as a result, methane is produce by anaerobic decomposition [34, 35]. Globally methane emission is much lower than CO_2 emissions annually. The concentration of CH_4 in the air is 200 times lesser than carbon dioxide [36] but approximately 20% effects of global warming, because of methane [37, 38]. Naturally it is emitted by marshland [39], termites, wildfires [36], grasslands [36], coal seams [40] and lakes [41]. Human sources of methane include public solid waste landfills coal mine paddy fields oil and gas drilling, pastures rising main sewers, wastewater treatment plants, manure management and agricultural products. Its emission through agriculture sector increased by 11–24% from 2000 to 2010 [33, 42–50].

2.4 Other natural and anthropogenic sources

Natural sources are particulate matter (PM) includes dust produced from the earth's crustal surface, coastal sea salt, form pollens of plant and animal debris [51]. Volcanic eruptions also contribute huge quantities of particles into the environment. Majorly an amount of 3.0 thousand tons of sulfur dioxide emits every day while episodes of great activity. Forest fires of rural areas produce large amounts of all kind of particulate matter including carbon black. Among other sources of natural pollution of air includes lighting in the sky that generate significant quantities of oxides of nitrogen (NO_x); hydrogen sulphide produced from oceans algae and marshy methane. Additionally, concentrations of ozone at ground level, formed because of reaction of nitrogen gases and volatile organic compounds in the presence of sunlight. As far as the human sources are concerned in urban areas, air pollutants come from human-activities, such as cars, trucks, air planes, marine engines, etc. and factories, electric power plants, etc. Nowadays, vehicles on the road constitute the major source of air pollution in the populated areas of countries. Carbon constituted fossil fuels produces carbon monoxide and hydrocarbons whereas NO_x a combination of nitrogen and oxygen gases produced at high temperature. Another very significant thing that road transport accounts a major source of air pollution [52]. It is specified that road transport is the second source of air emissions up to 28.6% after the industrial use of solvents which is 41.4%.

3. Mitigation

Countries, departments and researchers all over the world are dealing for several forms of mitigations for air pollution. In order to restrict global warming, there is a need to take different measures. Important is the addition of more renewable energy sources, substituting gasoline vehicles with zero-emission vehicles as electric vehicles. As an example rapid industrial expansion is China. In china the government is supporting coal-fired power plant. Similarly, in the United States, emission standards setting has improved the air quality, especially in places of worth importance. Contrarily by adding ventilation, using air purifiers, purifying radon gas, running exhaust fans in bathrooms and kitchens and avoiding smoking people can avoid indoor air pollution. While working on a home project, use paint and other products with less volatile compounds. Countries all over the globe have commitments to limit carbon dioxide emissions and other greenhouse gases in the light of Paris Agreement [53, 54] banning hydrophobic hydrocarbons (HFCs) other than chlorofluorocarbon CFCs [55].

3.1 CO_2 sequestering

In this method carbon dioxide is extracted from the air using a solid or liquid adsorbent. Examples of mostly used solid adsorbents include, activated carbon, zeolite, or activated alumina whereas liquid sorbents include, high pH solutions of sodium hydroxide, potassium hydroxide some organic solvents such as monoethanolamine [56, 57]. A method for capturing carbon dioxide from the air includes a number of steps including exposing CO_2 in air to a solution containing an alkali to obtain an alkaline solution that absorbs the carbon dioxide [56].

3.2 Biomass burning

Incomplete combustion of biomass results into production of hazardous gases. The main sources of such emissions are burning of wood, domestic waste, agricultural residues, waste, and charcoal. In developing economies combustion of biomass generally refers to the biofuels combustion for heating, lighting purposes and cooking in small combustion equipment. Because the conditions of burning and types of these fuels vary widely, measures for this category are highly difficult and uncertain to predict.

3.3 Coal mining

Produced of methane by coalification process, and vegetation is transformed into coal by many environmental conditions [58]. The amount of methane gas evolved by mining operations is a function of two main factors: coal depth and coal level [59]. From coal mining, there are four main sources of methane emissions, which are underground coal mines and surface coal mines. These processes account for most of the global emissions of methane from mining. Surface coal mines emit much lower methane as compare to underground coal mines because generally coal mines are at lower rank and capture methane into methane during post-mining operations. Activities of coal mining and processing, continues after operations which emit the methane [60].

3.4 Rice cultivation

Methane emissions through rice production and cultivation can be decreased by selecting proper rice varieties, fertilizers, and water systems. It has been proved that larger total weight rice varieties emit less methane [61, 62]. Fresh straw in the 3 months before transplantation and combined with straw fertilizers before transplantation, plus methane emissions, intermittent irrigation were reduced by 23 and 49%, respectively [63]. Application of potassium fertilizer during flowering period drainage reduce methane emissions.

3.5 Direct utilization of gas

For the production of liquid natural gas and to run leachate evaporators landfill gas can be directly used as fuel. In industrial processes such as kiln operations, boilers, drying operations, and asphalt and cement production landfill methane gas can be used and transported. Natural gas collected from landfills can be transported to local industries directly and use as an alternative or supplementary fuel [64].

3.6 Fuel conversion

Shifting to low-carbon fuels from high-carbon can be comparatively cost-effective principle to reduce the emissions of gaseous because this enhance the efficiency of combustion and reduce the amount of pollutants. In addition, briquette coal and carbon burnout techniques are used in fuel based power plants to minimize the production of pollutants. This pre-combustion method requires almost no hardware changes to the facility and therefore has a lower investment cost. Fuel conversion application to industrial sectors such as the steel, cement and chemical CO_2 emissions can be reduced by 10–20%. There are some essential interrogations about the opportunities that exist for converting fuels in a cost-effective manner. Fuel choices are usually industry dependent, so cost-effective alternatives are limited however, some special opportunities to replace coal-fired boilers with natural gas fired gas-driven steam production; and use natural gas instead of coal to burn blast furnaces [65]. For example, briquette alternative fuels result in a 9–16% increase in fuel costs, although an estimated 26% CO_2 emissions are reduced. Improved fuel efficiency and reduced standard pollutant emissions depends on variable fuel costs which cannot be completely estimated. According to an estimate carbon depletion can save 1.5% of fuel costs. Carbon reductions achieved from ash, by replacing the production of Portland cement is estimated to reduce 144,000 tons of carbon dioxide annually [66].

3.7 Combustion efficiency

Improvement in the current combustion systems have the potential to gear up the energy efficiency. The average thermal performance of current combustion is 32–33% [67]. Control of wasted heat into electricity may result into efficiencies of 45–55%. According to the Department of Energy, the combined energy projects are the main source of greenhouse gases reduction. Technologies like the natural gas combined cycle and combined cycle gas turbine proved for the improving of combustion efficiency and proportionally reduced greenhouse gas emissions and standard pollutant emissions. Additionally, integrated gasification combined cycle system is a step forward to reduce the costs associated with capturing and separating CO_2 from the exhaust stream. Increased operating and fuel costs may be offset by the combined benefits of increased efficiency, reduced pollutants, and credits for emission reductions. An ample evidence that industrial upgradation can reduce greenhouse gas emission, pollutants, and lower operating costs, and current environmental regulations have hindered the adoption of this technology [68]. Air quality regulations determine the operational fuel input rather than power output emission to upgrade of thermal efficiency. However, the environmental agencies provide a guidance document on energy efficiency which begun to address regulatory barriers to improving thermal efficiency [69]. Another source of energy efficiency that can be achieved in the industrial sector is the use of direct fossil fuels. Manufacturing is a major candidate for improving energy efficiency, both of which are achieved through many technological upgrades. Overall, process control and energy management systems for all industries can better control combustion efficiency and fuel use; combined heat and power systems can use waste heat as additional energy; high-efficiency, low-friction motors and drive systems improved the overall efficiency of successfully generating power. In addition to these general categories, various manufacturing industries also have opportunities to improve energy efficiency. Specific industrial sectors with greenhouse gas mitigation potential include cement manufacturing, metal production, refineries, pulp and paper mills, and chemical manufacturing [68].

Combustion efficiency of combustion systems depends on the factors such as type of combustion system, fuel, burner and air fuel ratio for combustion. Significant amount of air pollutants depending on nature of fuel enter into the environment. World health organization (WHO) has provided six listed air pollutants known as classic air pollutants [4]. If coal is used as a fuel, fly ash, sulfur dioxide and oxides of nitrogen are the major pollutant. Combustion of coal produces particulate air pollution whereas in case of oil, sulfur dioxide and oxides of nitrogen are major pollutants emitted to the atmosphere. Similarly, three major air pollutants, particulate matter (fly ash and soot) sulfur oxides (SO_2 and SO_3) and oxides of nitrogen (NO and NO_2) emitted from power station.

Method for calculating efficiency:

$$\text{Efficiency } (\% E) = 100 - \Sigma \text{ losses} \quad (1)$$

Losses are as:

1. Temperature flue gas.
2. Moisture in fuel.
3. Combustion of hydrogen.
4. Un-measured losses.

In one of our research work different textile units were examined for stack emissions from boilers and generators. **Table 1** illustrates the results of emissions from boilers. Values of carbon monoxide (CO) were in the range of 0 mg/Nm^3 in CT-Tex to 4903 mg/Nm^3 in HS-Tex. Most of the industries were in compliance of national quality standards of Pakistan, i.e., 800 mg/Nm^3. HS-Tex was exceeding the limit of standards for CO emission. Similarly, **Table 2** represents the gaseous emission of diesel generators. A massive amount of gaseous emissions are produced from generators along with heating which affect the climatic condition at the large scale [4].

Industries	Fuel	CO	CO_2	NO + NO_2	SO_2	H^2
		mg/Nm^3	mg/Nm^3	NO_x g/Nm^3	mg/Nm^3	mg/Nm^3
IP-Tex	Furnace oil	12	221,964	437	3363	0.09
CT-Tex	Natural gas	0	125,321	227	0	0.18
BR-Tex	Natural gas	20	139,857	213	0	1.34
KH-Tex	Natural gas	35	207,428	256	0	1.07
NF-Tex	Natural gas	20	207,625	187	0	1.52
HS-Tex	Natural gas	4903	58,732	121	0	174.2

Table 1.
Gaseous emissions of boilers of textile industries operating with different fuels [70].

Industries	CO	CO_2	NO + NO_2	SO_2	H_2
	mg/Nm^3	mg/Nm^3	mg/Nm^3	mg/Nm^3	mg/Nm^3
IP-Tex	975	21,714	542	80	3
CT-Tex	655	90,000	1342	175	2
BR-Tex	874	131,429	2297	211	2
KH-Tex	572	94,286	2445	265	0.7
NF-Tex	981	86,000	2144	145	3
HS-Tex	1927	76,143	315	65	4

Table 2.
Gaseous emissions diesel generators operation in different industries [70].

4. Conclusion

Quality of life (air) in cities is getting worse as the industrialization, population, energy use and traffic increase. Some air pollutants in larger amount crossing WHO standards, mainly in cities of industrialized countries permitting meaningful statistical trends to air pollutants. The complexity of air pollutants, particularly related to the health impacts in cities, has improved indicators to analyze the accessible monitoring data sufficient for decision making and reporting. Our assessment illustrates that the economic costs of the environmental clash proceeding from sources of combustion in industries tested is potentially excessive. Regarding to the living quality it will be serious concern if no additional control measures were implemented in future. For industrial air pollution there is an immediate need to improve the evaluation and monitoring systems. In cities where strategic planning is not-existing or weak, to improve the quality of air there should be an implementation of environmental management system.

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Conflict of interest

The authors declare no conflict of interest.

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